Efficient Gas Analysis, a Key to the control of Combustion Processes

The precise analysis of gas components in flue gases is essential to operate and regulate combustion processes efficiently; this is the case especially for the fossil fuels sector.
The first major factor for efficient gas analysis is to find the right balance between the investment for the analysis system and the cost of ownership. Extractive analysis, as well as close coupled systems, may offer a solution to making a reasonable financial outlay for precise data acquisition to finally achieve combustion efficiency.

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Combustion Control

The main target for operators of fossil fuel fired processes may vary from saving fuels such as gas, oil or coal, obtaining optimal product quality and output, or keeping close to emission regulations. It is, in any case, a challenge.

The most important achievement in such applications would be to have a very efficient combustion process from which 100% energy content is provided by the fuel, and the thermal losses can be minimised. Although the heat losses by surface radiation of the boiler itself are usually neglected, they should not be totally forgotten in calculating the general system balance.

Formula: flue gas losses versus O_2 contend

$$qA = (\vartheta_A - \vartheta_L)\bullet\left(\frac{A_2}{21-O_2}+B\right)$$

A2 and B are fuel specific,

Flue gas temperature

Ambient temperature

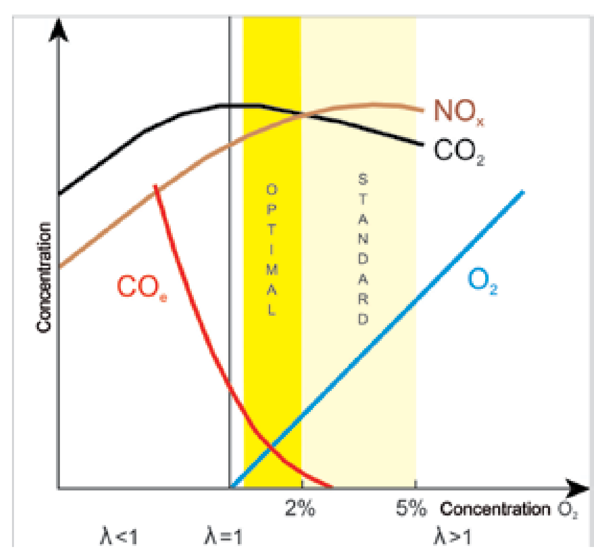
Flue gas thermal loss

The equation shows the correlation between the energetic efficiency of the process and the parameters of flue gas temperature and oxygen content in the flue gas. If one of these two parameters is not adjusted properly, thermal energy is lost and energy efficiency is reduced. As a consequence, the formation of either NOx or SOx will increase if the air supply is excessive, or smoke and unburned components will rise if the air supply is too low, and thus the whole process is running inefficiently.

The fuel economy at a certain air supply is described by lambda air-fuel equivalence ratio. Lambda is the relation between the real volume of air supplied and the theoretically necessary volume of air to provide a stoichiometric reduction of the specific fuel.

If lambda is 1 the stoichiometric combustion would be at a suitable level of efficiency. If lambda is >1 excess air is being consumed while if lambda is <1 a lack of air is provoking an under stoichiometric combustion. The diagram shows that if air is lacking (<1) the unburned components such as CO increase rapidly.

Operators know that a non-stoichimetric combustion reduces



the potential volume of generated heat which indicates an inefficient use of the fuel's energy capacity.

Varying fuel quality and varying air/fuel ratios force operators to run the process with a certain amount of excess air, but too much excess air provokes the production of NOx and SOx and reduces efficiency because of an increased loss of heat via flue gas emission.

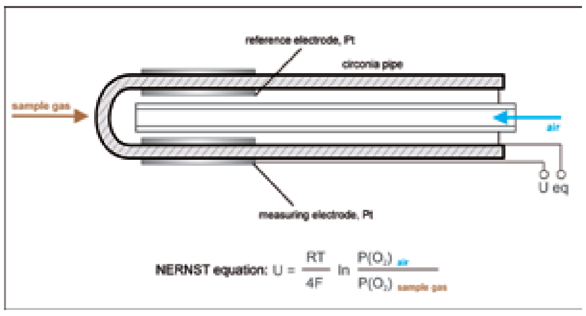
The described stoichiometric combustion scenarios illustrate the small margin left to the operator in which he is able to regulate the process parameters in order to achieve optimum efficiency. It is therefore easy to understand that accurate and fast analysis of the relevant gas components is a key issue.

This analysis can be based on the measurement of oxygen only or can include oxygen and carbon monoxide and lead on to a multi component analysis of O_2, CO_2, NO/NOx and SOx.

Close Coupled Oxygen Analysis

A very common practice is to just analyse Oxygen levels in the flue gas in order to run the process with excess air. For such applications closed coupled analysers like the BA 2000 offer a suitable solution. This analyser is based on a zirconia dioxide cell and is designed for direct attachment to the stack at the sample point.

The BA 2000 close coupled extractive analyser combines the advantage of the modules of the GAS 222.17 sample probe series and their economy of scale with the utilisation of an integrated aspirator, an integrated particulate filter plus a



robust zirconia cell. Both zirconia cell and aspirator are directly connected to the heated filter accommodation and are completely covered by a very effective insulation shell. A hinged weather shield covering the entire analyser gives sufficient protection against sun and rain.

The sample gas is drawn by the aspirator from the process into the filter element which removes all particulates from the gas. Directly after the filter the gas is exposed to the measuring cell before being lead back into the process again.

Close coupled analyser BA 2000

For maintenance, the filter element is easily accessible within seconds, without tools or the need to cool down or dismantle the analyser. The external positioning of the measurement cell ensures that the analyser is unaffected by the process' temperature and its potential fluctuations. Needless to say that this advantage is most conspicuous during start ups or closing down periods where water and acid dew points are very likely to be undercut.

The determination of the oxygen concentration is based on the NERNST equation. The oxygen conductivity of zirconia oxide raises exponentially with the temperature and reaches above 600°C sufficient levels for reliable O_2 measurement.

The cell of the BA 2000 consists of a tube made from ZrO_2 with one end closed. At the inner surface and the outer surface of the tube two electrodes made from platinum powder are placed. This entity forms a so-called 'electrolytical sensor'. A second tube with a smaller diameter is fed into the centre of the ceramic tube and exposed to the ambient air. To be able to measure oxygen free from cross interference with other gas components the cell is heated up to 700°C and stabilised by an electronic controller.

This arrangement provides fast oxygen readings at a reasonable financial investment and out performs traditional in-situ analysers by significant savings in cost of ownership.

Oxygen Plus CO Extractive Analysis

As already mentioned, carbon monoxide (CO) is, beside oxygen, a key component in flue gas for determining if a combustion process is running inefficiently and thus higher costs for fuel is likely.

A higher CO concentrations in the flue gas is a definite sign for an under stoichiometric combustion. Such incomplete combustion could cause higher corrosion, problems in the combustion chamber, will produce more ash or smoke and generate more emissions and waste fuel. If carbon monoxide is monitored simultaneously to O_2 it could help to increase efficiency and cut cost.

An NDIR analyser in an extractive analysis system would be able to provide precise data to get CO under control. These analysers can measure free from cross interference from, for example, combustible components like H_2. The influence of water vapour (typically 8000 ppm after the gas cooler) is no longer of concern either. With the ability to detect CO ranges between 10 and 500 ppm these systems could really contribute to improve the combustion process. This is a good alternative to in-situ cross stack analysis, where the stack dimensions very often require special path arrangements, the NDIR technology allows the operator to adapt the measuring ranges just by adjusting the cuvette.

The combined control of O_2 and CO would enhance the operation of the process further. Air leaking into the process, other from the regular air feed, could camouflage the combustion under excess air whilst the simultaneous measurement of CO would immediately discover a real lack of air supply because of higher CO concentrations showing up in the data.

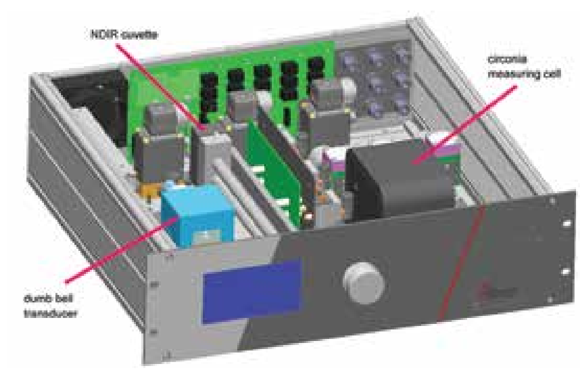
If the simultaneous control of the two gas components is a desirable alternative, multi component analysers, such as the BA3 select, could offer an ideal solution.

This type of modern analyser provides a common data acquisition platform/controller with a number of optional measuring devices. These devices, called transducers, can be

Multi component analyser BA3 select

plugged in according to the application's specific requirements. This modular technique makes the BA3 select versatile, not only to such applications where gas components should be measured at the same time in the same process like the a.m. combustion control, but also to control various gas components in different processes. It would even be possible to employ different principles for oxygen measurement, like paramagnetic or zirconia, in the same unit and the same or different process. Up to three different transducers can be installed. Neither the NDIR cells nor the paramagnetic cells need a constant extra supply of air or nitrogen.

The paramagnetic oxygen analysis is a tried and tested measuring principle. The so called dumbbell cell makes use of the paramagnetic susceptibility of oxygen, a physical phenomenon. The transducer used in the BA3 select is based on the principle of the dumbbell, a fast and accurate way for oxygen measurement. Two nitrogen filled glass spheres are mounted on a rotating suspension within a pair of magnets. A mirror is mounted centrally on the suspension and light is shone onto the mirror. Oxygen attracted into the magnetic field will displace the nitrogen filled spheres, causing the suspension to rotate. The reflected light is then directed onto a pair of photocells. The signal generated by the photocells is passed to a feedback system. The feedback system will pass a current around a wire mounted on the suspension. This causes a motor effect, which will try to keep the suspension in its original position. The current measured flowing around the wire will be directly proportional to the concentration of oxygen within the gas mixture. This cell has a very low cell volume for fast and linear response. The effect from background gases is insignificant and the high stability guarantees reproducible results. Low maintenance and a long service life are other benefits of this cell.



BA3 select

Which Technology to Choose?

The first section of this article was mainly focussed on measurements to run combustion processes efficiently. However, many such processes also have to focus on pollution abatement and need to take steps to achieve effective emission controls. The most common method to establish such control is the analysis of the effluent gases by means of extractive analyser systems. Contrary to the earlier case discussed in this article about close coupled extractive analysers directly attached to the stack, these extractive systems are installed remotely from the sample point in places with good working and/or ambient conditions.

Depending on the application's specific requirements, such extractive systems can vary from a fairly straight forward design, even as prefabricated standardised packages, or very complex installations accommodated in separate, air conditioned houses or cabinets.

In comparison to cross stack in-situ analysers, extractive systems more suited to many applications because of easier access for installation and maintenance, better measuring ranges or operating costs saved because there is no need for auxiliary air or nitrogen supply.

The extractive gas analysis is definitely the better choice if high or varying dust loads are present in the process stream.

Modern sample probe technology provides probes with highly efficient blow back systems like the GAS 222 series. The main focus of this probe design is on low operating cost and easy maintenance. For low dust loads the GAS series offers heated or unheated probes with integrated downstream filters. The filter element is easily accessible without tools and can be changed in seconds with no need for a shut down. If the dust loads are higher the probes perform filtration upstream (i.e. directly in the process stream). These probes feature a blow back system including a directly attached vessel with adequate air volume. As is the case with dust collectors, the efficiency of a blow back system depends directly on the ratio of filter volume to pressurised air volume blown across the filter element. Another essential of such systems is the removal of the cleaned off solids from the gas path. Again, even some of the GAS 222 blow back variants allow the removal of the filter element for inspection without the need for a shut down.

In order to keep up with pollution control regulations it might

Sample probe with blow-back system

be necessary to analyse additional components of the gas mix such as sulphur dioxide (SO_2) and nitrogen oxide NOx ($NO+NO_2$). A NOx converter in conjunction with additional NDIR analyser channels could be a cost effective answer for such applications. The NOx converter will transform the NO_2 to NO and then the NDIR analyser can measure the total NO. Advanced BÜNOx converter technology allows efficient reaction already at 400°C with no formation of by-products such as CO which would camouflage the true results of the analysis. Extensive research has lead to the development of converter materials which provide high conversion accuracy at a reasonable cost. This, together with lower energy consumption, makes the BÜNOx very competitive in any respect.

NoX Converter Bünox 2+

There are many more components in an extractive gas analysis systems contributing to reliability and cost of ownership. One item however, should also have special attention:

Bellows sample gas pumps

the sample gas pump! There are very few applications in which the process pressure is sufficient to transfer the sample gas all the way down to the analyser. If the pressure is insufficient, or other application specific reasons dictate, the sample gas must be pumped from the sample point to the analyser. From what this article has already discussed, it is obvious that the composition of the sample should not be changed before analysis. All wetted parts on its way down must not draw or add any component to the gas .This sets stringent requirements for the sample pump and one should not compromise on the quality of the pump as this would be a false economy. High corrosion resistant, impassable against condensate droplets, long service life are the basic benchmarks for a competitive sample gas pump. Only pumps which have been particularly designed for the gas analysis should be given consideration.

Conclusion

The efficiency of a combustion process essentially depends on the fast and accurate analysis of the effluent gas. This can be achieved by different methods of analysis and equipment. The complexity and the application specific requirements finally determine the method of analysis and consequently, which kind of a system will be chosen. This decision includes similar relevant factors like financial investment, installation cost, operating cost, maintenance needs, serviceability, accessibilty, flexibility and, last but not least, reliability.

Either way, close coupled or extractive could be the appropriate answer to a specific project's requirements. In both cases professionally designed solutions and systems will be the key to combustion processes with low emissions and high fuel economy.

The explained range of products developed and manufactured by suppliers clearly focussed on the sophisticated field of gas analysis are an excellent basis for advanced analysis solutions. Analysers such as the close coupled extractive BA 2000 and the Multianalyser BA3 select will help to make in particular combustion processes reliable and efficient.

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