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Optimizing Combustion Control with the TDLS8000

Industry: Refining, Oil and Gas, Chemical, Power
Product: TDLS

Introduction

Industrial Combustion sources such as thermal cracking furnaces and, process heaters play a critical role in the process industry. Because the large amount of fuel such as gas or fuel oil which is consumed in these processes, their combustion efficiency directly affects the performance and operational costs of the production facilities. Incomplete combustion and the use of too much excess air can lead to higher level of toxic emissions such as CO (carbon monoxide), CO_2(carbon dioxide), NOx (nitrogen dioxide), and SO_2 (sulfur dioxide).

Challenges

Combustion requires fuel and air (oxygen), and insufficient air causes fuel residue, resulting in incomplete combustion with soot and smoke. On the other hand, excessive air caused problems, such as a larger amount of exhaust gas and heating of excessive air, resulting in lower fuel efficiency. Figure 1 shows the principle of the air-fuel ratio and state of combustion. The air-fuel ratio plotted on the horizontal axis shows the ratio of actual supply air to the theoretical amount of air required for fuel combustion (theoretical air amount).

For combustion furnaces such as heating furnaces and boilers in plants and factories, small-scale controllers such as single loop controllers are employed to optimize the air- fuel control ratio for improving the combustion efficiency. In large combustion furnaces, distributed control systems (DCS) and advanced control (multivariable predictive control, etc.) are used. These mainly control the air-fuel ratio and internal pressure of the furnace to prevent CO, CO_2 and NO_x (nitrogen oxide) from being emitted and apply a cross limit circuit to prevent incomplete combustion while controlling combustion to maximize efficiency.

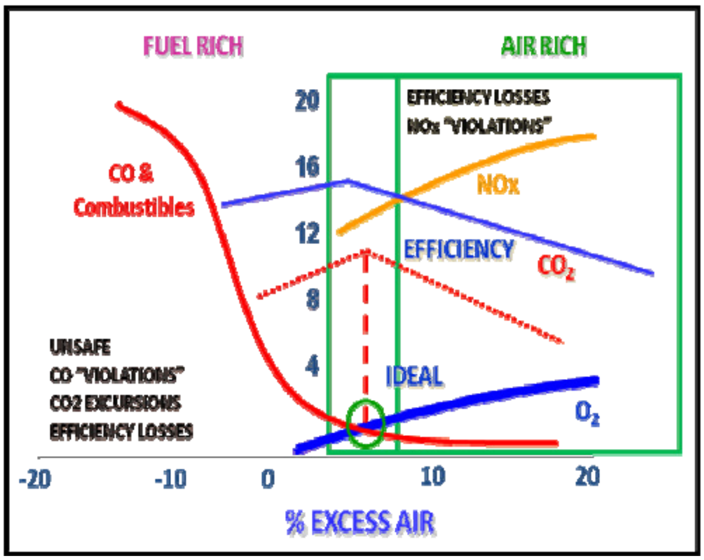

Figure 1 Relationship Between Air-Fuel Ration and Heat Efficiency (Combustion)

Solution

Overview of the TDLS8000 Laser Analyzer

Figure 2 shows the appearance of the TDLS8000 laser analyzer. This analyzer measures the process gas component concentration using tunable diode laser absorption spectroscopy (TDLAS), which measures molecule-specific optical absorption spectra. Figure 3 shows an example of using the TDLS8000 to measure the concentration of flue gas.

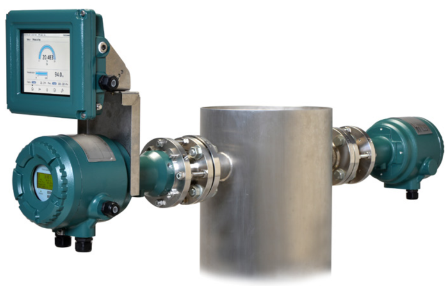

Figure 2 TDLS8000 Laser Analyzer

To measure spectra, we employ our originally developed peak area method for accurate measurement even in process environments where the composition, pressure and temperature fluctuate simultaneously. The TDLS8000 suffers no component interference owing to its high spectrum measurement resolution and is directly installed in a process enabling the laser beam to travel through the process windows in a non-contact measurement as shown in Figure 3. The specific process gas of interest can be reliably measured in near real-time (5 seconds) and at high speed even in high temperature (Max. 1500ºC) or corrosive environments. This advantage enables analysis signals to be utilized directly for process control and management systems, and the TDLS8000 has been rapidly introduced in various industries such as refineries, petrochem, iron and steel and thermal power generation to achieve process improvement and safe operation.

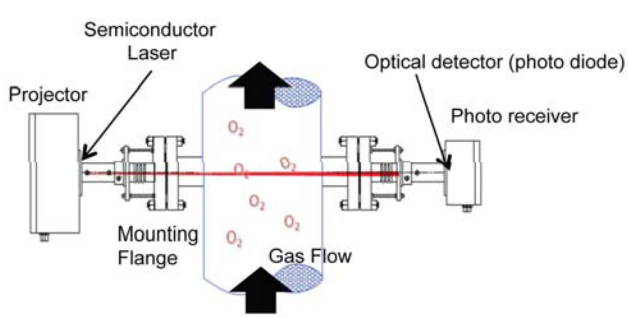

Figure 3 Installation Example of the TDLS8000

Measurement of O_2 and CO Concentrations in Combustion Gas by the TDLS8000

Figure 4 shows an example of using the TDLS8000 analyzer to measure O_2 and CO concentrations in a combustion furnace. This example shows that concurrent measurement of O_2 and CO concentration while gradually and manually reducing the amount of air supplied to the burner. This experimental data describes the situation; CO generation begun nearly at the O_2 concentrations of 2% and sharply increased at the concentration of almost 1.5%, resulting in incomplete combustion, then by increasing the amount of air supply to avoid incomplete combustion, the O_2 concentration rapidly increased and the CO concentration decreased again, resulting back to complete combustion. This data also indicated that the CO concentration increased from 100 ppm to 4,000 ppm in just a few minutes.

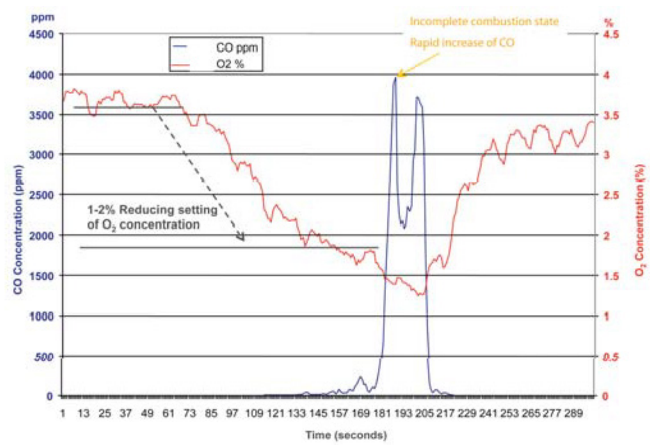

Figure 4 O_2 and CO Concentration Changes in a Combustion Furnace at Low Oxygen Concentration Operation

Air-Fuel Ratio Control Utilizing CO and O_2 Concentrations

According to Lyman F. Gilbert, the CO concentration in the optimum combustion zone (having the highest heat efficiency per unit amount of fuel) is around 200 ppm irrespective of fuel types and devices. However, CO concentration increases rapidly once it has broken through as shown in Figure 4. Thus, either a stable combustion must be kept with sufficient supply of air or a control system must monitor the CO concentration in real-time and keep it constant at a relatively low level.

The amount of air supplied to a burner is controlled by two methods: using a forced draft fan (FD) and damper as shown in Figure 5, or using natural air intake by controlling the opening degree of the damper of an induced draft fan (IDF). The O_2 and CO concentrations are measured by the TDLS8000 at the entrance of the flue and then supplied to the control system. The measured CO concentration can be used for combustion control by two methods: controlling O_2 when the O_2 concentration exceeds a prescribed value and overriding to CO control when the O_2 concentration falls below the value, or giving a CO concentration bias (compensation) to the O_2 concentration.

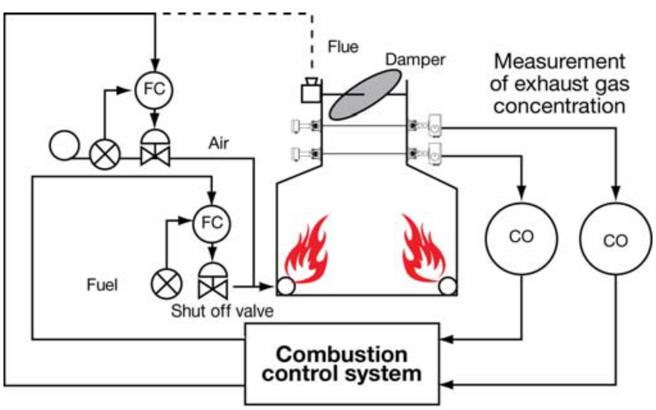

Figure 5 CO and O_2 Control System for Combustion Furnaces

Estimation of Economic Effects by Air-Fuel Ratio Improvement

Because the fuel required for generating the same amount of energy can be saved by lowering the set value of O_2 concentration in exhaust gas when performing air-fuel ratio control, the direct economic effect by the decrease of O_2 concentration in exhaust gas can be estimated. As the economic effects by the improvement, reduction in fuel cost which can be achieved by reducing the excessive O_2 while keeping the furnace temperature constant is calculated. Table 1 summarizes a calculation example.[1]

Table 1 Example of Economic Effect Calculation by Reducing Excessive Oxygen

Item	Symbol	Value	Unit
Prerequisites for fuel oil			
Caloric value per fuel unit weight (LHV: Low Heating Value)	LHV	9800	kcal/kg
Fuel cost per fuel unit	P	5	$/kl
Theoretical amount of exhaust gas	G0	11.07	Nm^3/kg
Theoretical amount of air	A0	10.46	Nm^3/kg
Prerequisites for air			
Oxygen-in-air concentration	Or	21	%
Air/exhaust gas specific heat*1	SH	0.33	kcal/ Nm^3/ deg
Operating conditions			
Exhaust gas temperatures	Th	400	°C
Ambient temperature	Tl	200	°C
Annual amount of fuel consumed	V	60000	kl
Excessive oxygen concentration	Ox	Before 2.50	%
		After 2.00	%
Calculation procedure			
1) Exhaust gas air ratio :Or/ (Or-Ox)	m	Before 1.14 After 1.11	
2) Actual exhaust gas volume*2 :G0 + (m-l)*A0	G	Before 12.48 After 12.17	Nm^3/h Nm^3/h
3) Thermal loss of exhaust gas :G*SH*(Th-Tl)	L	Before 1565.43 After 1526.25	kcal/kg kcal/kg
4) Reduced exhaust gas thermal loss	LD	39.18	kcal/kg
5) Ratio of reduced exhaust gas thermal loss :LD/LHV	q	0.004	
6) Annual amount of fuel saved: q*V	SV	239.89	kl/year
7) Annual money of fuel saved: q*V*P	SC	113	K$/year

*1: Assume to be constant, though it varies depending on the temperature, CO_2 concentrations, etc.
*2: (m-l)*A0 is air volume not used for combustion

This example shows a trial calculation for 0.5% reduction of excessive oxygen in the heating furnace of a petroleum normal pressure distillation apparatus (topper) which process oil of 100,000 barrels per day. The result indicates a fuel saving of about 240 kiloliters, worth $113,000 per year assuming a price of $470 per one kiloliter fuel oil.

Furthermore, by reducing the amount of fuel used, CO_2 emissions can be reduced. The carbon emission per one kiloliter of fuel is about three tons, so CO_2 emissions are reduced by 720 tons per year.

Safety Control by the TDLS8000

A burner management system (BMS) safely controls the burner of the combustion furnace and includes an interlock mechanism and a safety shut-off mechanism to prevent explosion. The BMS must comply with safety standards based on risk assessment such as the international standard (ISO12100) and the EU, USA and Japanese standards (EU standard: EN746, USQ standard: NFPA86, Japanese standard: JIS B9700).

Because the TDLS8000 monitors the CO concentration in near real-time, it increases the reliability of the safety system by inputting a signal of the detected CO concentration to the BMS and is expected for implementing the defined safety requirements. Figure 6 shows a typical system configuration in which the CO measurement capability is added to the BMS burner shut-off system. Yokogawa's ProSafe-RS integrated safety instrumented system can be employed as the BMS.

In addition to the measurement of CO the TDLS8000 can accurately measure CH_4 (Methane) levels providing an extra level of safety during start up where a flame out or a failed burner ignition can cause an explosion.

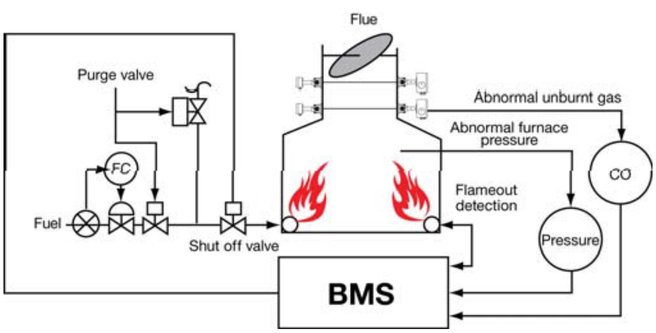

Figure 6 Safety Control in the Burner Control Equipment

Conclusion

The TDLS8000 is attracting considerable attention from many refinery and petrochemical plants because it requires little maintenance and can measure the concentrations of O_2/CO/ CH_4 in the furnace in near real-time.

The technology for combustion efficiency optimization, by measuring O_2 can CO concentrations in this application note was established more than twenty years ago.

The TDLS8000 provides a near real time measurement of O_2/CO/CH_4 in the radiant section of a large scale combustion furnaces and process heaters allowing process owners an unprecedented opportunity to optimize combustion.

Product Recommendations

TDLS 200 (O_2/CO/CH_4 analyzer)

Note: Various options are available please consult your local Yokogawa Sales Office for more information.

Notes

- Response time: 2-5 seconds
- Process pressure up to 20 bar
- Interference Free
- Process temperature up to 1500ºC
- TruePeak Measurement
- Optical Measurement- No sensor contact with process

References:

(1) Tsuneo, Hiraoka, "Reduction of Fuel Costs and CO_2 Control for Packaged Boilers," Yokogawa Technical Report, Vol. 44, No. 2, 2000, pp. 85-86 in Japanese

(2) Energy Efficiency and Renewable Energy, "Advanced Diagnostics and Control for Furnaces, Fired Heaters and Boilers," US Departments of Energy, 2007, http://wwwl.eere.energy.gov/industry/combustion/pdfs/advanced_diagnostics.pdf

(3) American Petroleum Institute, "Instrumentation, Control & Protective Systems for Gas Fired Heaters", API 556 2nd edition, April, 2011.

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