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Controlled Combustion

Arthur Groenbos, Yokogawa Europe, discusses tunable diode laser gas analysis for combustion management in fired heaters.

While fired heaters are used throughout refining and petrochemical processes as the source of process heat, they carry inherent risks and costs that make operating without current technologies problematic. To address safety concerns, industry standards are upgrading their recommended practice for instrumentation, control and protective systems for fired heaters and steam generators. While not yet required by regulation, plants not meeting the best industry practice guidelines will be at added risk in the event of an incident on a fired heater. Since many natural draught fired heaters do not meet this guideline with existing instrumentation and control systems, an upgraded system consisting of recommended technologies will be needed. Furthermore, since most natural draught fired heaters have only automated control of the fuel supply and not the air, excess air is often applied to the combustion process, thereby reducing thermal efficiency.

According to ARC Insights, “second only to raw materials costs, energy is the leading cost pressure currently affecting manufacturers. New analysis techniques, such as tunable diode laser spectroscopy (TDLS), can improve efficiency, maximise throughput, reduce emissions, and improve safety and reduce energy in combustion processes.”

This article highlights and describes the application of a new combustion management system using TDLS technology that has the ability to simultaneously control air and fuel supply to fired heaters by measuring average gas concentrations across the high

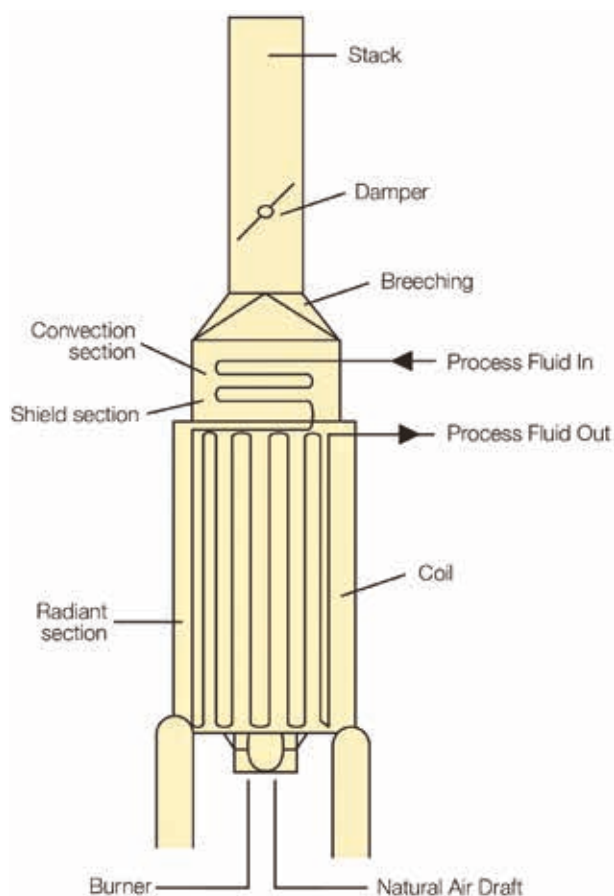


Figure 1. Diagram of a typical fired heater.

Table 1. Features and benefits of TDLS technology

Feature	Benefit
In situ analysis	Sample conditioning not required
Fast response	Real time data for control
Tunable laser	Interference free analysis
Non-contact sensor	Suitable for operations in harsh environments
Optical sensor	Low maintenance

Source: ARC Insights, Insight# 2009 - 50MP, November 2009

temperature radiant section. Reliable measurements of cross sectional averages of O_2 and CO at high temperatures have only recently become viable with the introduction of TDLS technology. The solution described in this article unites a TDLS analyser with a dedicated control system and a safety system certified to meet FM NFPA and SIL 2 standards.

The intrinsic value gained by adopting this new combustion technology can be summarised by the following:

- Best industry practices which can only be satisfied with new technology.
- Increased safety because both air and fuel are continuously controlled.
- Improved thermal efficiency as excess air is always optimised.
- Longer fired heater life (asset reliability) since heat is not concentrated at the bottom of the convection section.

- Lower greenhouse gas emissions through more efficient use of fuel.

Managing combustion in natural draft fired heaters

The air supply for most fired heaters is natural draught, not forced air, and these heaters typically lack the degree of automation normally applied to other process units in the plant. Natural draught fired heaters, as the name implies, use flue gas buoyancy to support combustion. These heaters can be either cylindrical or box type (Figure 1). The buoyancy of the flue gas (combustion product) relative to the surrounding air is determined by the product of the average density of the flue gas and the height of the heater. Furnaces are designed to run at a pressure of -12 to -25 Pa at the top of the radiant section, whether a heater is natural draught, induced draught or forced draught. Figure 1 provides a simplified diagram of a typical fired heater.

The low level of control on most fired heaters is due, at least in part, to the historical lack of reliable, effective instrumentation and automation technology to simultaneously measure and control the fuel, gas concentrations, and the air/fuel ratio.

An O_2 sensor is typically required at the stack base for thermal efficiency calculations, which require total excess air. While operators attempt to maintain 'excess' O_2 in the furnace for safety, the amount indicated from an existing sensor may be incorrect due to tramp air. In fact, it is possible that the burners may be starved of air, despite excess oxygen at the stack base. Because of the lack of air control, in practice operators will typically allow excess air into the fired heater, reducing its thermal efficiency.

The lack of effective instrumentation to continuously and rapidly measure O_2 and CO in the combustion chamber of the fired heater introduces considerable safety risk. Apart from the simultaneous control of fuel and air concentrations, it is possible for fuel rich conditions to arise, which increases the potential explosion risk. Note that under fuel rich conditions, temperature/fuel controllers no longer work properly.

The detection of combustibles, primarily CH_4 , in the radiant section of the fired heater is recommended by the American Petroleum Institute in API 556: a recommended practice for 'Instrumentation, control and protective systems for fired heaters and steam generators' that specifically applies to gas fired heaters and steam generators in petroleum refinery, hydrocarbon processing, petrochemical and chemical plants.

However, traditional analyser technology cannot be installed in the radiant section due to the high temperatures. As noted above, without accurate measurements of CH_4 , O_2 and CO concentrations, operators tend to allow more air than is necessary in the heater, reducing its thermal efficiency. To properly control the combustion air, CH_4 and CO must be measured at the top of the radiant section where combustion is completed, regardless of the burner loading. Note that O_2 and CO will coexist within the flames, where the temperature may be as high as 1200°C. Low NO_x burners may use delayed completion of combustion through staged air/fuel mixing, or external recirculation of cooler flue gas with combustion air, reducing peak flame

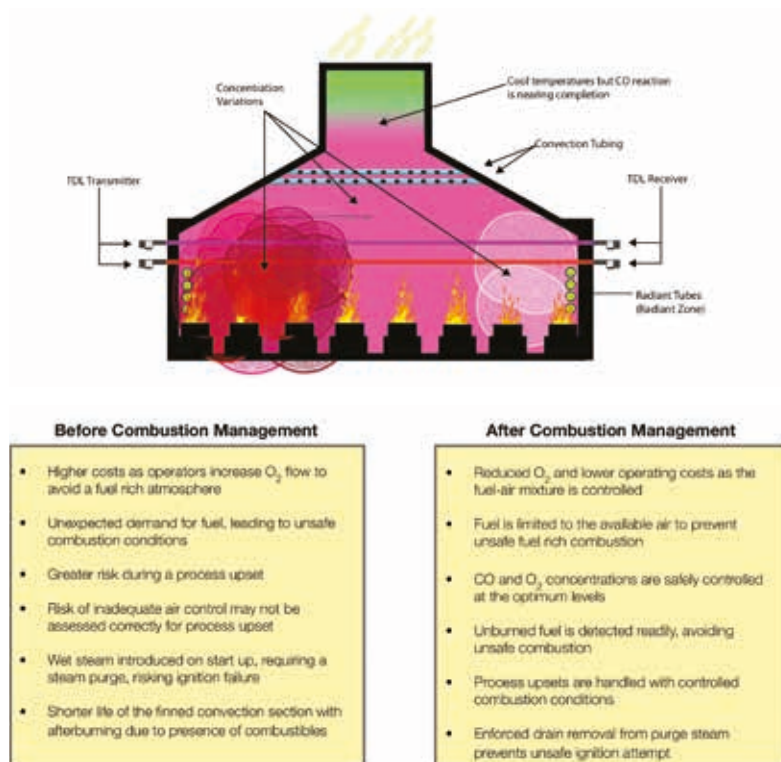


Figure 2. TDLS technology for combustion safety and optimisation.

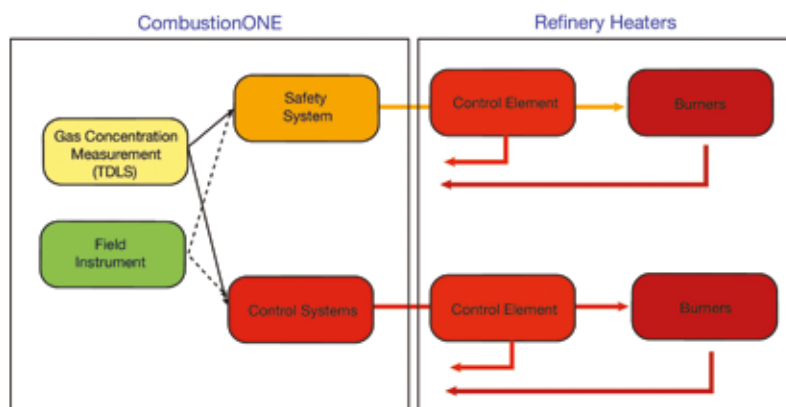


Figure 3. Basic functional capabilities of Yokogawa's CombustionONE™ integrated TDLS system.

temperature. In either case, to effectively control the combustion process it is essential to measure O_2 and CO at the top of the radiant section, ideally 1 ft below the roof tubes where combustion reaction is expected to complete under all heater operating loading conditions. Using the TDLS in concert with a dedicated controller, a cross sectional average O_2 and CO density rather than a localised spot measurement can be measured to determine the right air/fuel ratio. Using an average O_2 value and CO limit value produces safer burner control and greater overall heater efficiency.

Table 1 lists the features and benefits of TDLS technology, which has distinct advantages over single point in situ analysers that may give false readings because of varying gas concentrations at different locations in the fired

heater. Fired heaters have two principal unsafe operating conditions that must be avoided:

- Fuel rich, where air is reduced. CO will be produced by the burners and excess O_2 will be lower, which results in excess fuel from the burners
- Flame out, where loss of flame results in rapid loss of gas temperature. O_2 levels are high as burner air is not reduced by combustion, and uncombusted fuel is present.

Consequently, continually measuring the percentage of O_2 is critical to improving heater efficiency and to maintaining safe operating conditions. When firebox conditions are unacceptable, i.e. high levels of CO or combustibles exist, the effective combustion management solution must rapidly detect the condition and initiate the appropriate response.

In the system being described, the embedded control and safety systems will ensure that these conditions are avoided or that combustion is extinguished and fuel flow is interrupted automatically if these conditions are detected. The TDLS analyser technology will reliably respond to all ' O_2 events' in situations where conventional sensor technology would miss most of them.

How it works

Capable of measuring the average gas concentration across the radiant zone of the fired heater, the TDLS system addresses both the above less than optimum conditions by simultaneously controlling the fuel and air (O_2) supply based on fast (typically less than five second) sample intervals. Measuring the gas concentration in the radiant zone is also a requirement of API 556.

Measurements from the system include CO , CH_4 , O_2 , and temperature. Using an average gas concentration produces safer burner control and greater overall heater efficiency. By optimising air flow control, O_2

concentration is typically reduced from 6% to 2%, increasing thermal efficiency of the furnace.

The combustion management system manages fuel flow and arch draft through the existing plant DCS via Modbus, while combustion airflow is controlled directly with the CO override function.

The simplified architecture diagram in Figure 3 illustrates the key components comprising the solution. Because the TDLS is a non-contacting measurement, never touching the flue gas, and has no moving parts, the whole system enjoys very high reliability. This TDLS analyser technology has been operational on furnaces since 2003 without incident, and most of those units have not required calibration. The analyser has full diagnostic capability, and if there is an issue it will alert the operator. Moreover, the

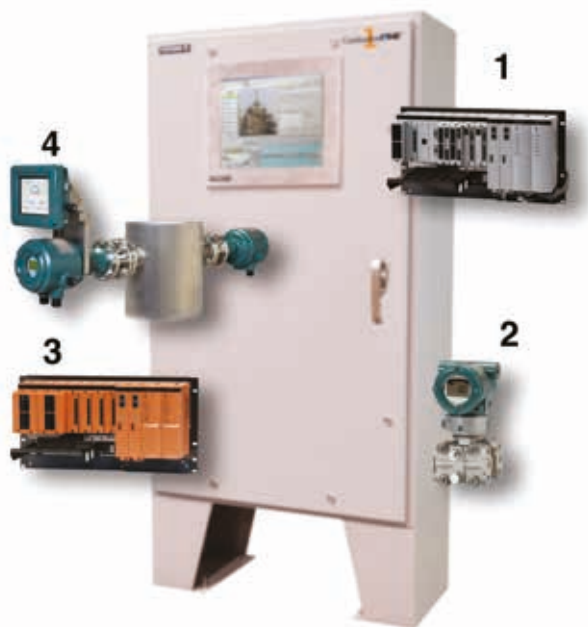


Figure 4. Hardware included in the CombustionONE™ TDLS system: 1) dedicated controller; 2) sensing and actuation; 3) safety interlock system; 4) tunable diode laser spectrometer.

measurement signals from the TDLS are unaffected by the presence of other gases in the flue gas, unlike sensor based systems. The TDLS uses a path average measurement, as opposed to the traditional point measurement, making the value of concentration much more accurate.

Refinery application

The most critical times of heater operation are at start up and shutdown. Recognising that a much faster, more reliable analyser is required to measure O_2 , CO and CH_4 concentrations, a European refining operation has adopted the TDLS solution for combustion management. Since the system measures gas concentration in the radiant section of the fired heater, it is expected to improve heater safety and overall operational efficiency.

In this application, the system is installed with two TDLS analysers for measurement of O_2 , CO and CH_4 concentrations in the radiant section of the heater. A dedicated controller uses these measurements while feeding these values to an existing DCS for monitoring and future control of the heaters. The dedicated control hardware is equipped to receive additional signals from the heater, which will be used to control the airflow in the burners in a subsequent phase of the project. Space has also been allotted for a future safety shutdown system.

The system is designed to be tested during upset conditions, with the response of combustion gases being analysed to confirm the desired response to unsafe conditions. This data can then be correlated to the output from the existing stack gas analyser to verify the results. Data collected during this testing will be incorporated into the future safety shutdown system. A modular procedural automation capability will enforce safe operating

conditions during start up and shutdown. Once the safety interlock system is in place, the system will be able to detect and prevent any unsafe operating conditions.

Natural draught heaters lack the capability to use air to purge the heater. Instead, steam is used. If the steam is not dry, water will accumulate on the burners or igniters, preventing ignition. The start up sequence is designed to purge the condensate from the steam line, thus providing dry steam to purge the heater before ignition.

The system has been operational in the refinery since June 2010, and the TDLS analysers continue to operate reliably with no maintenance needed. The operators have been able to reduce the percentage of O_2 by 1% to 1.5%, thus making the heater more efficient. The furnace is now near its optimum operating point, using minimum excess air. The TDLS measurements have been verified by the existing stack gas analysers, but with a percentage O_2 reading of 1% to 1.5% lower than the stack gas analysis because the measurements are taken in the radiant section. Furnace conditions can now be controlled (or shut down) quicker since the TDLS system is taking concentration measurements at five second intervals in the radiant section. If there were to be an excess concentration of CO or CH_4 in the furnace, these gases can be detected earlier than with the conventional stack gas analyser, enabling the heater to be shut down sooner and avoiding unsafe conditions.

Integrated solution

The combustion management system described in this article (Figure 4) is an integrated, self contained system that can be rapidly installed on any fired heater. It comprises four principal components:

- TDLS technology for gas concentration measurements at fast (less than five second) intervals.
- A dedicated system for control of fuel and air value and ratio based on a fired heater model with CO override function.
- An OSHA compliant safety system to prevent unsafe conditions from persisting.
- Sensing and actuation for additional measurements and air flow control as needed.

Two TDLS systems (transmitters and receivers) are typically installed in the radiant section of the fired heater, which is the most accurate location for optimum combustion management. At minimum, one unit measures O_2 and the other CO and CH_4 . Since fired heaters have differing configurations, capacities, environmental and process conditions, custom mounting brackets are built to hold and position the laser across the radiant section. This is the best location to obtain the most accurate gas concentration and temperature measurements. The dedicated controller is used to simultaneously control fuel and air volumes based on five second sampling measurements of average gas concentrations across the radiant section from the TDLS.

Since the combustion management solution is completely self contained and requires little integration with existing control systems and instrumentation, installation is typically straightforward. 