Optimizing Reboiler Efficiency Using In-Situ Combustion Probes

Reboiler heat transfer

Heat transfer media such as steam, paraffinic oils and synthetic fluids are required at many industrial sites to transfer heat to reaction vessels and heat exchangers. Heat production occurs in boilers and furnaces, where the combustion of fuels such as natural gas generates heat that is absorbed by the heat transfer media. Perfect mixing of fuel with air in a furnace is rarely possible, so excess air is needed to ensure sufficient oxygen to complete combustion and optimize heat transfer across the boiler or furnace range. Incomplete combustion is inefficient. Furthermore, carbon monoxide (CO) and hazardous air pollutants like dioxins and furans are a byproduct of incomplete combustion, which poses a health hazard, and CO and unburned fuel can pose an explosive safety risk. Therefore, for health, safety and efficiency reasons, good combustion is essential and can be accomplished through optimizing flue gas excess oxygen (O_2) operating conditions using Emerson's Rosemount™ zirconia combustion O_2 analyzer technology.

Rosemount zirconia technology

Zirconia technology uses a heated electrochemical cell made of yttria-stabilized zirconia. The zirconia is placed in a stainless steel holder. Gold braze is applied between the zirconia and holder for a hermetic seal. The gold braze is one aspect that sets the Rosemount O_2 sensor apart, making it the most accurate, robust, and long-lasting in the industry. Each side of the zirconia disk is coated with a platinum electrode. One side of the zirconia disk is in contact with the process gas, while the other side is in contact with a reference gas, typically air. O_2 ions travel across the zirconia from high to low concentration, generating a millivolt potential that is governed by the Nernst equation.

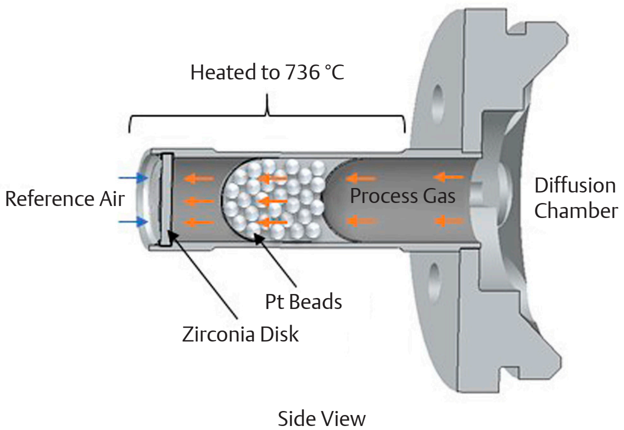

Figure 1. *Zirconia Oxide Cell*

Another differentiating aspect of the Rosemount sensor is the zirconia location. As shown in Figure 1, the zirconia is placed at the end of a narrow tube that is packed with platinum-coated beads. The process gas diffuses down the tube. Any residual unburned fuel in the process gas is oxidized by the platinum beads providing a direct measurement of excess O_2, which relates directly to combustion air-fuel ratio or stoichiometry. The beads also oxidize sulfur reducing its potential for cell deterioration.

Reboiler applications

Combustion O_2 analyzers are installed downstream of the furnace process heaters in a host of applications, many to do with steam production like electricity production, central heating, steam reforming, utility steam and reboiler distillation. The simplest reboiler is known as the kettle reboiler. Kettle reboilers are shell and tube heat exchangers that use heat transfer media in the shell side and column bottoms product in the tube side to produce vapors that are returned to the bottom of the distillation column. Thermosyphon reboilers use natural circulation driven by density differences between the reboiler inlet and outlet rather than pumping of the bottoms product. Still, fired reboilers are process heaters in which the bottoms product is pumped through the heater's radiant and convection sections and delivered back to the column. Regardless of reboiler type, the vapors generated by the reboiler are essential in driving component separation in the distillation column. Reboilers such as the one in a triethylene glycol

(TEG) unit in the natural gas processing industry can operate at very narrow temperature margins.

Crude natural gas from the wellhead contains water and crystalline solids, which can damage downstream pipelines. Lean TEG is mixed with natural gas to absorb the water. The rich TEG is then sent to a recovery or regenerator unit, as shown in Figure 2 below. The Glycol Regenerator unit is a distillation column that separates the water from the TEG so that the TEG becomes lean again and ready for reuse. Extensive studies have shown that reboiler temperatures of this recovery column of 400 °F will yield the purest TEG at greater than 98.5%. However, most natural gas processing sites will run between 380–390 °F, because TEG begins to decompose at 404 °F. Running at lower temperatures will make it more difficult to achieve the required TEG purity, therefore the conditions of the heat transfer media to the reboiler must be carefully controlled. Many factors are critical in controlling the reboiler temperature and pressure; the design of the heat exchanger, flow rate of heat transfer media, and temperature and pressure of the heat transfer media. The latter is controlled by firing rate or fuel heat-input and the air-to-fuel ratio, or excess O_2.

One other crucial reboiler in the natural gas processing industry is found in the amine recovery unit from gas sweetening. Monoethanolamine (MEA) or diethanolamine (DEA) is used to remove the poisonous and lethal gas, hydrogen sulfide, and rich MEA or DEA is sent to a recovery unit. Although the reboiler in amine regeneration does not require as narrow a temperature margin as in TEG regeneration, optimal temperature and pressure of heat transfer media is still needed for reboiler efficiency. In other words, maintaining the excess O_2 in the furnace is crucial for efficient reboiler performance.

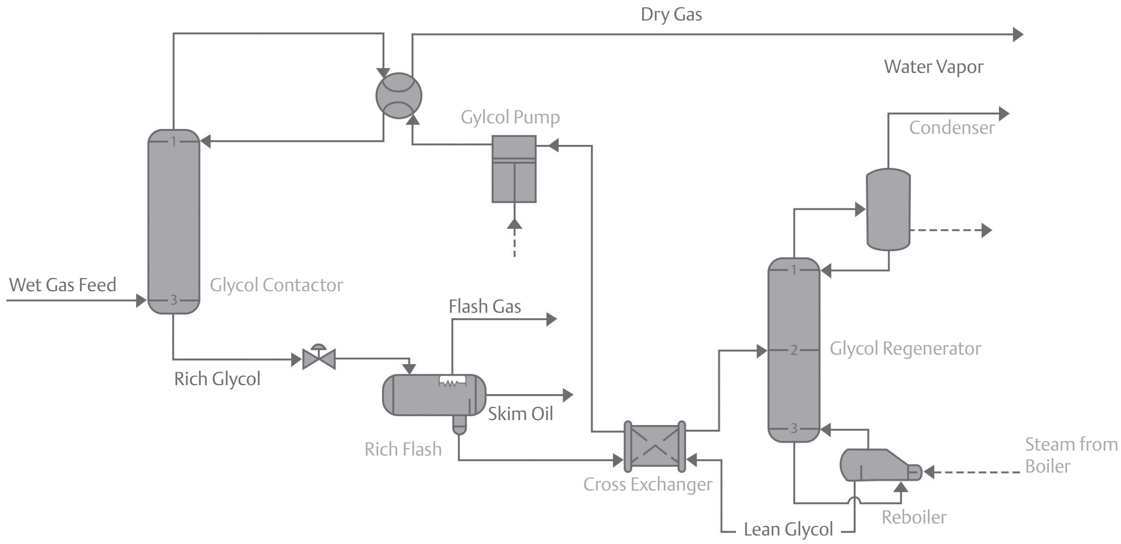

Figure 2. *Glycol Dehydration Unit. Reboiler can be seen at the bottom of the Glycol Regenerator.*

The Emerson solution

The air-to-fuel ratio and therefore excess O_2 is among the most important factors in controlling the conditions of the heat transfer media to a reboiler. Rosemount offers both in-situ O_2 probes and close-coupled extractive O_2 and combustibles analyzers. The Rosemount 6888 in-situ O_2 probe can be installed downstream of the furnace exit to help achieve and maintain the necessary air-to-fuel ratio for a given fuel heat input by measuring the excess O_2 concentration in the flue gas. Different sites may choose to operate at different levels, but furnaces using clean-burning fuels like natural gas typically operate as low as 10–15% excess air, which amounts to 2–3% excess O_2 in the flue gas exhaust. As the firing rate is reduced, excess air is typically increased over 30% to reduce flue gas temperature and maintain convective heat transfer from the flue gas to the steam. Furthermore, the Rosemount OCX8800 can also be installed at the furnace exit to measure both O_2 and combustibles like CO and hydrogen. The combustibles concentration is instrumental in determining combustibles breakthrough levels for furnaces operating lean in O_2.

Each reboiler in a natural gas processing plant normally has its own dedicated boiler or furnace, in which a combustion O_2 analyzer can be installed. The Rosemount analyzers are designed with the most robust and accurate zirconia electrochemical sensors in the industry to attain accurate excess O_2 concentrations in the flue gas, or in other words, accurate air-to-fuel ratios. This in turn ensures a controlled heat of combustion necessary for precise heat transfer media quality going to the reboiler.

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