Optimizing Catalyst Regeneration with an In Situ Oxygen Probe

Optimizing the Performance of the Catalytic Cracking Process Through Better Gas Analysis

Catalytic crackers have long been utilized to extract additional gasoline from heavier components resulting from the distillation process. The distillation process is the physical separation of a MIXTURE of different molecules, based upon the different boiling points of these molecules. The catalytic cracking process splits larger hydrocarbon molecules into lighter and higher value components such as gasoline by using a catalyst, which aids the reaction or “cracking” process. The cracking process produces carbon, or coke, which remains on the catalyst particle, reducing its effectiveness over time. Fluidized Catalytic Cracking Units (FCCU) will continuously route coked catalyst into a regenerator unit where oil remaining on the surface of the catalyst is stripped off with steam or solvent. The catalyst is then sent into the regenerator, where air is introduced to burn the coke off of the hot catalyst, usually in suspension. There are many different variations in the regeneration process, including the Continuous Catalyst Regenerator (CCR) process.

The regeneration of catalyst frequently becomes a bottleneck that limits the throughput of the catalytic cracking process, so optimizing this process is important.

Complete Burn Regeneration

A complete burn regeneration process burns all of the coke off, and the resulting flue gases are routed through gas-cleaning equipment, and then to a smokestack. Oxygen is measured in the flue gas resulting from the coke burn-off to maximize the coke removal, and throughput. This may take place at the top of the regeneration tower, and under pressure, or after a turbo-expander that recovers energy and results in lower pressures closer to the smokestack (see Figure 1). In-situ zirconium-oxide oxygen analyzers can be utilized to measure the flue gas O₂ resulting from regeneration in either location. Pressure affects the analyzer readings, so a pressure balancing system is recommended for pressures above 2 PSI.

Partial Burn Regeneration

A partial burn regeneration process endeavors to volatize, or outgas the coke, and produce CO gas that is then burned in a separate CO boiler. Some coke is also burned in this process, and one goal is to control the CO-to-CO₂ ratio in the regeneration off-gases in order to maximize the burn-off, and hence the throughput. An extractive analytical system utilizing gas chromatographs or Infra-red process analyzers is typically used to measure and control the CO and CO₂ ratios. Refer to Application Note PGC_ANO_Refining_Improving_Catalytic_Cracking_Vapor for a detailed description of these measuring systems.

Oxygen Enrichment Improves Throughput (see Figure 2)

Enriching the air used in the regeneration process can increase the coke burn-off rate. Many refineries will mix pure oxygen with the air used for regeneration, resulting in a mixture of 21 to 25 % O₂, which increases the efficiency of the regeneration process.

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This oxygen measurement can be used for operator information, alarming, or automatic control of the oxygen injection valve (see Figure 1). Pressures are normally 35 PSI, so the probe must be pressure-balanced with reference air (see reverse side).

**Figure 3 - CCR Regenerator**

**Oxygen Enrichment Improves Throughput**

Enriching the air used in the regeneration process can increase the coke burn-off rate. Many refineries will mix pure oxygen with the air used for regeneration, resulting in a mixture of 22–30% O₂, which increases the speed and throughput of the regeneration process.

The rate of oxygen injection can be controlled by an O₂ analyzer just after the mixing valve injection valve (see Figure 1). Pressures are normally 35 PSI, so the probe must be pressure-balanced with reference air.

**Continuous Catalytic Regenerator (CCR)**

Utilized with a "moving bed" process, the CCR employs a regeneration gas loop to control temperature and O₂ levels in the regenerator "burn zone." This recirculation loop heats or cools the combustion flue gas resulting from the regeneration process to control temperature, and air is also controlled to an optimum O₂ concentration (see Figure 3). The O₂ measurement is critical to maintaining optimum rate of regeneration, and for preventing thermal damage inside the burn zone. Process pressures may be close to atmospheric, or pressurized to approximately 35 PSI. Pressure balancing may be required, and an isolation valving system could be needed if probe insertion or withdrawal is required with the process on-line. Pressure balancing will adjust to pressure variations, while traditional O₂ systems place a fixed compensation into the electronics. Chlorine is injected into this unit to assist in getting an even coating of platinum or other catalyst materials. A special HCL-resistant sensing cell is required.

**Pressure Balanced O₂ Probe**

Most in situ oxygen analyzers utilize zirconium oxide sensing technology, which is sensitive to pressure variations in the process. An output change of approximately 1% of reading (not 1% FS, or 1% O₂) can be expected for every 4” of H₂O pressure in the process. Special accommodation must be made to balance the process pressure with the inside of the oxygen probe. Rosemount Analytical has a special probe design that balances the inside of the probe to the same pressure as the process. A sealed probe is used along with a "booster relay" which duplicates the pressure of the process with the instrument air being used as a reference gas (see Figure 4). For accurate, reliable oxygen analysis, Rosemount Analytical offers the 6888 O₂ Analyzer with integral electronics. The user friendly design of the probe allows convenient access to internal probe components for in-house service. In addition, the Rosemount Analytical patented electronic cell protection automatically protects the sensor cell’s electrodes from harmful corrosive gases. And, the HART® Field Communications Protocol permits all operator functions to be performed from the control room.

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The Emerson Solution
Emerson Process Management offers a wide array of instrumentation for improving the operation of the catalyst regeneration process including physical measurements (pressure, temperature, and flow), complete analytical solutions, valves and actuation, and SMART Process advanced control solutions. Emerson’s technologies have set the standard for on-line process measurement and control.