PRACTICE SHARING

O_2 Monitoring in FCCs during Non-Normal Operation

Purpose and Use:

The purpose of this document is to share the practice of monitoring oxygen (O_2) concentration in a Fluidized Catalytic Cracking (FCC) main column overhead system during unit startups (SU) and shutdowns (SD). The most important process safety principle related to the operation of an FCC Unit is to keep air/oxygen, which is present in the regenerator (referred to as the “Air Side” of the Unit), away from hydrocarbons present in the reactor and downstream equipment (referred to as the “Hydrocarbon Side” of the unit). However, air/oxygen ingress to the FCC reactor and downstream equipment is often inevitable when circulating catalyst from a regenerator containing a high level of excess oxygen since this gas is present in the catalyst/emulsion phase flowing into the regenerated catalyst standpipe and onward to the reactor. It is possible to measure and control oxygen concentration in areas of the FCC unit where oxygen is most likely to accumulate in order to help manage this potential hazard.

Practice Sharing Documents are meant to share information on process safety practices in order to help improve process safety performance and awareness throughout industry. The goal is to capture and share knowledge that could be used by other companies or sites when developing new process safety practices or improving existing ones. The Practice being shared has been used by an industry member, but this does not mean it should be used or that it will produce similar results at any other site. Rather, it is an option to consider when implementing or adjusting programs and practices at a site.

BY THEMSELVES, THE PRACTICE SHARING DOCUMENTS ARE NOT STANDARDS OR RECOMMENDED PRACTICES. THEY ARE NOT INTENDED TO REPLACE SOUND ENGINEERING JUDGMENT. THEY DO NOT PRECLUDE THE USE OF ALTERNATIVE METHODS THAT COMPLY WITH LEGAL REQUIREMENTS. A SUBJECT MATTER EXPERT SHOULD BE CONSULTED PRIOR TO DETERMINING WHETHER A PRACTICE SHARING DOCUMENT CAN BE USED IN ANY SPECIFIC SITUATION.

Background:

FCC catalyst standpipes transfer catalyst between the reactor and regenerator(s). Gas fluidizes FCC catalyst and facilitates this movement. Catalyst in the reactor stripper/regenerator accelerates when entering a standpipe and results in gas/vapor being drawn in. During normal operation, gas near a regenerator standpipe entrance is mostly inert and this entrained gas is detected as measurable amounts of N_2 and CO_2 in FCC dry gas. However, during non-normal operation this gas can contain significantly higher amounts of O_2 since regenerator oxygen concentrations are much higher and reactor temperature does not result in conversion to CO_2. This gas will flow as dictated by pressure balance (whether fluidized catalyst is present or not) when slide valves are closed (slide valves are not gas tight). When slide valves are open and catalyst is being circulated, the amount of gas entrained to the reactor and downstream equipment will vary with catalyst circulation rate, standpipe density, and other operating conditions per the following formulae on the following page.

When circulating catalyst during non-normal operation (i.e., reactor heat-up during startup, or hot standby operation), the entrained gas will have a high concentration of O_2, which will pass through unreacted to the main fractionator and overhead system. This entrained O_2 is purged from the FCC main column overhead system (or Gas Con) to prevent accumulation and potential hazard.

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$$\text{Voidage} = \sum = \rho_f/\rho_s$$

&

$$\text{Carry Under (SCF/hr.)} = \text{CCR}/\rho_f * \sum \times (T/520) \times (14.7/P_a)$$

Where:

ρ_f = Flowing Density (lb./ft^3)
ρ_s = Skeletal Density (~164 lb./ft^3)
CCR = Cat Circulation Rate (lb./hr.)
T = Regen bed temp. (°R)
P_a = absolute pressure in regen standpipe, typically above slide valve (psia)

Description and Implementation:

Monitoring O_2 concentration on the hydrocarbon side of an FCC during a SU or SD can be done by sampling vapor from the main column overhead receiver. Vapor is sampled in this location because O_2 is concentrated in this stream following condensation of steam in the main column overhead system. The sample can be drawn either continuously or intermittently and analyzed for O_2 via gas detection equipment. The exhaust gas from the analyzer can be routed to the refinery flare header or other location for safe disposal. A common method used to control O_2 concentration is addition of natural gas to the main column overhead system. It is important to ensure that any gas addition for this purpose does not interfere with forward flow of steam from the FCC reactor nor jeopardize it staying inert.

Several types of O_2 analyzers are available. They range from simple, portable analyzers (such as those used for testing atmosphere prior to hot work), to a purpose built, in-situ analyzer, operated via a third-party contractor. Another option is to pull samples periodically and have them analyzed by the refinery lab.

Figure 1 shows the sample collection point used for monitoring O_2 in an FCC during non-normal operation.

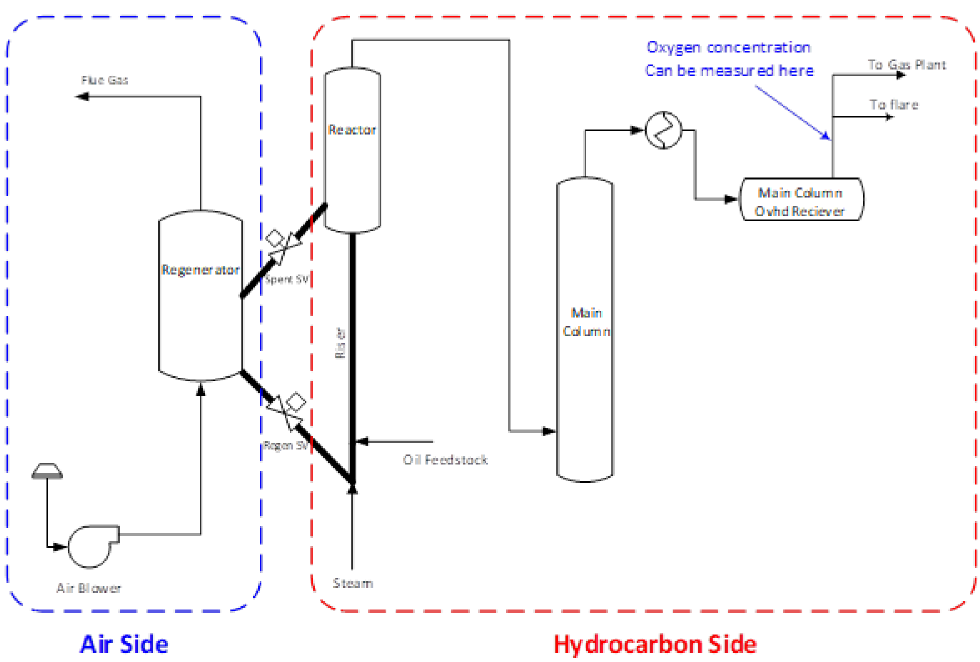

Figure 1. Sampling location for monitoring O_2 in an FCC during non-normal operation

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In a recent planned outage, one operating company utilized a third-party contractor to set up, calibrate, and maintain an analyzer during SD and SU. This option was chosen due to the limited time available to select the analyzer and install it prior to the planned outage. The refinery partnered with a contractor with prior experience in stack testing for this installation. The O_2 concentration in the main column overhead system was monitored throughout SD and SU. As a temporary solution to provide real-time monitoring of the data, a webcam was pointed at the analyzer read-out and was viewable at the FCC DCS console. The O_2 data was recorded, and later, the time stamped data was overlayed vs. the SU and SD timeline to analyze the effects the different phases of SU and SD had on the amount of reactor O_2 levels.

Another operating company utilized portable gas detection equipment to routinely monitor O_2 concentration in the FCC main column overhead stream during non-normal operation. Natural gas was used to control the O_2 concentration with the overhead pressure being controlled to relief. Readings were logged in a tracking sheet contained in the operating procedure document. Monitoring and control of O_2 concentration was conducted by FCC operations personnel using typical gas detection equipment. See below for a picture/example of this configuration.

Figure 2. O_2 concentration monitoring in the FCC main column overhead stream during non-normal operation

References:
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Revision	Date	Summary of Changes
Initial Draft	October 2021	Initial Version
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Revision	January 2022	PSW Review
Legal Review	April 2022	AFPM Legal Review
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