

## Catalyst Regeneration

**Industry:** Crude Refinery  
**Product:** TDLS200

### Introduction

Cracking is used to break down the long chains of hydrocarbons that crude oil is comprised of into smaller hydrocarbon chains. Cracking was originally done thermally, and continued until 1933, when the Houdry process for catalytic cracking was developed. The Houdry units were preferentially adopted in following years due to producing a much higher portion of higher octane gasoline during cracking. The process was improved once again and became known as Thermoform Catalytic Cracking (TCC) and involved the use of a moving catalyst bed. The first commercial TCC unit was developed in 1943 in Beaumont, Texas and it is speculated that TCC and Houdry units played a large part in the allied victory of World War II. Around the same time, MIT professors Lewis and Gilliland developed a Fluidized Catalytic Cracking Unit (FCCU) which involves passing just enough air through the catalyst that it floats, allowing it to function as a fluid. FCCUs have since become the dominantly produced cracking unit. FCCUs used in conjunction with catalyst zeolite Type Y have increased the yield (~45% of total yield from the feed) and octane rating of gasoline far above of what would be achievable with thermal cracking. As of 2011, catalytic cracking produced over 8,700,000 barrels of motor gasoline per day in the US alone.

### Process

Hot crude oil is pumped in a riser which contains hot, clean, catalyst beads from the regenerator. The crude oil contacts the hot catalyst and is broken down to vapors via cracking. The vapors continue through the riser which fluidizes the catalyst and continues to the reactor. The cracked hydrocarbons are subsequently separated from the catalyst mechanically and using steam stripping. The vapors go to the distillation column for further separation. The catalyst however, has been rendered much less effective due to coke deposits from cracking which reduce the number of active sites on the catalyst. The catalyst is sent to a regenerator to restore the catalysts' cracking abilities by removing the coke.

In the regenerator, air is introduced to burn the coke deposits off of the catalyst. The hot catalyst is then sent back to the riser to repeat the process. The flue gas leaves the regenerator after the catalysts are mechanically removed and the amounts of CO and O<sub>2</sub> present are measured to control combustion air sent to the regenerator.

Traditionally, CO has been measured using Infrared Photometry and O<sub>2</sub> has been measured Paramagnetically. Both units require complex sampling systems to prevent damage. They also have moving parts which require maintenance and must shutdown the process to perform said maintenance. Paramagnetic measurements can also have false readings due to interfering molecules. Tunable Diode Laser Spectroscopy (TDLS) alleviates these problems because no measurement parts make contact with the process. The TDLS units can be mounted either in-situ or with extractive setups, and allow the cleaning of catalyst fines from the analyzers' windows without process shutdown. TDLS is not susceptible to interference from other molecules because it makes a direct measurement, and does not rely on second principles such as magnetic properties.

The flue gas is then sent to drive a compressor for electricity (given enough flow) and subsequently sent to a CO utility boiler to produce steam for the refinery.

## Expected Benefits

- No sample system required
- If using a sample system and it fails, no analyzer damage occurs
- No downtime for cleaning
- 14 days of historical data and spectra
- In-situ automated validation
- No interference from other molecules

## Cost Analysis

Over 8,700,000 barrels of motor gasoline were produced at 148 refineries in the US and sold for an average of \$2.867 USD per gallon in 2011. This means that nearly 2,500 barrels of gasoline were produced per hour worth \$36,000. That is representative of an expected average revenue loss from an hour of downtime.

Maintenance costs can be eliminated by utilizing an in-situ measurement system.

Utility costs can also be decreased by tightly controlling the amount of CO present in the flue gas for the utility boiler.

## Product Recommendations

\*Feedback control for combustion air fed to the regenerator and assurance of de-coked catalyst by measuring flue gas after the regenerator in-situ with a TDLS200 or extractive with a TDLS220.

### FLUID CATALYTIC CRACKER PLANT

