Maximizing Efficiency and Profitability: Mitigating Challenges through Nitrogen Monitoring and Control in FCC-OPP Operations

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Overcapacity and investments surpassing the anticipated demand has contributed to a downturn across the petrochemical marketplace. Nowhere is this more evident than in the propylene segment where, despite continued bullish sentiment on the market growth, prices have reverted to the mean. As the market goes through these growing pains, these effects are projected to persist until 2026. As with previous downturns, the winners will be judged in part by their ability to utilize their assets in the most efficient manner.

One of the most exciting avenues of propylene production that is often discussed is on-purpose propylene by fluidized catalytic cracking technology (FCC-OPP). This process involves modifying the operation and catalyst of an existing fluidized catalytic cracker (FCC) to optimize the process for propylene production from naphtha instead of the typical production of fuels from gas oil. The advantage of this approach is the ability to repurpose existing assets for a new purpose, requiring only a moderate investment while retaining a certain degree of flexibility.

Nevertheless, FCC-OPP does present a new set of challenges. The catalyst poisoning by nitrogen-containing molecules, an issue typically of minor concern in a fuels-based operation, becomes significantly more problematic in an OPP operation. Numerous factors contribute to this, beginning with the feedstock itself. Instead of the gas oils conventionally fed to an FCC, naphtha is used for propylene production. And because naphtha is a blendstock for gasoline, the highest quality naphthas are reserved, leaving lower quality naphthas like coker and visbreaker naphtha for FCC-OPP. However, these naphthas carry a higher nitrogen load on average, and which can vary significantly, sometimes reaching levels as high as 2000 ppm.

Nitrogen is a catalyst poison, and a particularly potent one for the essential ZSM5 catalyst which enables FCC-OPP technology. As a Lewis base, its lone pair of electrons bind with the acid sites in the catalyst, resulting in the blockage of the active site. This obstruction causes nearby hydrocarbons to coke instead of crack, resulting in the deposition of coke on the catalyst. The production of coke itself is a loss of value but it also further reduces the reaction rate due to the blocked active site, leading to a loss in efficiency.

In a typical fuels-mode FCC, these challenges are manageable. The lower nitrogen levels and the more forgiving catalyst enable efficient catalyst recovery in the regenerator. However, an FCC-OPP already operates at higher temperatures, higher pressures, and smaller pore sizes compared to a fuels-based operation. The process is highly sensitive to heat imbalances, and achieving the optimal propylene rate becomes unattainable if the regenerator constantly contends with the nitrogen load.

Although adjusting the catalyst-to-oil ratios can be employed to effectively “dilute” the nitrogen load, this approach introduces its own set of severity issues. Therefore, it is crucial to emphasize that the nitrogen load significantly impacts the quantity and quality of propylene produced, and is a major factor that determines the economic viability of an FCC-OPP. Consequently, careful measurement and, if possible, control of this parameter are essential.

ElemeNtS is an advanced, modular, analytical system for detection of total sulfur and total nitrogen using ultraviolet fluorescence (UVF) and chemiluminescence (CLD) in solid, liquid, gaseous materials, and LPG samples.

Assessing the Value of Nitrogen Poisoning

If the conversion loss due to the temporary nitrogen catalyst deactivation leads to an estimated 2% loss of conversion in an average 120,000 BBl/day FCC that is making 10% propylene at $1000/MT loses about $25k/year. Some of the higher propylene yields reach around 20% where the loss is greater, about $48k/year.

In cases of permanent catalyst deactivation, even a marginal 1% increase in the daily consumption rate of 10-20MT amounts to a substantial annual expenditure of $55k to $110k.

These figures unequivocally warrant the implementation of an analyzer program for source monitoring and control. But how can this be achieved?

Solution for Measurement of Total Nitrogen

PAC, and previously ANTEK, has been at the forefront of laboratory total nitrogen measurement since the 1960s, with almost four decades of experience in process instrumentation. We remain the sole global provider of online combustion chemiluminescence for nitrogen analysis. The combustion-chemiluminescence technique, akin to UV fluorescence commonly employed for sulfur analysis, involves subjecting the sample to complete oxidation in a highly efficient furnace with an adequate supply of oxygen. This process converts all organic nitrogen species into nitric oxide. Subsequently, the nitric oxide reacts with ozone, generated onboard the instrument, creating nitrogen dioxide in a quantum excited state. The ensuing release of photons from this excited state, resulting from a chemical reaction, is known as chemiluminescence.

Following these steps, the analytical process proceeds in a standard manner. A photomultiplier tube (PMT) measures the emitted photons, and the response curve is integrated to quantify the nitrogen content. This methodology is applicable to both gases and liquids. If a process stream flows and efficiently oxidizes at 1100°C, it is highly likely that it can be analyzed.

In the process environment, our nitrogen analyzer is the NSure. It derives its name from its configurability to measure both total nitrogen and total sulfur. These configurations can be strategically positioned within the process wherever the need arises to ensure compliance with product quality specifications for sulfur and nitrogen or to protect catalyst integrity. Our analyzers have established a reputation for reliability, precision, and user-friendliness, with over a thousand installations in plants and processes worldwide.

Additionally, we offer a laboratory instrument, ElemeNtS, designed for nitrogen and sulfur analysis, which complements NSure. Built upon the same combustion-fluorescence technology, ElemeNtS adheres to all the standard nitrogen and sulfur methods applicable to the refining and petrochemical sectors.

NSure provides dependable and consistent total sulfur and total nitrogen measurements across a broad range, even during fluctuations in the process. It ensures a strong correlation with primary test methods and incorporates updated technology for effortless usability and maintenance. This innovative solution is designed for gas, LPG, and liquid samples, making it perfect for online monitoring in blending and refinery operations, as well as petrochemical, wastewater, and emissions management.

Conclusion

The impact of nitrogen in the operation of on-purpose propylene (FCC-OPP) processes within the oil and gas industry cannot be overlooked. Temporary nitrogen catalyst deactivation leads to conversion losses, while permanent deactivation results in increased catalyst consumption rates. These factors not only affect the efficiency and profitability of propylene production but also underscore the need for effective source monitoring and control.

Analyzing and quantifying nitrogen levels in real-time plays a crucial role in optimizing FCC-OPP operations. PAC, with its extensive experience in laboratory total nitrogen measurement and in-process analysis, offers solutions such as the NSure and ElemeNtS analyzers. By utilizing chemiluminescence technology, these analyzers accurately measure total nitrogen, ensuring compliance with product quality specifications and safeguarding catalyst integrity. With numerous installations worldwide, these analyzers have proven their reliability, precision, and ease of use. These instruments adhere to industry-standard methods and provide valuable insights for refining and petrochemical applications.

Considering the substantial economic implications associated with nitrogen in FCC-OPP processes, the investment in analyzer programs and advanced technologies for nitrogen monitoring is easily justified. By proactively managing nitrogen levels, producers can mitigate conversion losses, optimize catalyst resources, and ultimately improve the overall efficiency and profitability of their FCC-OPP operations.