Cracking Heater Convection Retrofit with Integral SCR

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Summary

When faced with a state imposed mandate to reduce NOx emissions from a steam cracker, Chevron Phillips Chemical Company LP (Chevron Phillips) determined the most advantageous solution would be a retrofit of new convection sections on the existing 13 cracking furnaces, incorporating both integral Steam Superheating coils and Integral SCR for NOx removal. This allowed Chevron Phillips to reduce stack heat losses as well as NOx emissions in the cracking heaters, while completely idling a low efficiency Steam Superheater and avoiding the NOx generated therein.

Technical and design issues were addressed by a team incorporating members of Chevron Phillips, ABB Lummus Heat Transfer, who provided the heater thermal and mechanical design, and Haldor Topsoe, who supplied the SCR catalyst. A testing program using catalyst coupons placed in the operating heaters was instituted early in the project to determine the impact of chrome poisoning, sulfur and dust loading on catalyst deactivation.

Previous commercial installations of SCR into cracking heater applications have been plagued with rapid catalyst deactivation, linked to masking of the catalyst by chromium species present in the flue gas. The chromium species are thought to be linked to the high chrome content of the radiant heating surface used in pyrolysis service.

Coupons placed in 3 different operating cracking heaters each provided more than 12,000 hours of data. Independent tests at operating flue gas temperature of 400^{o}F and 700^{o}F indicated an implied temperature dependency on chromium lay down. Significant chromium was deposited at both temperatures, but a higher rate was observed at 400^{o}F.

Significant design issues were identified and addressed, in terms of the design of the Ammonia Delivery System and the Ammonia Injection Grid (AIG). As the revamp of the convection sections required additional heating surfaces for higher thermal efficiency and also new services (Steam Superheat), the height of the revamp convection section would increase by 30 ft. over the existing design. The associated increases in dead weight and wind load imposed on the structural members and foundations were concerns that ultimately required significant additional bracing and fortifications of the supporting steel.

In order to minimize the overall height, a very compact design was developed for the AIG that allowed it to be located a short 6 ft. below the catalyst face. Heat transfer surface was located between the AIG and catalyst face to further reduce the height and promote mixing for the dilute ammonia with flue gas. Computational Fluid Dynamic (CFD) modeling allowed the grid design to be optimized for ammonia mixing, while external controls on the ammonia distribution allowed the ammonia distribution to be biased to match any potential NOx maldistribution.

Project execution planning for a major revamp in an operating unit, while minimizing lost production due to heater downtime is key to any cracking heater SCR retrofit. Detailed and specific execution planning allowed 12 of the 13 cracking furnaces to be revamped in a 122-day period surrounding a plant turnaround, with 8 of these furnaces revamped during the 52-day turnaround while the plant was down.

The Ethylene Plant Steam and Fuel balances were impacted significantly by the revamp, and associated shutdown of the low efficiency Steam Superheater. The overall thermal efficiency of the cracker was improved from 83% to 92% LHV. Net fuel consumption was decreased by 130 MM Btu/hr firing avoided, at equal throughput. This translates to a reduction in CO_2 emissions equivalent to 58250 tpy, in addition to the net NOx reduction of 649 tpy.