
Question 62: We have run a full-burn FCCU for many years. We are considering processing more resid and operating in a partial CO combustion mode. What is a carbon runaway, and how can it be addressed?

CHRIS STEVES (Norton Engineering)

A carbon runaway or “snowball” occurs in an FCC that is operating in partial CO combustion mode and very high CO levels. In the runaway situation, the carbon on regenerated catalyst (CRC) rises to levels such that additional coke that is laid down on the catalyst cannot be burned from the catalyst in the regenerator, causing the CRC to continue rising like a snowball that gets bigger and bigger as it rolls down a hill. As the unit moves deeper and deeper into partial-burn (with higher CO levels from the regenerator), the regenerator temperature will fall and the catalyst entering the reaction zone may have a difficult time fully vaporizing the feed to the unit, resulting in heavy oil laydown on the catalyst that is returned to the regenerator for combustion. Eventually, the feed from the unit will need to be significantly reduced or removed in order to recover from the runaway, and the subsequent “burnoff” of the catalyst may result in extremely high regenerator temperatures and potential damage to the catalyst and regenerator equipment.

The operating conditions that may lead to a runaway will vary from unit to unit, as regenerator design and the mixing of catalyst and air in the regenerator play large roles in the carbon levels on regenerated catalyst. To prevent a carbon runaway, a reliable CO analyzer on the regenerator flue gas is essential, as well as specific guidelines for proper CO levels in flue gas, carbon on regenerated catalyst, and target regenerator temperatures. Operators should also be trained and have quick response guides on how to respond to operating conditions that may initiate a carbon runaway.

PHILLIP NICCUM (KP Engineering)

A carbon runaway refers to a situation where the rate of carbon burning in the FCC regenerator falls below the rate of coke being produced in the reactor, steadily increasing the concentration of carbon on catalyst in the regenerator. This situation has also been referred to as ‘carbon snowballing’ or ‘getting behind in burning’.

Carbon runaways were much more common generations ago when FCC regenerators operated in an oxygen-lean mode of regeneration at temperatures near 1100°F. These operations were also characterized as having flue gas oxygen concentrations close to zero—say, 0.0 to 0.2 vol% (volume percent)—and CO₂/CO ratios close to 1.0. At these conditions, the carbon on regenerated catalyst (C_{ORC}) was normally in a range around of 0.4 wt % or more.

In those days, online flue gas analyzers were not available and flue gas samples were sent to the

laboratory for Orsat analysis. FCC unit operators monitored the regeneration by keeping a running set of regenerated catalyst samples in muffin tins so that they could infer the carbon content via visual inspection. If the catalyst became darker, compromising its catalytic activity, adjustments to the unit –such as increasing air rate or reducing coke make –would be made to reduce the carbon on regenerated catalyst. Operating without excess oxygen, the coke-burning rate was limited by the air rate. Therefore, increasing concentrations of coke on regenerated catalyst had little impact on the heat balance and the increasing coke on catalyst could go unnoticed. When the catalyst turned black, the unit was said to be in a carbon runaway.

Once in a carbon runaway, the coke make in the reactor has to be reduced while maintaining or increasing the regenerator air rate and continuing to circulate catalyst to remove heat. This operation has to be done carefully and slowly to avoid overheating the regenerator. Procedures for dealing with the “Snowball Emergency” would include (1) increasing regenerator air rate;(2) reducing coke make by switching to lighter feeds, recycling naphtha or LCO, increasing feed dispersion steam, and lowering reactor temperature; and (3) taking regenerated catalyst samples every 15 minutes until the situation was resolved.

The regenerator temperature in a modern partial-burn residue feed FCCU operation is likely in a range between 1300 and 1360°F; the CO₂/CO ratio is likely to be in a range of 3 to 5; and both the flue gas oxygen concentration and CORC is likely to be only one-or two-tenths of a percent. The majority of the CO produced from carbon burning is combusted in the regenerator because of higher operating temperature and catalysis by high catalyst metals content, even without adding CO combustion promoter. Answers to Question 10 from the 1996 NPRA Technology Q&A provide a rich discussion of controlling partial-burn regenerators with respect to the interrelated variables of bed temperature, CO₂/CO ratio, CO promoter use, and carbon on regenerated catalyst.

A positive temperature differential between the regenerator dilute phase and bed temperatures provides an indication that the regenerator bed is operating with some excess oxygen, precluding the creation of a snowball. Some units are instrumented to control the afterburning temperature differential by adjusting the regenerator air rate. Carbon runaways are also less common today because FCC units are instrumented with online CO and O₂flue gas analyzers; therefore, operators are not overly dependent on visual inspections of catalyst samples to detect increasing carbon. Should a snowball occur, the remedy would be similar to that of the past; reduce coke make, keep the catalyst circulating, and adjust other variables as needed to control regenerator temperature while the excessive coke is burned off.

Print as PDF:

Tags

[Catalysts](#)

[Electrostatic Precipitator System \(EPS\)](#)

[Emissions](#)

[Feed Quality](#)

[Process](#)

[Reactor Vessel](#)

[Regenerator](#)

[Slide Valves](#)

Year

2016