Question 91: What are the characteristics of FCC catalyst to minimize particulate emissions at the stack?

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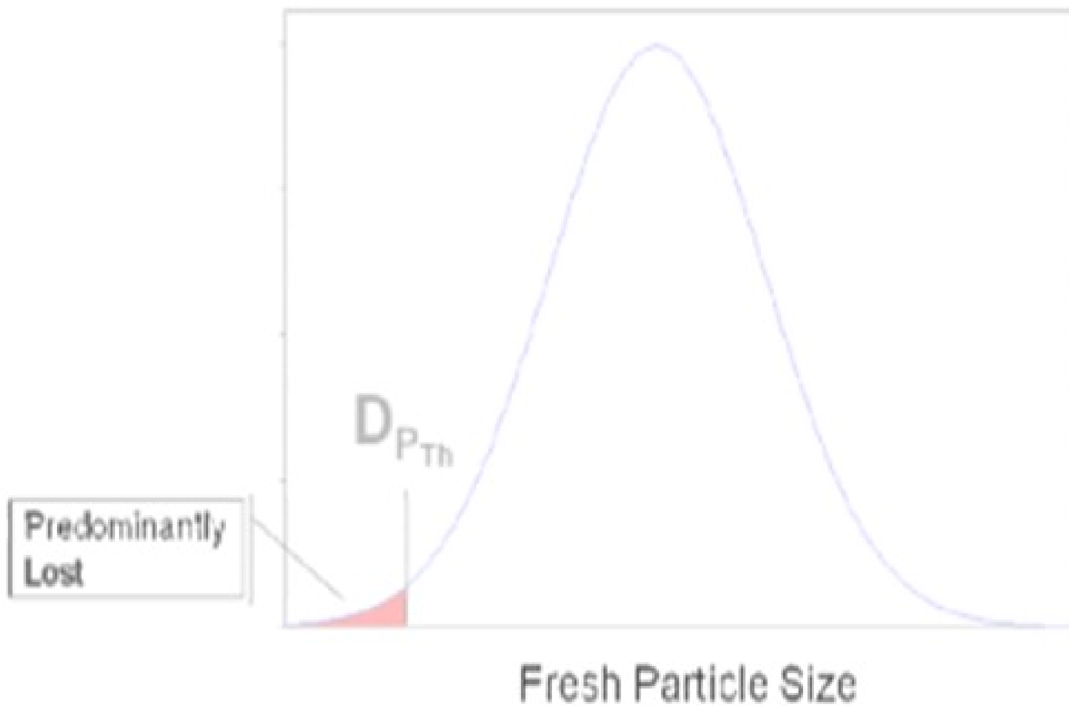
While there are several operational and mechanical factors that can influence a unit's particulate emissions, the question asks specifically about the FCC catalyst; as such, the following discussion will address characteristics of fresh catalyst only.

There are four basic characteristics of FCC catalyst that can have direct effects on particulate emissions. These same characteristics will also affect particulate losses to the fractionator and slurry product. The first characteristic is simply the amount of fines content coming into the unit with the fresh catalyst due to the manufacturing process. Figure 1 is an example of a typical fresh catalyst particle size distribution, with a theoretical depiction of a cyclone's ability to retain fresh catalyst particles. DPTh is the smallest particle diameter which can reliably be collected by a cyclone and is used to model cyclone performance. Particles below this size will be lost by the cyclone.

A review of the Grace Ecat database showed that none of the FCCU's in North America can retain any 0-20 ? range particles. In addition, they only retain an average of approximately 4.0 wt% in the 0-40 ?range. Fresh catalyst typically ranges anywhere from 9 to 16% of 0-40 ? depending on the supplier andmanufacturing process. Some units require higher amounts of 0-40 ? range particles to help with circulation.

Figure 1 Theoretical Depiction of a Cyclone's Ability to Retain Particles



The next characteristic of fresh catalyst that must be considered is the particle density. he DPTh mentioned above will decrease with increased catalyst particle density, per Equation 1 below. This means that cyclones can retain smaller particle sizes as the particle density increases. This is due to the centrifugal force acting on a heavier particle. However, particle density is not the same as apparent bulk density (ABD). Industry typically measures and reports ABD as part of the routine Ecat analysis, but this should not be mistaken for particle density for cyclone efficiency purposes. Since Al_2O_3 is denser than SiO_2, catalysts with higher alumina content will have higher catalyst particle density.

Equation 1 Cyclone Performance Theory Calculation

$$D_{P_{Th}} = \sqrt{\frac{9\mu_G L_W}{\pi N_S V_i (\rho_P - \rho_G)}}$$

$$\mu_G, \rho_G, V_i = \text{Gas viscosity, density and velocity}$$

$$L_W, N_S = \text{Width, number of spirals}$$

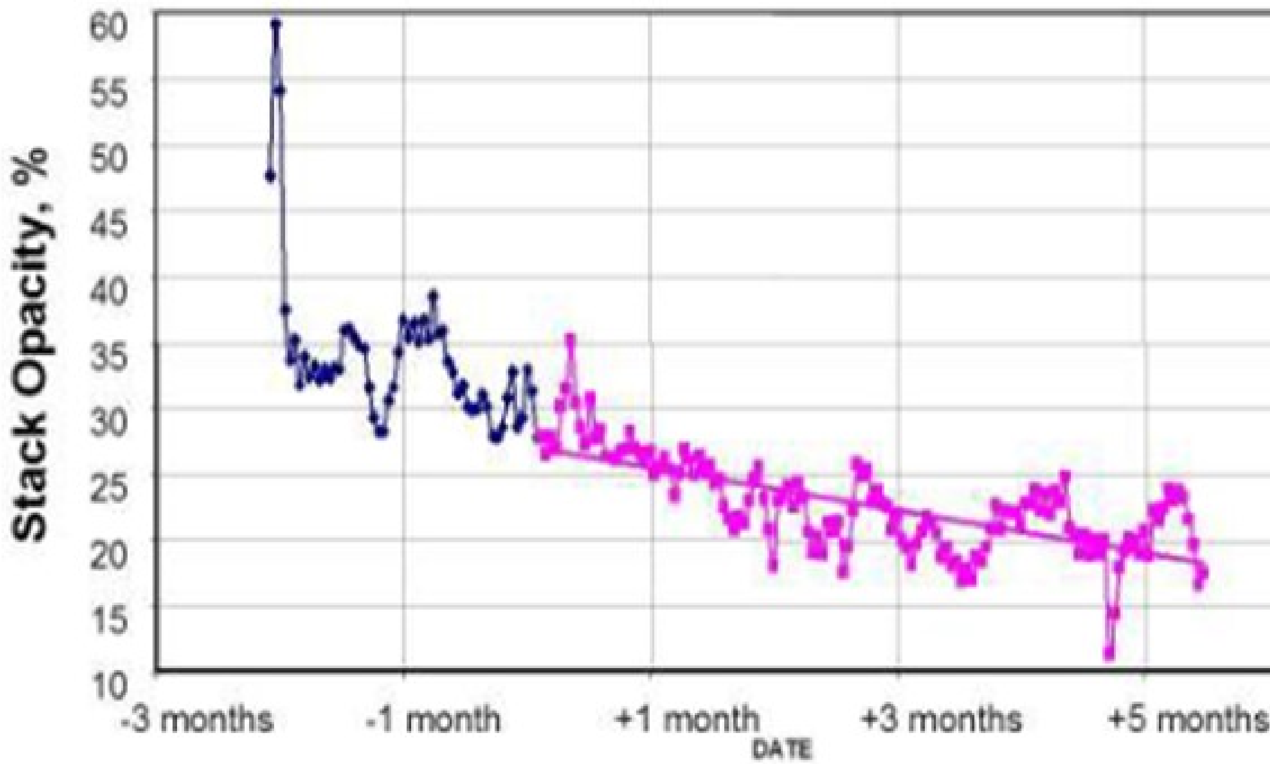
$$\rho_P = \text{Particle density}$$

The third characteristic is the inherent attrition resistance of the fresh catalyst. Industry measures the attrition resistance via a variety of tests, with the primary goal of providing a relative indication of catalyst attrition resistance. Grace utilizes the DI test or Davison Index. On the DI scale, a lower number is less likely to cause attrition and generate microfines. It is usually not valid to compare attrition resistance results obtained from different laboratories. Additionally, it is important to note that the energy applied to a catalyst sample during attrition testing is much more severe than commercial conditions.

As discussed above, the majority of the microfines created in the FCCU will leave the unit through either the reactor or regenerator cyclones, with the latter potentially contributing to increased particulate emissions at the stack.

'The attrition resistance of the catalyst is a function of the manufacturing process and the binder material utilized during the manufacturing process. Figure 2 is an example of how a refiner improved the FCCU stack opacity with catalyst formulation. The reduction was achieved changing to a Grace supplied catalyst with lower DI and lower 0-40 ? content in the fresh catalyst.

Figure 2 Commercial Application of Lower DI Fresh Catalyst



The final characteristic of fresh catalyst that affects particulate emissions is its morphology. Morphology can be defined as the study of the form and structure of a particle and its specific structural features. A catalyst particle that has a smoother exterior surface is less likely to generate microfines in an FCCU. Even catalysts with a low fresh DI measurement can cause increased particulate emissions if there are surface irregularities resulting from the manufacturing process. In order to demonstrate this visually, Figures 3 and 4 present SEM's (scanning electron microscopy) of "bad" and "good" fresh catalyst morphology for a side-by-side comparison.

Figure 3 and 4 SEM's of Fresh Catalyst (magnified X250)

"Bad Morphology" "Good Morphology" In conclusion, there are several characteristics of fresh catalyst that can be controlled to reduce particle losses and thereby reduce flue gas emissions. Specifically, to lower emissions the fresh FCCcatalyst should possess the following characteristics: a particle size distribution with an optimal range of 0-40 ? particles, higher catalyst particle density, lower DI, and superior morphology. Grace's alumina-sol technology provides superior binding to the catalyst particle leading to best-in-industry attrition resistance. The versatility and performance of alumina-sol catalysts coupled with Grace's manufacturing capability, have resulted in wide-market acceptance and as a result, Grace is the preferred FCC technology for loss sensitive units around the world.

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