Sorbent Performance in Fluidized-Bed Combustors

Goal
Sorbents are utilized in fluidized-bed combustors (FBC) to capture the SO₂ formed during the combustion of a sulfur-bearing fuel. In the mid- to late-1980’s, FBC manufacturers specified that the CaCO₃ content of the sorbent be greater than 85 wt.%. This specification limited the sorbent resource base in Pennsylvania, which was experiencing rapid FBC deployment.

The sorbent performance project had two goals: 1) to determine if lower purity sorbents could be utilized to capture SO₂ effectively, and 2) to develop a better understanding of why certain sorbents, all with similar chemical compositions, exhibited vastly different SO₂ capturing performance.

Team
The EMS Energy Institute worked closely with the aggregate and FBC industry on this project. Participants included: Pennsylvania Energy Development Authority, Pennsylvania Aggregate and Concrete Association, National Stone Association, Pennsylvania Geologic Survey, Bradley Pulverizer, and 16 Pennsylvania aggregate suppliers. Meckley Limestone Products processed and delivered all of the 200-ton test sorbents used in the full-scale tests at the Westwood Generating Station.

Project Discussion
The sorbent performance project was a two-year study that involved both laboratory and full-scale testing. Twenty sorbents were selected and tested. The sorbents examined in this study represented a broad cross section of the major stratigraphic intervals that are commercially available throughout Pennsylvania. The stratigraphic intervals varied widely in thickness, aerial extent, chemical composition, hardness, depositional and post depositional history, stratigraphic variability, and petrographic constituents.

The first phase of the study concentrated on the laboratory characterization of the twenty sorbents. The laboratory characterization included: 1) determining chemical composition, 2) determining the Hardgrove Grindability Index, 3) testing in a bench-scale fluidized bed reactor, and 4) determining the petrographic variability using conventional and advanced microscopy. Sorbent performance was determined prior to full-scale testing.

Background
Pennsylvania was an early leader in the development and commercialization of independent power producer (IPP) generating stations that utilized FBC technology. PA’s leadership was in part attributable to the large volumes of anthracite culm in eastern Pennsylvania and bituminous gob in western Pennsylvania that had accumulated as a coal industry waste product since the early 1900’s. The Energy Institute worked with numerous aggregate suppliers to characterize the SO₂ capturing performance of sorbents being considered for use in these newly constructed FBC power stations. Laboratory tests indicated that the CaCO₃ content of the sorbent was a poor indicator of sorbent performance.

In Phase II, approximately 200 tons of each test sorbent were studied at the 30 MW(e) Westwood Generating Station located near Joliet, PA. Prior to the full-scale testing, Penn State provided the Westwood Station with the anticipated sorbent feed rates to ensure the plant would maintain emissions compliance using the laboratory fluidized bed reactor data. Upon review of the laboratory data, the test sorbents were then processed in a Bradley Pulverizer “6000” Screen Mill by Meckley Limestone Products of Herndon, PA. Meckley Limestone Products and Penn State coordinated the sorbent delivery and isolation. Emptying the main sorbent silo while maintaining a full 13-ton sorbent surge bin isolated incoming sorbents. When the surge bin was emptied, the test sorbent was transferred into the sorbent feed system.
Results

Twenty sorbents, collected from 16 different counties in Pennsylvania and ranging in CaCO$_3$ content from 99.4 to 49.6 wt.%, were examined. Data from both the bench-scale and full-scale tests indicated that low purity limestones and dolostones can be utilized in FBC applications. In the full-scale tests, the twenty sorbents maintained mandated SO$_2$, NO$_x$, and opacity compliance levels at the Westwood Generating Station. This deduction is significant because prior to the study, many of these sorbents would have been precluded from use based solely on their chemical composition. The utilization of low purity limestones and dolostones in fluidized-bed applications significantly increases both the available reserves of sorbent and the number of sorbent suppliers. Although high purity sorbents can also be used in fluidized-bed applications, such reserves are often quarried to supply other markets (e.g., the manufacture of lime).

One of the study’s major findings was the documentation of how the sorbent’s geology can be used to explain why sorbents that have similar chemical compositions exhibit markedly different sulfur capturing capabilities. Specifically, grain size was found to have a dramatic effect on sulfur capturing performance of limestones. Fine-grained micritic limestones typically were susceptible to the formation of a CaSO$_4$ reaction rim along the exterior of the particle (b). The reaction rim was found to retard the penetration of SO$_2$ into the interior of the particle where it could be captured. Conversely, coarse-grained limestones typically formed thermally induced fractures (TIFs) along grain boundaries that allowed the SO$_2$ to travel deeply into the particle’s interior where it was captured (d). The importance of the TIFs was documented through the innovative use of some unique equipment. An ElectroScan environmental scanning microscope (SEM) was used to study the behavior of limestones as they were thermally stressed to 1000°F. This hot-stage SEM permitted real time viewing of the TIFs as they formed during the thermal-stressing of the limestone. Once the TIFs were documented, several samples were calcined and sulfated in a bench-scale reactor. The sulfated samples were then sectioned and the sulfur distribution was mapped using a Cameca microprobe. The microprobe clearly showed that the TIFs acted as conduits for the SO$_2$ to deeply penetrate the particle’s interior.

Ample laboratory and full-scale data now exists to prove that the sulfur capturing performance of a sorbent in FBC applications is not related to its CaCO$_3$ content. Since this study concluded, many of the Pennsylvania FBC power plants have opted to utilize less expensive sorbents with CaCO$_3$ levels below 90 wt.%.  

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Key Publications


