Desulfurization Sorbents for Transport-Bed Applications

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Introduction

Advanced coal-fired power generation systems employing coal gasification offer increased efficiency and reduced emissions over pulverized coal-fired boiler systems currently in service. Integrated gasification combined cycle (IGCC) is the leading coal gasification-based system which is being advanced worldwide to produce electricity from coal. This technology has the potential to reduce sulfur and nitrogen emissions, so-called precursors of "acid-rain," and could lead to significant reductions in carbon dioxide emissions, which are believed to be major contributors to global warming. One of the key components of this IGCC technology is a hot-gas desulfurization system employing efficient regenerable mixed metal oxide sorbents. Successful commercialization of the IGCC technology requires economic competitiveness with other power generation systems. This economic competitiveness has propelled research and development of hot-gas desulfurization systems, which employ regenerable mixed metal oxide sorbents.

A number of mixed metal oxide sorbents have been investigated for removal of reduced sulfur species (H_2S, COS, CS_2, etc.) at high-temperature, high-pressure (HTHP) conditions (Gupta and Gangwal, 1992), but the best candidates have been the ZnO-based sorbents because of their ability to reduce fuel gas sulfur levels to a few parts per million. The ZnO-based sorbents that have been researched include zinc ferrite, zinc titanate, Z-Sorb, and METC-10.

Early designs and previous research work involving hot-gas desulfurization sorbents were based on fixed-bed reactors because of their simplicity of operation (Gangwal, 1991). However, recent research has concentrated on fluidized-bed systems because of the potential for such systems to be operated continuously and to handle the temperature rise due to the high exothermicity of the regeneration reaction (Gupta and Gangwal, 1992).

In this project, earlier work involved development and testing of highly reactive and durable zinc titanate sorbents in the 100- to 300-µm particle size range for bubbling fluidized-bed reactors. These efforts led to the development of the ZT-4 formulation, which was prepared using a granulation technique (Gupta et al, 1993). A number of life-cycle tests were performed on the ZT-4 sorbent to demonstrate its long-term chemical reactivity and attrition resistance using simulated coal gas mixtures (Gupta and Gangwal, 1995). Tests were also conducted using fuel

gas produced directly from coal gasifiers at three pilot plant sites: Enviropower in Finland, the U.S. Department of Energy/Federal Energy Technology Center (DOE/FETC) at Morgantown, West Virginia, and Coal Technology Development Division (CTDD) in England. Despite the superior performance exhibited by the ZT-4 sorbent in these bubbling fluidized-bed tests, its physical and chemical properties were not adequate for the high solid circulation rates and particle and gas velocities of a transport reactor.

As an alternative to the granulation method, a spray-drying process to prepare zinc titanate sorbent was investigated. Spray drying is extensively employed in the production of catalysts, particularly fluid catalytic cracking (FCC) catalysts, for use in fluidized-bed reactors. Spray drying offers a number of advantages over a granulation process. For example, spray drying is a commercial process that can be readily scaled to industrial production using existing technology to produce large quantities of a product. Spray drying facilitates the addition of other additives and reagents to the composition since additional reagents can be added simply to a slurry prior to spray drying. Furthermore, spray drying provides particles of highly uniform size and shape.

With the adaptation of transport reactor technology to hot-gas desulfurization by M.W. Kellogg in the Piñon-Pine Clean Coal Technology demonstration project, an immediate need for sorbents for transport reactors was recognized. For transport reactors, (1) a sorbent must possess and maintain high chemical reactivity for removing sulfur species from coal gas within 1 to 2 seconds of residence time; (2) it must maintain an attrition rate below design specifications; (3) it must maintain regenerability with neat air under cyclic operation; (4) it must possess good flow characteristics; and (5) it should be competitively priced.

Initial efforts to produce suitable sorbents for this application by spray drying led to the development of the CMP-107 sorbent. The CMP-107 sorbent was manufactured by Contract Materials Processing (CMP), Inc., of Baltimore, Maryland. Pilot-scale testing of this sorbent at Kellogg indicated that the sorbent readily removed H_2S to <5 ppmv (the analytical detection limit), but its attrition rate was more than twice the target value that Kellogg used in its design of transport reactor for the Sierra plant.

Objectives

This project extends the prior work on the development of fluidizable zinc titanate particles using a spray-drying technique to impart high reactivity and attrition resistance. The specific objectives are:

• To develop highly reactive and attrition-resistant zinc titanate sorbents in 40- to 150-µm particle size range for transport reactor applications;

• To transfer sorbent production technology to private sector; and

• To provide technical support to Sierra Pacific Clean Coal Technology Demonstration plant and FETC's Hot-Gas Desulfurization Process Development Unit (PDU), both employing a transport reactor system.

Project Description

This project is a collaborative effort with Intercat Development, Inc., of Sea Girt, New Jersey, a commercial catalyst manufacturer specializing in spray-drying FCC additives for petroleum refineries and the M.W. Kellogg Company of Houston, Texas, that developed the transport reactor technology for hot-gas desulfurization. Both Intercat and Kellogg were subcontractors to the Research Triangle Institute (RTI) on this project. Intercat also had a grant (No. DE-FG02-96ER82189) under Small Business Innovation Research (SBIR) Phase I from DOE. RTI and Intercat entered into a teaming agreement to jointly develop and commercialize the spray-dried zinc titanate sorbents.

Criterion for Commercial Sorbent Selection

Comprehensive analysis of results obtained during bench-scale testing at RTI, transport reactor test unit (TRTU) testing at Kellogg, and modular gas cleanup rig (MGCR) testing at DOE/FETC as reported in Gupta et al. (1996) with CMP-107 sorbent indicated that a proper combination of reactivity and attrition properties is necessary to minimize the impact of sorbent costs on operation of the hot-gas desulfurization unit in an IGCC plant. Figure 1 depicts the interrelationship of various process parameters involved in the sorbent selection process. All the sorbent properties (as shown in Figure 1) must be considered for selecting a suitable sorbent for transport reactor applications. For example, a sorbent with very high reactivity and poor attrition resistance may not be cost-effective as it will require frequent replenishment. Alternatively, a sorbent with very high attrition resistance and poor reactivity might not be suitable as it will not remove the desired amount of sulfur species in specified residence time.

Based on the screening process of Figure 1, analysis of CMP-107 sorbent test results led to the following recommendations by Kellogg:
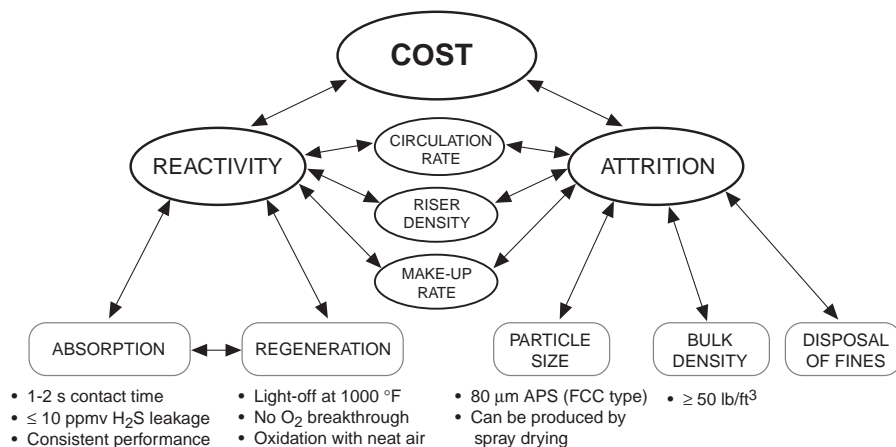

Figure 1. Criteria for Commercial Sorbent Selection.

• Sulfidation activity of the sorbent was quite adequate;

• Bulk density should be increased to ≥ 50 lb/ft^3;

• The average particle size (APS) should be between 80 and 90 µm with <5 percent below 40 µm and <1 percent below 20 µm;

• During regeneration, the sorbent should light-off at a temperature $\leq 1,050$ °F (565 °C) with neat air to operate the transport reactor system in an isothermal mode with minimal sulfate formation; and

• Attrition resistance of the sorbent should be improved by a factor of three to meet the 15 lb/h design target for Sierra.

Adaptation of Intercat Binder Technology to Zinc Titanate System

As target properties of density, attrition resistance, and particle characteristics for zinc titanate sorbents were very similar to the properties of products developed by Intercat for use in FCC processes, application of Intercat's binder technology for zinc titanate sorbents promised to yield dense, attrition-resistant particles for use in a transport reactor. The primary challenge was to maximize sorbent activity while maintaining maximum attrition resistance and density.

Intercat has developed and patented several technologies relating to the formation of attrition-resistant microspheres for use in the FCC petroleum refining process. Two of those technologies are briefly discussed below:

• Silica-Alumina Binder Technology—A binder based on the use of colloidal forms of silica, alumina, and/or zirconia has been developed and disclosed in U.S. Patent No. 4,826,793; and

• Clay-Phosphate Binder Technology—A novel binder technology based on clay and a source of phosphate has been disclosed in U.S. Patent Nos. 5,190,902 and 5,288,739. The development of this binder technology has allowed production of extremely dense, attrition-resistant particles at a very economical cost compared to colloidal silica or colloidal alumina particle technology.

The above technologies have been adapted to several Intercat products for FCC processes. These products typically contain from 5 to 60 wt% of an active component. Examples of the active components are sorbents for regenerator SO_x absorption, zeolites, and metal trapping materials for catalytic cracking.

Using these novel binder technologies, Intercat prepared a number of zinc titanate sorbent compositions.

Sorbent Preparation and Screening

Physical properties of ZT-4 and CMP-107 sorbent formulations were used as a reference for various zinc titanate sorbent preparations made in this project.

The attrition resistance of sorbent samples was measured using a three-hole air-jet attrition tester described in American Society for Testing and Materials (ASTM) Standard D5757-95. The test procedure used was essentially identical to the ASTM method except that attrition was determined over 2 hours rather than 5 hours as prescribed in the ASTM method. Additionally, the first hour of the 2 hours is typically discarded to eliminate particle size effects on attrition. The attrition index (AI) is the percent fines generated over the second hour; a lower number is better. On selected samples, the 5-hour attrition was also measured and found to be comparable to or less than the 2-hour AI. It is generally accepted in the catalyst industry that materials with an AI of 5 or below are suitable for use in a transport reactor.

Initial preparations of spray-dried sorbents by Intercat involved samples of plain zinc titanate sorbents with and without bentonite binder similar to earlier recipes. As expected, the attrition resistance of these formulations was quite poor (AI >25) and was clearly unacceptable.

Preparation of new sorbent formulations was carried out with two sets of binders: (1) a clay-phosphate system; and (2) an alumina-based binder. As stated previously, both binder systems have been used extensively by Intercat in making spray-dried inorganic metal oxide type sorbents. As shown in Table 1, the clay-phosphate binder system produced extremely hard and relatively dense particles, but with essentially no chemical reactivity. The AI and thermogravimetric analyzer (TGA) reactivity of zinc titanate formulations prepared using the alumina-based binder system were acceptable.

Additional preparation trials were made to optimize chemical reactivity and attrition resistance. After a series of HTHP bench-scale tests with these samples in RTI's sorbent test facility (shown in Figure 2), a superior composition, designated as EX-S03, was identified.

Table 1. Properties of Improved Zinc Titanate Formulations

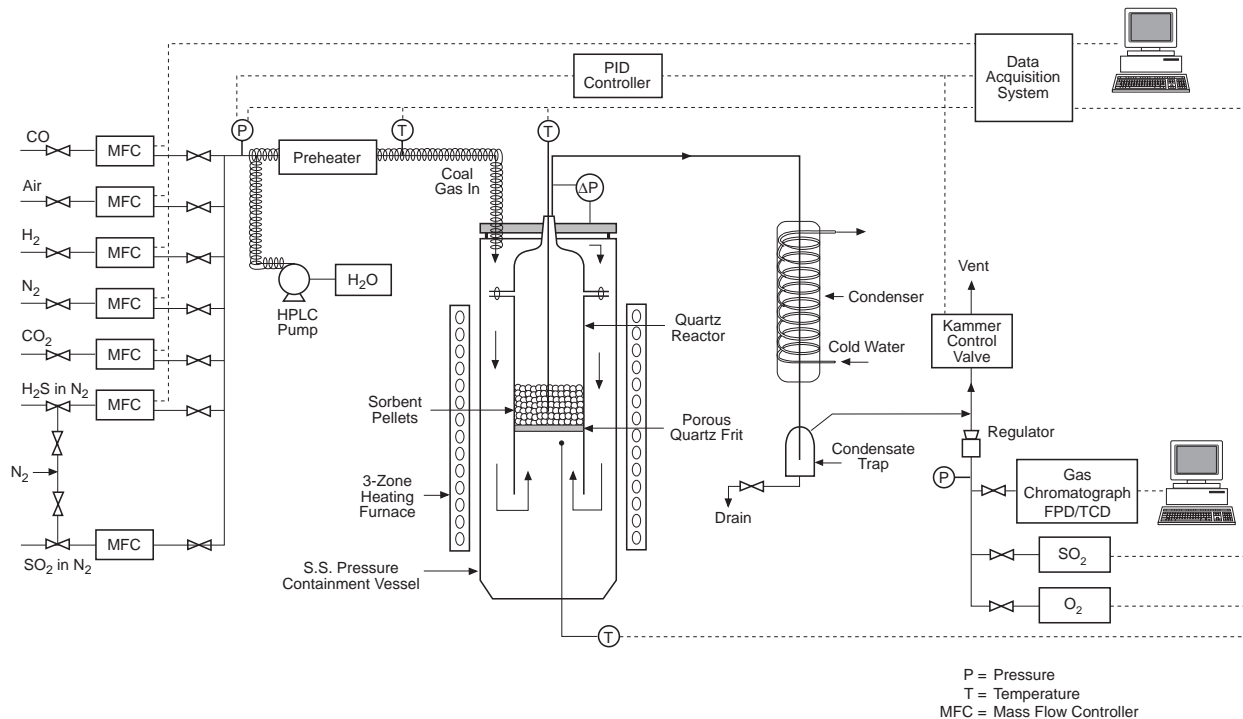| Binder system	Clay-phosphate	Alumina-1	Alumina-2
ABD (g/cm^3)	0.92	0.73	0.64
AI	1.2	6.3	4.5
Surface area (m^2/g)	88	119	150
TGA sulfur capacity (wt%)	1.8	6.4	10.8
APS (μm)	98	77	74
Wt% 0-20 μm	1	1.4	1.7
Wt% 0-40 μm	13	19	18

Figure 2. RTI bench-scale test facility.

A 2-lb batch of this material was produced in Intercat's laboratory spray drier. After detailed physical and chemical characterization, HTHP bench-scale testing of this formulation was performed at RTI with promising results. At this point, it was decided to use this recipe to produce a batch for TRTU testing at Kellogg.

Scaleup of the EX-S03 Formulation in a Commercial Spray Drier

Because scaleup of the spray-drying method from lab-scale to a commercial scale is nontrivial and can often lead to complications in obtaining a product of desired quality (or specifications), it was decided to use a commercial-size spray drier. A 1,000-lb batch of finished sorbent was produced to demonstrate the scaleup. About 150 lb of this sorbent was supplied to Kellogg for TRTU testing and a 10-lb batch was provided to RTI for bench-scale testing and characterization.

Bench-Scale Testing of EX-S03 Formulation at RTI

Two multicycle HTHP tests were carried out at RTI with the EX-S03 sorbent to determine its long-term chemical reactivity and mechanical strength. Each test consisted of 10 sulfidation-regeneration cycles. The first test simulated conditions in Kellogg's TRTU, while the second test was performed to mimic operating conditions expected at Sierra. It is to be noted that Kellogg is not set up to simulate Sierra conditions as no provisions for introducing CO and CO_2 exist at

Kellogg. A comparison of test conditions is given in Table 2.

The H_2S breakthrough curves for RTI Run #1 are shown in Figure 3. One feature apparent in Figure 3 is that all 10 breakthrough profiles are almost identical including the extended sulfidations during Cycles 1, 5, and 10, suggesting negligible sorbent deactivation. Another apparent feature is an average H_2S leakage of 800 ppmv corresponding to 92 percent H_2S removal. Considering H_2S in the simulated coal gas was set at 30 times that of typical Sierra operating levels to facilitate testing in a reasonable time period, H_2S leakage is anticipated to be <20 ppmv for actual Sierra conditions. Regeneration of the sorbent was typically carried out at temperatures between 1,000 and 1,100 °F. The temperature increases observed during regeneration were between 200 and 250 °F.

As discussed in the next section, these results matched the TRTU test results obtained at Kellogg under similar coal gas composition. Similarities between the two sets of results ranged from almost identical H_2S leakages with coal gas containing 10,000 ppmv H_2S to almost identical O_2 and SO_2 concentration profiles during regeneration. These similarities between results from RTI's HTHP unit and Kellogg's TRTU prompted the decision to conduct a second 10-cycle test under conditions simulating the operating parameters at Sierra, as indicated in Table 2.

Table 2. Comparison of Test Conditions for HTHP Runs at RTI

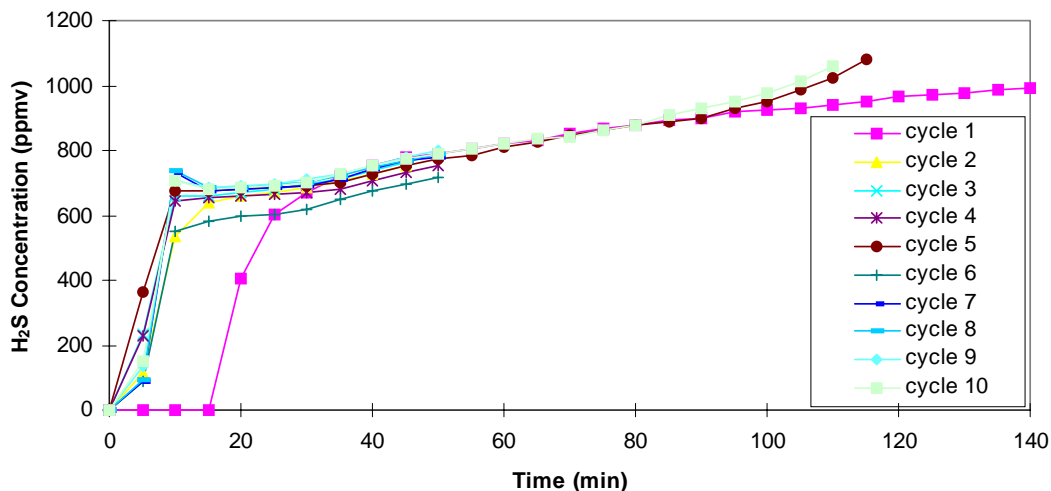| RTI Run #	1	2
Sorbent loading (g)	200	200
Sulfidation		
Temperature (°F)	1,000	1,000
Pressure (psig)	100	262
Total gas flow rate (std L/min)	12	30
Superficial gas velocity (cm/s)	3.76	3.36
Gas composition (vol%)		
N_2	94.0	48.4
H_2	5.0	15.0
CO	0.0	25.0
CO_2	0.0	5.0
H_2O	0.0	5.0
CH_4	0.0	1.4
H_2S	1.0	0.2
Total	100.0	100.0
Exposure time (min)		
Cycle 1	134	126
Cycles 2-4	48	114
Cycle 5	122	210
Cycles 6-9	50	114
Cycle 10	152	220
Regeneration		
Temperature (°F)	1,000 to 1,110	1,000 to 1,100
Pressure (psig)	100	262
Total gas flow rate (std L/min)	12	10
Superficial gas velocity (cm/s)	3.76	1.12
Gas composition	Neat air	Neat air
Addition of additive	No	Yes
Amount of additive (wt%)	0	5

Figure 3. H$_2$S breakthrough curves for RTI Run #1.

The H$_2$S breakthrough profiles for RTI Run #2 are shown in Figure 4, which clearly shows the cycle-by-cycle improvement in the amount of time that H$_2$S leakage remains below 20 ppmv. For RTI Run #2, H$_2$S concentration of the feed (2,000 ppmv) was between three and seven times higher than levels anticipated at Sierra to permit completion of testing within a reasonable amount of time.

Typical regeneration O$_2$ and SO$_2$ concentrations and sorbent-bed temperature profiles can be seen in Figures 5 and 6. Figure 5 shows regeneration with RTI's proprietary light-off additive initiating at a sorbent-bed temperature of 1,000 °F. Figure 6 shows regeneration after a majority of the light-off additive has been consumed starting at a sorbent-bed temperature of 1,100 °F. The increase in the amount and length of time SO$_2$ is released during regeneration further cor-roborates the increase in reactivity and sulfur capacity of this sorbent during this 10-cycle test. It also demonstrates the ability of the light-off additive to provide the extra heat needed to initiate regeneration at 1,000 °F. Activity of the light-off additive decreased to zero after four to five regenerations.

Physical and chemical properties of fresh sorbent, post-RTI Run #1 sorbent and a post-test sorbent from Kellogg's TRTU are presented in Table 2 and Figure 7. The TGA results shown in Figure 7 indicate that both post-test reacted sorbent samples reacted with H$_2$S slightly faster and had greater sulfur capacity than the fresh material. Comparison of the physical properties of fresh and post-RTI Run #1 sorbent shows similar values for bulk density, surface area, and APS, but attrition resistance of the reacted material is significantly higher than the fresh material. A similar comparison of the physical properties of fresh and post-Kellogg test sorbent showed essentially identical values for APS, AI, surface area, and bulk density. These results suggest that the sorbent becomes more active over 8 to 10 sulfidation and regeneration cycles with little or no adverse change in the sorbent's physical properties.
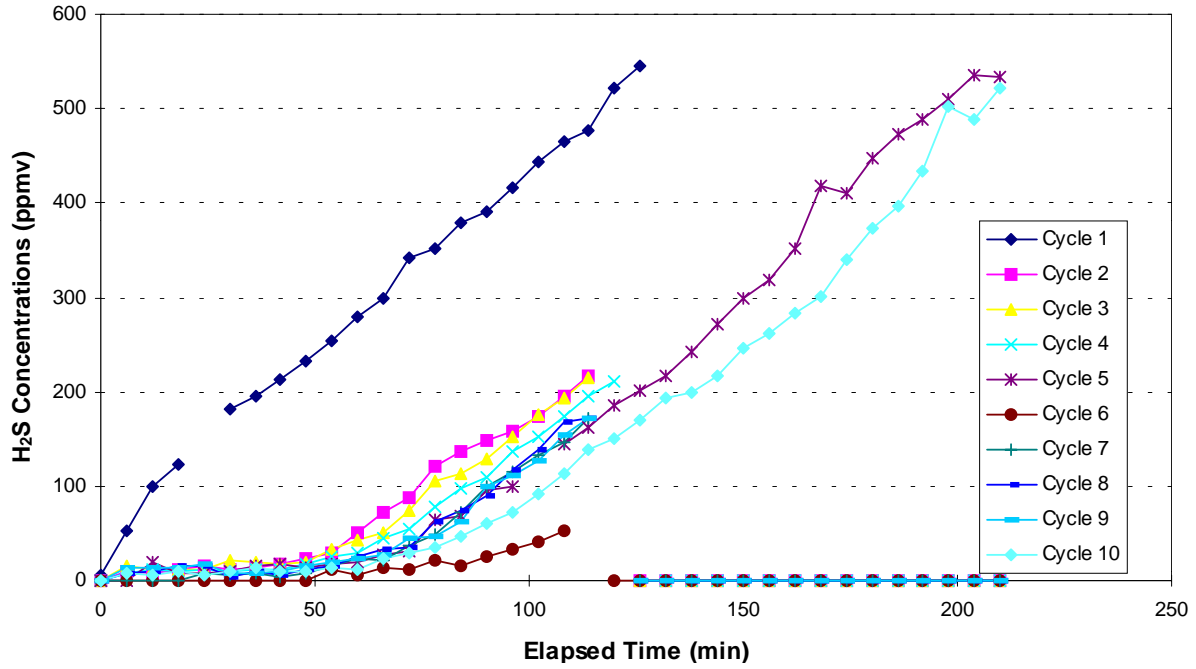
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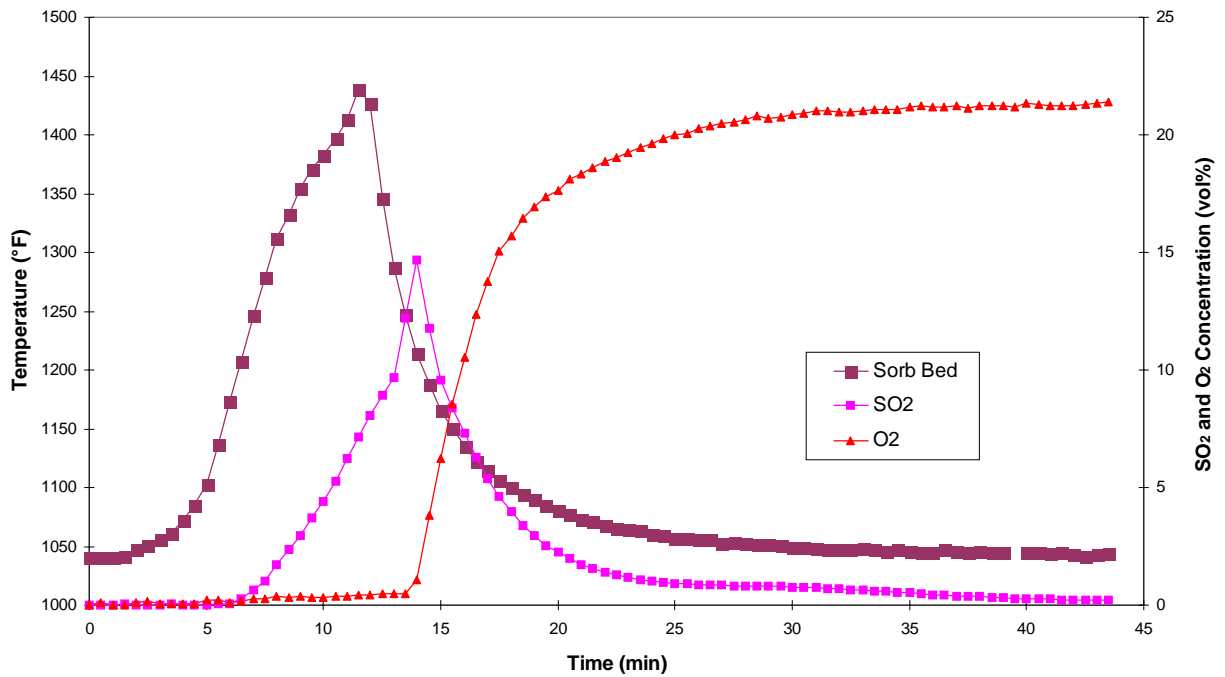**Figure 4. H$_2$S breakthrough curves for RTI Run #2.**

Figure 5. Sorbent bed temperature, SO$_2$ and O$_2$ evolution profiles for Cycle 1 in RTI Run #2.
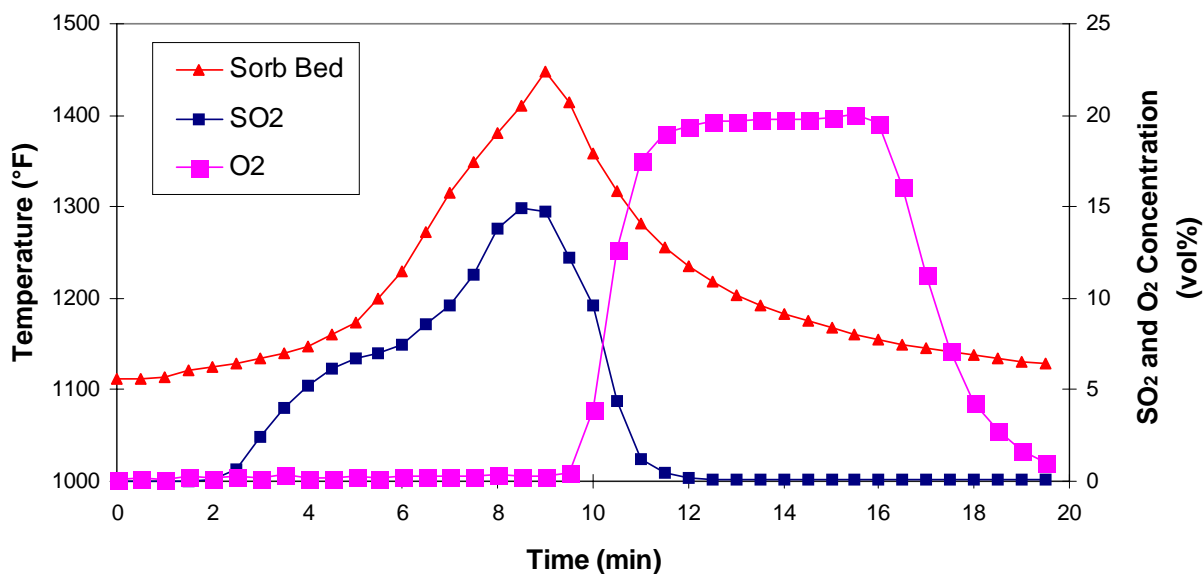
Figure 6. Sorbent bed temperature, SO$_2$ and O$_2$ evolution profiles for Cycle 8 in RTI Run #2.
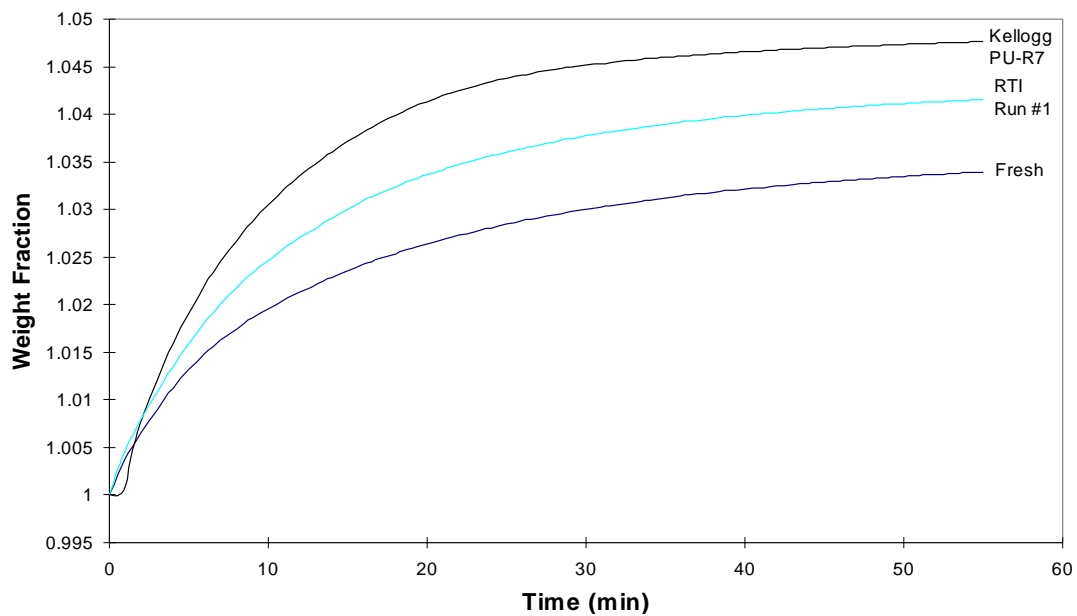

Figure 7. TGA sulfidation activity of fresh and reacted EX-S03 sorbent samples.

TRTU Testing at Kellogg

TRTU testing of EX-S03 sorbent was carried out under a subcontract from RTI to Kellogg to determine its suitability for use at Sierra. Two batches of sorbent from the same lot were tested in the TRTU. A complete description of Kellogg's TRTU is provided in Gupta et al. (1996).The first batch was subjected to three sulfidations and two regenerations and then circulated in the Cold Flow Model to study its flow properties and to determine its attrition. The second batch was tested over eight cycles of H_2S absorption and regeneration of the sulfided sorbent in order to determine the change in sulfur absorption capacity with the number of cycles and attrition characteristics.

Both absorption of H_2S and regeneration of the sulfided sorbent were performed in the mixing zone and the riser. Because the gas residence time in the mixing zone is much higher compared to the riser, the regeneration was effectively completed in the mixing zone. In most of the cycles, regeneration was conducted until the SO_2 concentration decreased below about 1,000 ppm, and absorption was conducted until H_2S breakthrough was observed at 500 to 1,000 ppm. Sulfur absorption was performed to saturate the sorbent which is nominally about 8 to 9 wt% of sulfur in all cycles. Flow upsets associated with switching from sulfidation to regeneration caused significant amounts of the sorbent inventory to be removed from the system and collected in a barrier filter designed to trap fines generated by attrition. As the material collected in the barrier filter was mainly sorbent removed from the system during flow upsets, this material was collected, weighed, and periodically charged to the reactor to bring the sorbent inventory to the initial level.

Fines formed due to attrition of sorbent were determined from the particle size distributions of the bed and the filter samples which were measured using a laser-based particle size analyzer. These were used to determine the amount of fines generated per pound of sorbent circulated. The post-test characterization of physical and chemical properties of reacted sorbent is shown in Table 3.

Table 3. Comparison of Fresh and Reacted EX-S03
Under Kellogg Test Conditions

	Fresh	After RTI Run #1	After TRTU testing at Kellogg
APS (µm)	90	80	97
AI	4.0	2.6	3.9
BET surface area (m^2/g)	8.1	7.0	10.7
Average bulk density (g/cm^3)	1.4	1.39	1.67
TGA sulfur capacity (wt%)	8.0	8.6	9.7

Observations made based on the results from the test consisting of eight cycles in the TRTU are discussed below.

Absorption

- With an inlet H_2S concentration of 6,400 ppmv, H_2S leakage prior to H_2S breakthrough was below 20 ppmv in the gas outlet as can be seen in Figure 8. At an inlet H_2S concentration of 10,000 ppmv the pre-breakthrough H_2S concentration of the gas outlet increased significantly. No SO_2 was detected at the gas outlet during absorption.

- A significant improvement in sorbent performance was observed during the first cycle. Post-test TGA tests showed an increase in both sulfur capacity and rate of reaction with H_2S.

- The sulfur absorption capacity of the fresh sorbent was about 9 wt% at H_2S breakthrough (at 1,000 ppm in the exit gas). The sorbent capacity was calculated based on absorption time and sorbent inventory. Thus, there was no loss in sulfur absorption capacity after eight cycles. The sorbent capacities reported were confirmed by solids analysis for sulfur.
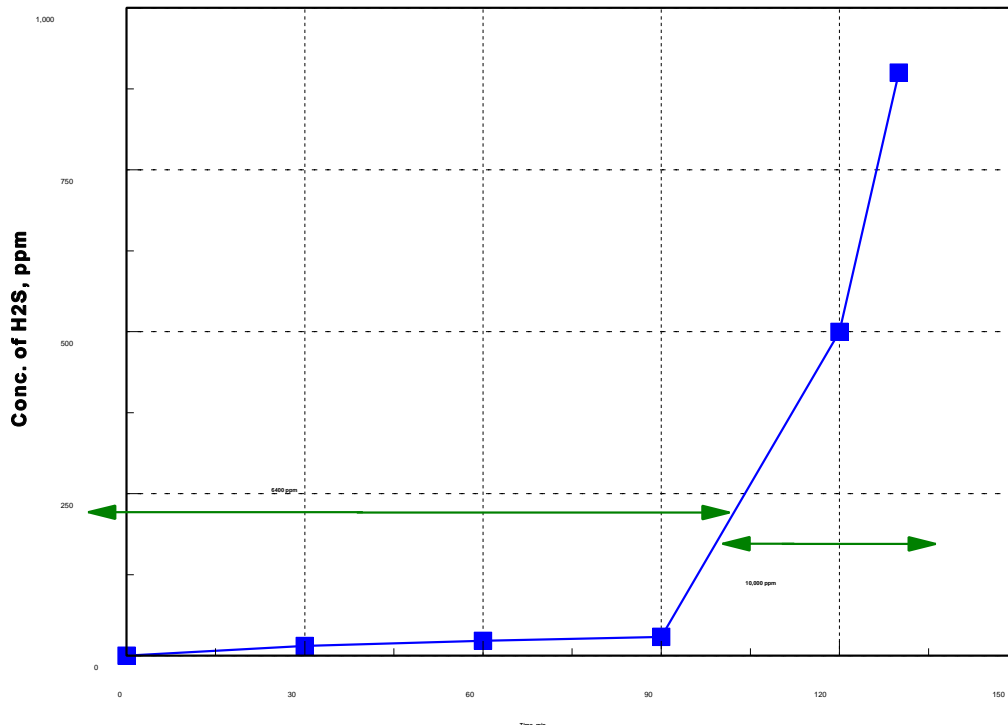

Figure 8. H$_2$S breakthrough behavior at 1,200 °F.

Regeneration

- With 5 wt% of RTI's light-off additive, the sorbent temperature required to regenerate the sorbent was 1,000 °F as shown in Figure 9. However, without RTI's light-off additive a temperature between 1,100 and 1,200 °F was necessary to regenerate the sorbent.

- Sorbent regeneration during the eight cycles tested had no detectable O_2 leakage prior to O_2 breakthrough and peak SO_2 concentrations were stoichiometric. Stoichiometric SO_2 concentrations suggest that the O_2 being consumed was producing SO_2 and not sulfates. This was confirmed by sulfate analysis of the post-test solids.

Sorbent Attrition

The sorbent attrition rate was estimated based on the size distributions of the feed, the bed drain, and the amount of filter fines collected at the end of eight cycles in the test.

Table 4 shows the particle size distribution of fresh sorbent, sample removed after third regeneration, sample removed after seventh regeneration, filter fines generated during 75 hours of TRTU testing, and sample removed from the cold flow unit after 6 hours of testing of fresh material. These data clearly show that no fines below 11 µm generated in any particle stream. The filter
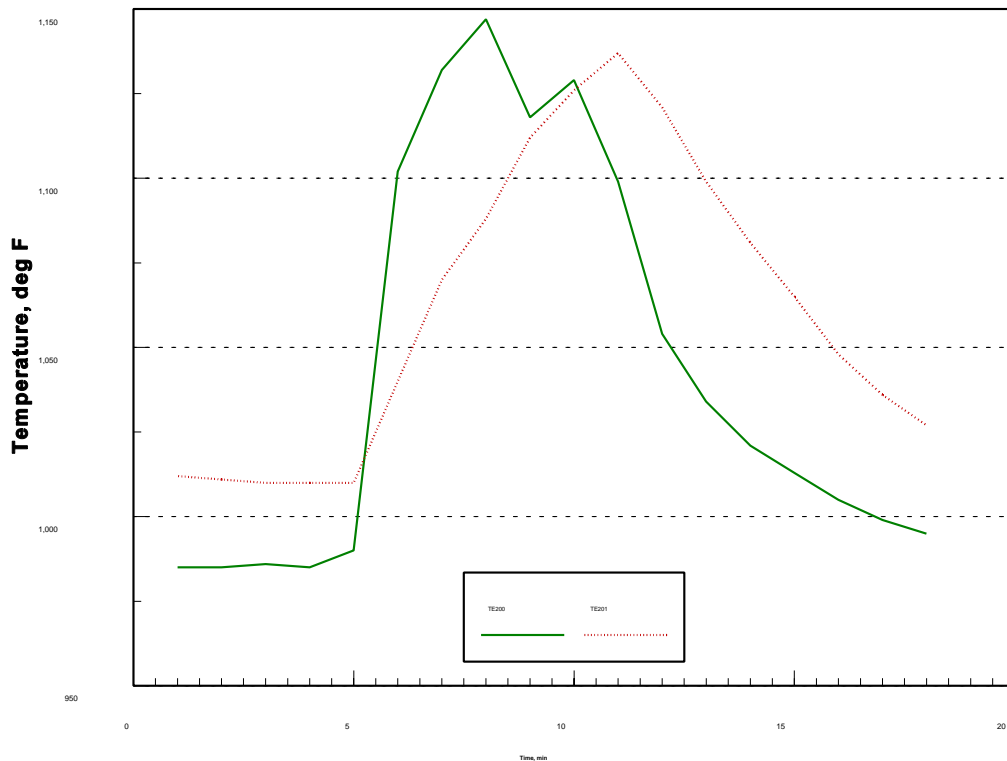

Figure 9. First regeneration of first sorbent batch.

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**Table 4. Particle Size Distributions of Fresh and Reacted Sorbents During
TRTU Testing at Kellogg**

Particle size (µm)	Fresh	After third regeneration	After seventh regeneration	Filter fines	After cold flow testing, 6 h
			(values reported as wt%)		
0-11	0.0	0.0	0.0	0.0	0.0
0-22	0.0	0.0	0.0	1.4	0.0
0-44	6.0	0.7	1.5	22.5	3.9
0-88	56.2	36.6	39.2	80.2	52.9
Distribution			(values reported in µm)		
d_{10}	49.3	65.3	61.6	35.8	53.2
d_{50}(APS)	82.8	98.5	96.9	60.2	85.7
d_{90}	148.0	177.1	175.8	112.3	156.4

fines contain 1.4 wt% below 22 µm. These particle size distribution measurements were made using a laser-based technique.

An approximate material balance is shown in Table 5 to estimate the amount of particles smaller than 22 µm present in the filter solids as a percentage of the sorbent inventory. This percentage was used in calculating the attrition rate observed in the multicycle test. Initially, 20 lb of the sorbent was charged to the TRTU. No additional fresh sorbent was added to the bed during the testing. Sorbent collected in the filter was removed and added to the reactor periodically to maintain a constant sorbent inventory during the test, as flow upsets resulted in significant solids loss. The filter fines obtained after the seventh sulfidation contained 1.4 wt% of fines smaller than 22 µm and none smaller than 11 µm. No other sample taken during the test contained any fines. The sorbent sample used in the first batch was not suitable for attrition evaluation as the RTI additive (size distribution of 0 to 44 µm) was used for regeneration during the test.

The amount of fines generated was about 7.5×10^{-6} lb/lb of sorbent circulated based on amount of fines below 22 µm. This attrition rate corresponds to about 4.5 lb/h loss of sorbent at Sierra based on the solid circulation rate. This is an order of magnitude smaller compared to any sorbent previously tested in the TRTU and represents a significant performance improvement.

Table 5. Sorbent Material Balance

Weight of solids charged to TRTU for multicycle test (lb)	20
Weight of solids generated <22 µm during multicycle test (%)	1.4
Fines generated during the test (lb)	0.28
Total operating time for the multicycle test (h)	75
Solid circulation rate (lb/h)	500

Conclusions

The following points summarize the pertinent findings of the sorbent development work.

• A highly attrition-resistant sorbent was produced with acceptable chemical reactivity.

• The EX-S03 sorbent in its present state is ideally suited for Sierra IGCC in which the hot-gas desulfurization system operates in the polishing mode. It will bring H_2S levels down to below 20 ppmv in the Sierra system. However, for bulk desulfurization, it may not meet the 20 ppmv leakage requirement.

• Based on TRTU testing of this material at Kellogg, the projected attrition rate for this sorbent is below the design value of 15 lb/h. This design value is based on a definition of fines to be below 11 µm. No fines were generated below 11 µm during TRTU testing of EX-S03 and the attrition rate based on fines below 22 µm was estimated to be about 4.5 lb/h, a factor of three below the target limit. This value is an order of magnitude less than previous sorbents tested in TRTU.

• With incorporation of RTI's proprietary regeneration additive, sorbent can be regenerated at 1,000 °F, as demonstrated during bench-scale testing at RTI and TRTU testing at Kellogg.

• In a transport reactor, a higher density sorbent (90 to 100 lb/ft^3) provides more mass to adsorb the heat generated during the exothermic regeneration producing smaller temperature rises in the regenerator. These smaller temperature rises allow either increased thermal efficiency in absorber operation or increased sulfur removal capacity. As EX-S03 is between one and a half to two times as dense as typical FCC materials, its use will allow a significant increase in absorber thermal efficiency or sulfur removal capacity.

• No chemical deactivation was observed during long-term testing at RTI as well as at Kellogg. In fact, chemical reactivity of the reacted material was better than the fresh material.

• Sorbent possesses excellent flow characteristics.

Applications

The success of IGCC technology is greatly dependent on the success of a cost-effective manner to remove the sulfur compounds from the hot coal gas. Intercat and RTI have successfully developed an H_2S sorbent that has a unique combination of physical and chemical properties which are superior to any present technology. At present, a commercial manufacturing process is already in place as 1,000 lb of sorbent was produced as described in this paper.

The near-term beneficiary of the sorbent developed would be Sierra Pacific, Kellogg, and DOE. Sierra Pacific would have a commercially manufactured and evaluated sorbent to select from, thus ensuring a cost-effective alternative to the present technology. Kellogg would benefit from this sorbent by making design modifications to future hot-gas desulfurization systems based on transport reactor technology. Availability of an effective sorbent, which can be produced in commercial size batches as needed, will also provide FETC's PDU with a sorbent to test and use as a reference to benchmark the PDU's performance. Finally, the long-term beneficiary of IGCC technology will be power plants nationwide and worldwide as a new source of clean energy becomes available.

Future Activities

Sorbent development work will continue with particular emphasis on the development of sorbents for bulk desulfurization, improved regeneration, scaleup, and commercialization of sorbent technology. The current EX-S03 sorbent formulation is an excellent candidate for demonstration at Sierra Pacific's plant. For further development work, this formulation will be used as a baseline material. Efforts will continue to convert RTI's regeneration light-off additive into a commercial product.

Acknowledgments

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