WRI-05-R013

OPTIMIZATION OF TRONA/LIMESTONE INJECTION FOR SO_2 CONTROL IN COAL-FIRED BOILERS

Jointly Sponsored Research Proposal
Task 53 Final Report Under DE-FC26-98FT40323

September 2005

For
Mobotec USA
Walnut Creek, California

And
U.S. Department of Energy
National Energy Technology Laboratory
Morgantown, West Virginia

By
Western Research Institute
Laramie, Wyoming

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agencies thereof, nor any of its employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe on privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ABSTRACT

Mobotec USA develops and markets air pollution control systems for utility boilers and other combustion systems. They have a particular interest in technologies that can reduce NOx, SOx, and mercury emissions from coal-fired boilers, and have been investigating the injection of sorbents such as limestone and trona into a boiler to reduce SOx and Hg emissions.

WRI proposed to use the Combustion Test Facility (CTF) to enable Mobotec to conduct a thorough evaluation of limestone and trona injection for SO_2 control. The overall goal of the project was to characterize the SO_2 reductions resulting from the injection of limestone and trona into the CTF when fired with a high-sulfur eastern bituminous coal used in one of Mobotec's Midwest installations. Results revealed that when limestone was injected at Ca:S molar ratios of 1.5 to 3.0, the resulting SO_2 reductions were 35-55%. It is believed that further reductions can be attained with improved mixing of the sorbent with the combustion gases.

When limestone was added to the coal, at Ca:S molar ratios of 0.5 to 1.5, the SO_2 reductions were 13-21%. The lower reductions were attributed to dead-burning of the sorbent in the high temperature flame zone. In cases where limestone was both injected into the furnace and added to the coal, the total SO_2 reductions for a given Ca:S molar ratio were similar to the reductions for furnace injection only. The injection of trona into the mid-furnace zone, for Na:S molar ratios of 1.4 to 2.4, resulted in SO_2 reductions of 29-43%. Limestone injection did not produce any slag deposits on an ash deposition probe while trona injection resulted in noticeable slag deposition.

TABLE OF CONTENTS

TABLES AND FIGURES

EXECUTIVE SUMMARY

Mobotec USA develops and markets air pollution control systems for utility boilers and other combustion systems. They have a particular interest in technologies that can reduce NOx, SOx, and mercury emissions from coal-fired boilers, and have been investigating the injection of sorbents such as limestone and trona into a boiler to reduce SOx and Hg emissions. Before they implement sorbent injection in commercial boilers, they need to understand how to optimize the process to maximize SO_2 reductions while minimizing slag buildup.

WRI proposed to use the Combustion Test Facility (CTF) to enable Mobotec to conduct a thorough evaluation of limestone and trona injection for SO_2 control. The overall goal of the project was to characterize the SO_2 reductions resulting from the injection of limestone and trona into the CTF when fired with a high-sulfur eastern bituminous coal used in one of Mobotec's Midwest installations. The specific objectives are to determine SO_2 reductions as a function of limestone/trona injection rate and the upper furnace injection location, determine SO_2 reductions in the CTF when limestone is blended with the pulverized coal, and determine slagging effects of the various limestone/trona injection strategies.

The tests involved injecting limestone and/or trona with nitrogen into the mid-furnace region of the CTF, and characterizing SO_2 levels for different sorbent injection rates. Results revealed that when limestone was injected at Ca:S molar ratios of 1.5 to 3.0, the resulting SO_2 reductions were 35-55%. It is believed that further reductions can be attained with improved mixing of the sorbent with the combustion gases. This may be accomplished with Mobotec's ROFA (rotating opposed-fire air) boosted air injection system.

When limestone was added to the coal, at Ca:S molar ratios of 0.5 to 1.5, the SO_2 reductions were 13-21%. The lower reductions were attributed to dead-burning of the sorbent in the high temperature flame zone. In cases where limestone was both injected into the furnace and added to the coal, the total SO_2 reductions for a given Ca:S molar ratio were similar to the reductions for furnace injection only. The injection of trona into the mid-furnace zone, for Na:S molar ratios of 1.4 to 2.4, resulted in SO_2 reductions of 29-43%. Limestone injection did not produce any slag deposits on an ash deposition probe while trona injection resulted in noticeable slag deposition.

INTRODUCTION

Mobotec USA develops and markets air pollution control systems for utility boilers and other combustion systems. One of their most widely known products is the MobotecSystem™ for reducing NOx, SOx, and mercury emissions. This system is based on three separate steps: ROFA (rotating opposed-fire air), Rotamix (rotary mixing of additives), and SCR (selective catalytic reduction).

Regarding the Rotamix step, Mobotec is investigating the potential of limestone and trona/limestone mixtures for SOx and Hg reduction in coal-fired power plants. While the Rotamix system was shown to be effective, the testing raised technical questions that Mobotec would like WRI to assist them in further understanding. Specifically, Mobotec is in the process of commercializing a SO_2 reduction process that relies on Rotamix and trona/limestone injection. The major problem that Mobotec foresees in this process is limiting slag buildup. It is Mobotec's view that much of the slagging problem can be addressed by (a) trona and limestone blending and (b) carefully controlling the temperature of the sorbent in the upper furnace.

WRI proposed to use the Combustion Test Facility (CTF) to enable Mobotec to conduct a thorough evaluation of limestone and trona injection through a modified Rotamix injection system. These tests will help Mobotec refine their process by providing them with a mechanism to test ideas and fine tune their modeling capabilities. Mobotec plans to take this information and analysis and apply it to their full furnace design process

OBJECTIVES

The overall goal of the project was to characterize the SO_2 reductions resulting from the injection of limestone and trona into the CTF when fired with a high-sulfur eastern bituminous coal. Specific objectives are:

1. Determine SO_2 reductions in the CTF as a function of limestone/trona injection rate and the upper furnace injection location.

2. Determine SO_2 reductions in the CTF when limestone is blended with the pulverized coal.

3. Determine slagging effects of the various limestone/trona injection strategies

EXPERIMENTAL FACILITY

The facility is a nominal 250,000 Btu/hr balanced-draft system designed to closely replicate a pulverized coal-fired utility boiler. The unit was set up to simulate a tangential-fired boiler in Arizona, but it may be adapted to wall-fired or other configurations. The fuel feed system consists of screw-based feeders and pneumatic transport to four burners inserted in the corners of a refractory-lined firebox. The unit is equipped with appropriately sized heat-recovery surfaces to replicate the time/temperature profile of a utility boiler. These comprise a water-cooled waterwall section, and air-cooled superheater, reheater, and economizer simulators. The CTF also includes provisions for preheating the combustion air to mimic a utility air preheater, and over-fire air injection ports for combustion staging. The unit is equipped with a bag filter and solids and gas sampling. A schematic of the CTF may be found in Appendix A.

The flue gas analysis system includes a sample gas conditioner and dedicated on-line analyzers for O_2, CO, NOx, and SO_2. WRI has since installed a mercury Continuous Emissions Monitor (CEM), outside the scope of this project, that allows continuous measurement of both elemental and total vapor-phase mercury in the CTF stack gases.

EXPERIMENTAL RESULTS

Tests were performed where sorbents were both injected into the furnace and added to the coal. The sorbents tested were limestone, trona, and an 80:20 limestone/trona blend. Table I summarizes the test conditions.

Sorbent	Injection Rates	Injection Locations
Limestone	Ca/S ratios of 2.0, 2.4, 3.0	Mid-furnace port*
Limestone	Ca/S ratios of 0.5, 1.0, 1.5	Addition to coal
Limestone/trona 80:20 blend	(Ca+Na)/S ratios of 1.5, 2.0, 2.5	Mid-furnace port*
Trona	Na/S ratios of 1.4, 1.9, 2.4	Mid-furnace port*
Limestone	Ca/S ratios of 2.4, 3.4	Mid-furnace port* combined with coal addition

Table I. Summary of test parameters and ranges

**The mid-furnace port was at a location where the flue gas temperature was 1950-2000ºF*

A high-sulfur eastern bituminous (Illinois basin) coal was provided for this test program. Appendix B contains an ultimate and proximate analysis of the coal while Appendix C summarizes the chemical and physical characteristics of the limestone and trona sorbents.

The tests focused on the effects of sorbent injection/addition on SO_2 levels. In all furnace injection tests, the sorbent was injected with 1.2 scfm nitrogen. This resulted in a 4% dilution of the flue gas. All measured SO_2 concentrations were then corrected for both the N_2 dilution and excess O_2 levels, and expressed in ppm at 3% O_2. The results are summarized in Figures 1 and 2.

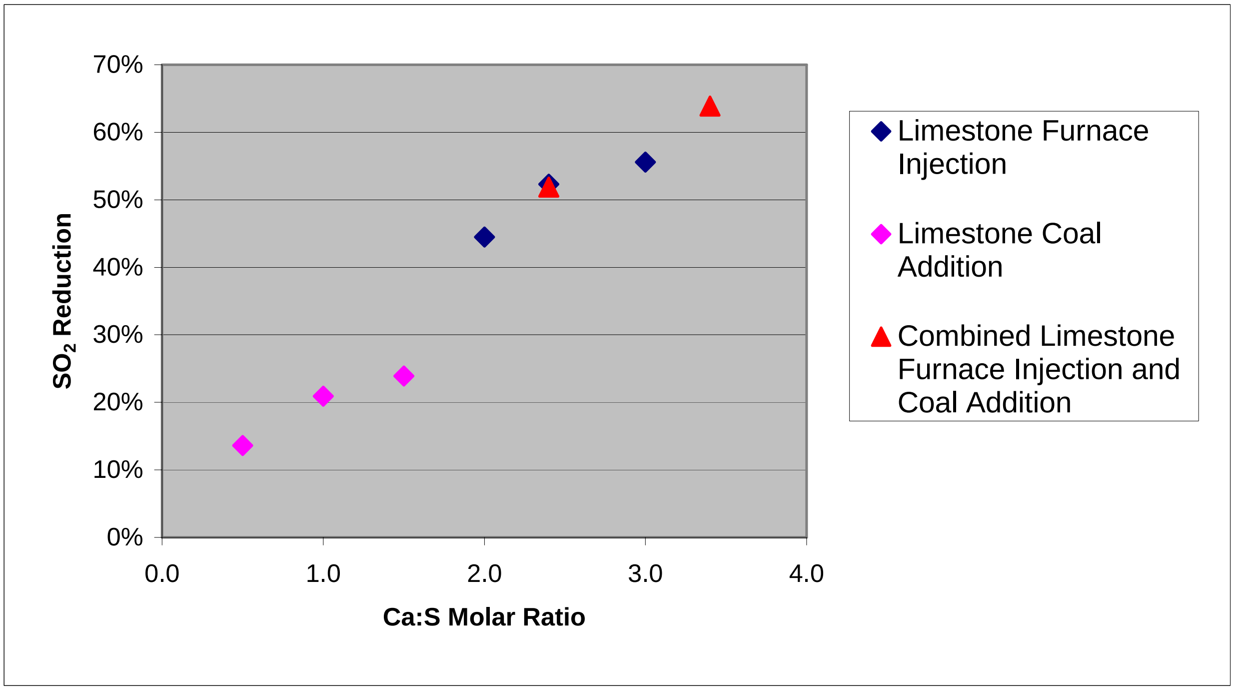


Figure 1. SO_2 Reductions for Limestone Injection Tests

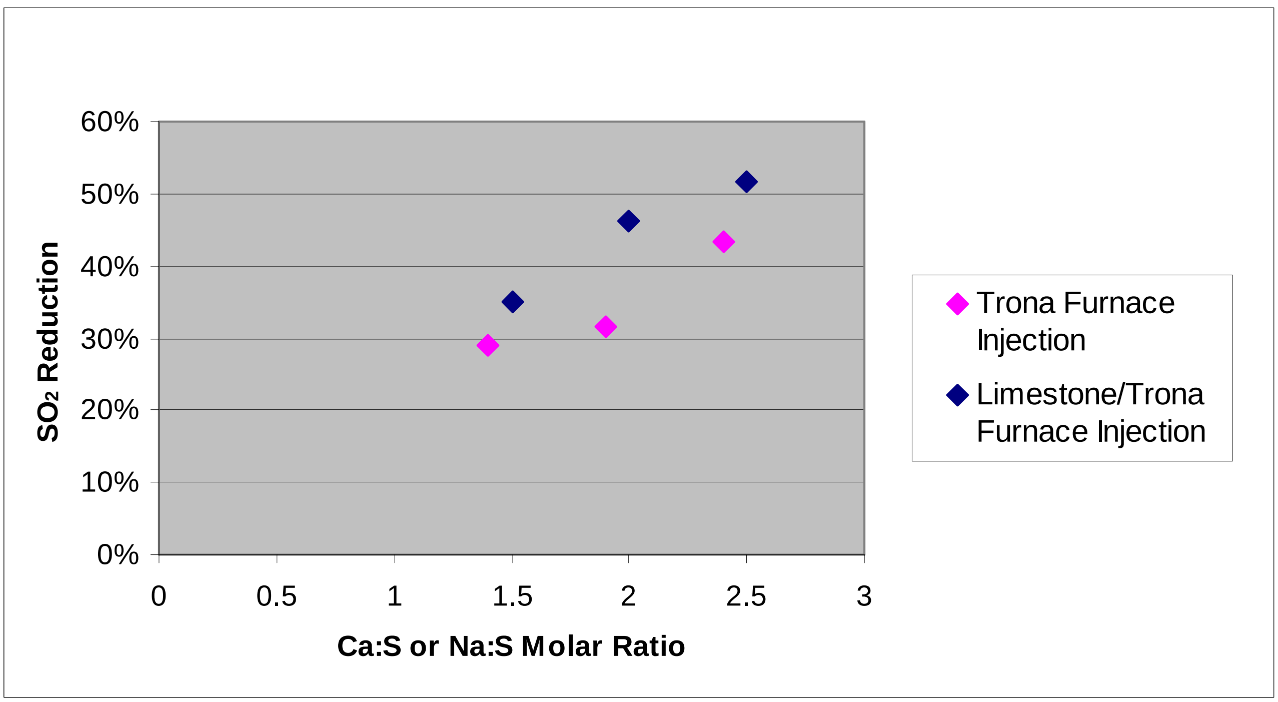


Figure 2. SO_2 Reductions for Trona and Limestone/Trona Injection Tests

These results indicate that the injection of limestone into the mid-furnace zone, for Ca:S molar ratios of 1.5 to 3.0, resulted in SO_2 reductions of 35-55%. However, it is believed that further reductions can be attained with improved mixing of the sorbent with the combustion gases. The addition of limestone to the coal, for Ca:S molar ratios of 0.5 to 1.5, resulted in SO_2 reductions of 13-21%. It appears that sorbent addition to the coal is less effective than furnace injection. This is attributed to possible dead-burning of the sorbent in the high-temperature flame zone. In cases where limestone was both injected into the furnace and added to the coal, the total SO_2 reductions for a given Ca:S molar ratio were similar to the reductions for furnace injection only.

The injection of trona into the mid-furnace zone, for Na:S molar ratios of 1.4 to 2.4, resulted in SO_2 reductions of 29-43%. It appears that trona injection is less effective than limestone injection, for corresponding Ca:S and Na:S molar ratios. The injection of a 80:20 limestone/trona blend into the mid-furnace zone, for (Ca+Na):S molar ratios of 1.5 to 2.5, resulted in SO_2 reductions of 35-51%. These were similar to those from the limestone furnace injection tests.

An ash deposition probe was inserted into the furnace to assess the tendency of the various sorbents to promote slagging. In all the limestone injection tests, no slag deposits were observed on the probe. However, in the trona injection cases, definite slag deposits were observed. Figure 3 shows a picture of the ash probe after a typical trona injection test.

Figure 3. Image of ash deposition probe following trona injection test

CONCLUSIONS

The conclusions may be summarized as follows:

- Limestone furnace injection, for Ca:S molar ratios of 1.5 to 3.0, resulted in SO_2 reductions of 35-55%. It is believed that further reductions can be attained with improved mixing of the sorbent with the combustion gases.

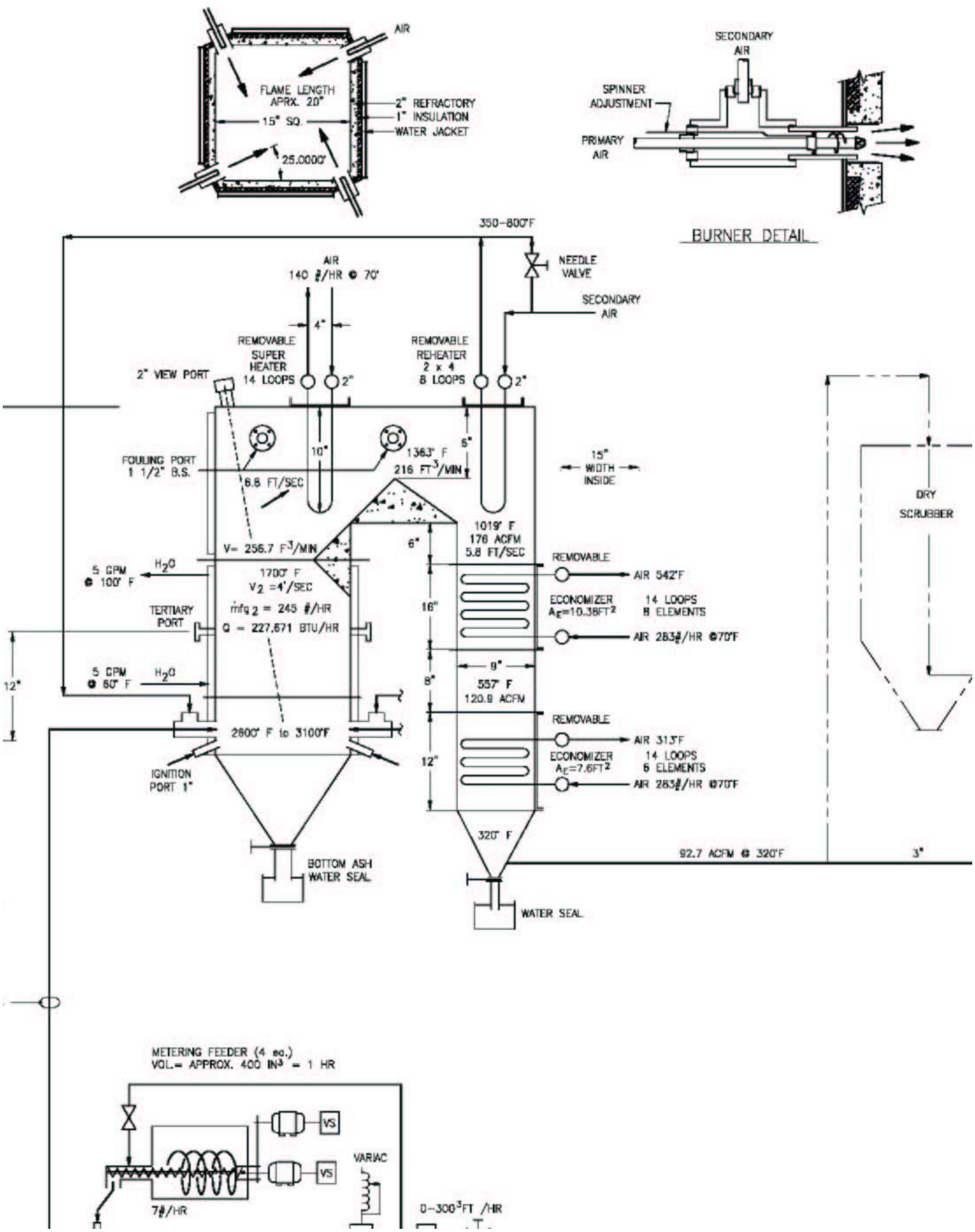
- The addition of limestone to the coal, for Ca:S molar ratios of 0.5 to 1.5, resulted in SO_2 reductions of 13-21%. This was attributed to possible dead-burning of the sorbent.

- In cases where limestone was both injected into the furnace and added to the coal, the total SO_2 reductions for a given Ca:S molar ratio were similar to the reductions for furnace injection only.

- The injection of trona into the mid-furnace zone, for Na:S molar ratios of 1.4 to 2.4, resulted in SO_2 reductions of 29-43%.

- Limestone injection did not produce any slag deposits on an ash deposition probe while trona injection resulted in noticeable slag deposition.

APPENDIX A
Schematic of Combustion Test Facility (CTF)



APPENDIX B

<u>Ultimate and Proximate Analysis of Coal</u>
Sample date: 11/15/2004

	As Received wt. %	**Moisture Free wt. %**	**Moisture & Ash Free wt. %**
Proximate:			
Moisture	0.88		
Ash	13.91	14.03	
Volatile matter	33.36	33.66	39.15
Fixed carbon	51.85	52.31	60.85
Total	100.00	100.00	100.00
Heating Value (Btu/lb)	12,568	12,680	14,749
Ultimate:			
Moisture	0.88		
Hydrogen	4.57	4.61	5.36
Carbon	71.09	71.72	83.42
Nitrogen	1.48	1.49	1.73
Sulfur	2.44	2.46	2.86
Oxygen	5.63	5.68	6.61
Ash	13.91	14.03	
Total	100.00	100.00	100.00

Hydrogen and oxygen values reported do not include hydrogen and oxygen in the free moisture associated with the sample

APPENDIX C
Characteristics of Limestone and Trona Sorbents

1. Limestone
Source of limestone: "Cal 325" limestone from Colorado Lien Company

Sieve Analysis

Sieve Size	Ave Passing
100 (150 microns)	100.00%
200 (75 microns)	99.97%
325 (45 microns)	93.78%
pan	0%

Chemical Characteristics

	Average	Std. Deviation
Calcium Carbonate	96.30%	0.26%
Calcium Oxide	53.90%	0.14%
Acid Insoluble	2.40%	0.26%
Magnesium Carbonate	0.58%	0.01%

Bulk Density: 56.2 lbs/cu. ft.

2. Trona
Source of trona: Solvay T-200 from Solvay Chemicals, Inc.

Sieve Analysis

Sieve Size	Ave Passing
<70 μm	75%
<28 μm	50%
<6 μm	10%

Chemical Characteristics

	Typical Analysis
$Na_2CO_3.NaHCO_3.2H_2O$	97.5%
Free moisture	0.01%
H_2O Insoluble	2.3%
NaCl	0.1%

Bulk Density: 49.0 lbs/cu. ft.