GASEOUS EMISSION CONTROL OF A BASIC CHROME SULFATE PLANT BY AN INNOVATIVE METHOD TO MEET ENVIRONMENTAL STANDARD

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Abstract

In the production of Basic Chrome Sulfate (BCS) from sodium dichromate solution employing sulfur dioxide reduction method, effluent gases coming out from the reactor (Packed bed reduction tower) contain mainly unreacted sulfur dioxide/sulfurous acid mist, and air saturated with water vapor. These SO₂/H₂SO₃ mist may pollute the surrounding environment if not properly controlled. The conventional method of scrubbing the effluent gases with an alkaline solution produces another liquid effluent.

This paper describes an innovative method adopted to control the gaseous emission within the environmental standard of Bangladesh. This method consists of recovery of SO₂/H₂SO₃ mist by cooling the effluent gases in a water-cooled shell and tube heat exchanger. The recovered sulfurous acid solution is separated and it is recycled to the feed tank of the reduction tower. The non-condensed gases before going to the stack are heated in a shell-and-tube heat exchanger with steam. This innovative method was found to be cost effective and environment friendly for a BCS plant of 10 t/day. The BCS reactor system has been further modified by incorporating this concept recently. Concentration of SO₂ gas in the exhaust today is 0.50 – 0.60 ppm.

Introduction

Wata Chemicals Ltd., a private company has small capacity (10 tpd) plant producing tannery grade Basic Chrome Sulfate (BCS) from sodium dichromate solution using sulfur dioxide reduction method. The plant is located at Bhulta about 25 km north-west of Dhaka city. On the same site the company operates a 40 tpd sulfuric acid plant and other facilities producing Zinc Sulfate, Alum, Magnesium Sulfate etc.

The BCS plant receives SO₂ gas from the sulfuric acid gas plant from the common SO₂ for the production of sulfuric acid. The production of BCS involves a reaction between aqueous sodium dichromate and SO₂ gas in packed bed reduction tower. The effluent gases leaving the reactor what is designated as reduction tower contain mainly N₂, O₂ and water vapor plus some unreacted SO₂ gas/ H₂SO₃ and the effluent gases leave at temperature 70 °C. SO₂ content in the effluent gases exceeds the limit set for a sulfuric plant. When this was reported to DOE in 1998, DOE asked the company to redress the emission problem or else close down the operation. Thereafter the company approached the Chemical Engineering Department at BUET to look into this problem.

This paper deals with how this emission problem was contained using innovative ideas.

The Production Process and the Problem

The work involved the visit of the plant and study of the process in operation. The conversion of sodium dichromate to BCS by SO₂ is done batch wise. At first sodium dichromate solution is taken into BCS circulation tank and then it is circulated through packed bed reduction tower counter-current flow to SO₂ by BCS circulation pump. The SO₂ gas coming from the SO₂ combustion chamber is a mixture of N₂, O₂ and SO₂ and concentration of SO₂ is about 8 vol. %. It takes about 8 hrs for completion of the reduction process. The unabsorbed and unreacted N₂, O₂ and water vapor plus residual SO₂/H₂SO₃ at about 70 °C leave the reduction tower through the nozzle at the top and finally enter the atmosphere through the stack via a scrubber. The system as existed is shown in Figure 1.

Removal of SO₂ in the packed bed scrubber by Na₂CO₃ solution was not satisfactory leading to SO₂/H₂SO₃ emission problem. The stack emitted a white plume. The authors examined several options for removing SO₂/H₂SO₃ mist from the emission stream. The formation of H₂SO₃ was due to the reaction between SO₂ gas and mist.
Options considered were:
- Classical chemical absorption with an alkaline media
- Scrubbing with water

These involved additional equipment, chemicals etc., and recovery of disposal of the newly created effluents. The authors decided to do away with these options and planned something very simple but innovative.

It was proposed to cool the effluent stream from 80 °C to 40 °C in a heat exchanger and then heat the cold stream to some 50 °C. Since the stream is saturated with water vapor carrying SO₂, Figures 2 and 3 respectively indicate that the proposed idea would substantially reduce SO₂/H₂SO₃ from the effluent stream in the cooler. For example, if saturated air at 80 °C is cooled to 40 °C, the vapor load is reduced from 0.95 lb H₂O/lb air to 0.018 lb H₂O/lb air, a reduction of 98.1% while that for SO₂ (based on partial pressure of SO₂ over 1 gm SO₂ in 100 gm water) is 66.5%. Once water has started to condense, SO₂/H₂SO₃ also gets dissolved in water condensates and removes simultaneously.

Implementing the Scheme

The plant personnel as a part of implementing the scheme put two double pipe heat exchangers as proposed with a stream from the stack as inlet stream to the inner pipe of the cooler. The arrangement is schematically shown in Figure 4.

When the scheme was put into operation by installing two shell-and-tube exchangers as shown in Figure 5, it worked well. No significant SO₂/H₂SO₃ emission was observed. The unsightly white plume disappeared from the stack. DOE found the plant acceptable.

This system was operated for three years. Based on operational experience, the plant personnel reorganized BCS reaction system by incorporating the above concept as shown in Figure 6. The system worked very satisfactorily. The gases leaving the BCS plant now contains SO₂ in the range 0.5 to 0.6 ppm measured with GASTEC tube method while the DOE’s guidelines state the SO₂ concentration in industrial area shall be 120 ppm while that for rural area 80 ppm.

Achievement of the Implementation of Innovative Idea

Besides meeting the DOE’s requirement for the emission of SO₂ the other benefits derived from this simple innovative modification include:
- Recycling of the condensed acidic stream to the reactor has led to decrease in the reaction time from 8-9 hrs to 6-7 hrs.
- Less consumption of make-up water
- Less consumption of SO₂
- The almost invisible white plume and the tall stack have disappeared.
- Disposal of liquid effluent has been eliminated.

This has done away with the hassle of the conventional ETPs.

References

1. Plant Documents of Wata Chemicals Ltd.
Figure 1: Schematic Diagram of the Reaction System BCS Production
Figure 2: Humidity Chart for Mixtures of Air Water Vapor at a Total Pressure of 101.325 kPa (760 mm Hg)

Figure 3: Partial Pressure of H₂O and SO₂ over aqueous solution of sulfur dioxide (1.0 gm SO₂/100 gm Water)
Figure 4: Arrangement of Double Pipe Exchanger

Figure 5: Schematic Diagram of Modified BCS Process Plant
Figure 6: Control Scheme for Sulfur Dioxide Emission for BCS Plant\textsuperscript{1}