SULPHURIC ACID TECHNOLOGY UTILISED BY BATEMAN ENGINEERING

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Abstract

Bateman Engineering Project's acid-plant track record goes back to 1977. Bateman Engineering can design sulphuric plants based on gas from sulphur burners, metallurgical off gas as well as pyrite roasting systems. Bateman Engineering has a technology marketing agreement with NORAM Engineering Ltd of Canada to provide state-of-the-art, well-proven acid plant technology, and also has access to roaster technology from several sources, including Chinese technology.

Utilising the Noram technology agreement, Bateman was awarded the Engineering and Procurement (EP) contract for the Ambatovy Nickel Project, Sulphuric Acid Facilities in 2007. This is the first Greenfield sulphuric acid plant Bateman has designed for many years, producing a combined 5,500tpd, and is one of the largest sulphur burning acid plants in the world.

This paper gives an overview of the sulphuric acid plant for the Ambatovy Nickel Project, advantages of Noram’s unique technology on offer, an overview of work conducted on a recent study of a pyrite roasting acid plants as well as a new technology currently being developed by Bateman for the direct combustion of solid sulphur to form sulphur dioxide.

Introduction

Bateman’s acid plant experience spans ~30 years (all plants utilising 3rd party technology):
- Rössing 1977 Rössing, Namibia
- Fedmis 1979 Phalaborwa, RSA
- Buffelsfontein 1980 Potchefstroom, RSA
- Ambatovy 2008 Tamatave, Madagascar

Bateman has a long term Technology Marketing agreement with Noram Engineers and Constructors of Canada. Utilising this agreement, Bateman was awarded the Engineering and Procurement (EP) contract for the Ambatovy Nickel Project Sulphuric Acid Facilities in 2007, incorporating a Noram technology design and supply of proprietary equipment package.
This is the first sulphuric acid plant Bateman has designed and supplied in over 30 years and at 5,500 t/d sulphuric acid from two equal trains is one of the largest sulphur burning acid plants built in the world in recent times.

This paper gives the reader an overview of:

- The sulphuric acid plant for the Ambatovy Nickel Project
- Sulphuric acid plant studies conducted
- Noram’s technologies which include
  - Radial flow™ heat exchangers
  - Stainless steel converters
  - Smart™ acid distributors
  - Ceramic packing
  - Anodically protected acid coolers
- Bateman’s new sulphur burning technology

Technical Discussion – Ambatovy Project

Project Overview

Bateman and Noram started the engineering design in August 2007 and completed the design and procurement phases of the project by March 2009 at which time the majority of the equipment had already been delivered to site.

The acid plant section of the plant was designed by Noram with fabrication by Bateman utilising a Chinese fabricator, Junye for the acid towers, sulphur furnaces, cold interpass exchanger pump tanks and stacks and Metso ND in South Africa for the two massive stainless steel converters. The steam circuit comprising Waste Heat Boiler, Economisers, Superheaters and De-superheaters was designed and supplied by Sinopec Nanjing Design Institute (SNDI) of China. The sulphur melting circuit and peripheral circuits were designed by Bateman. The construction of the plant is currently underway with completion expected in 2010.
Prefabrication Strategy
As a result of the project location and the limited infrastructure in Madagascar, Bateman was presented with a unique opportunity to design and fabricate almost all equipment as single complete units in the fabricator’s facilities and ship them to site. In some cases tanks were fabricated, insulated and cladded and walkways installed in the fabricators facilities prior to shipment. The stacks, furnaces and acid absorption towers were prefabricated in China and delivered as single units to the project site. The two 395 tonne stainless steel converters, 14.5m in diameter and 24m tall, were delivered to site from Durban as single units:

Figure 1: 3D rendering of the sulphur melting plant and 2 x 2750 t/d sulphuric acid plants

Figure 2: Ambatovy Acid Plant Construction (Tamatave, Jan 2008)
By following this prefabrication and shipping strategy, Bateman was able to reduce the amount of time required for site erection significantly and the knock on effect was improved quality and reduced risk of incidents on site.
Acid plant capabilities

Bateman has over the last two years submitted many proposals to a variety of clients for acid burning and pyrite roasting sulphuric acid plants. As a result of this work, Bateman has a significant database of information on acid plant equipment, vendors and pricing.

Bateman also recently conducted a detailed study for a client for a pyrite roasting acid plant. Bateman, through cooperation with SNDI in China offered a competitive roasting plant which will produce sulphur dioxide as feedstock to the Noram technology acid plant.

Bateman’s scope of supply for this client included:
- General technical specification
- Mechanical equipment specifications
- Piping specifications
- Electrical and instrumentation specifications
- Civil and structural specifications
- Quality control specifications
- Health and safety specifications
- Process flow diagrams
- Piping and instrumentation diagrams
- Mechanical equipment list
- Three dimensional modelling
- Schedule of volumes
- Logistics study

Noram Technology

General

Noram’s Acid Plant technology comprises:
- Acid towers, Smart™ acid distributors and Ceramic packing
- Acid coolers (Anodically protected)
- Radial™ and split™ flow heat exchangers
- Stainless steel converters

Noram has extensive expertise in retrofitting existing acid plants throughout Canada and the United States and has had great success where its technology has been implemented over the past ten years at a sulphuric acid plant in Canada. All of the original technology equipment at this plant have been changed to Noram designed equipment with the exception of the main blower. In doing this, the plant capacity has increased from 570 t/d to 830 t/d with significantly less maintenance and operational downtime than before.
Acid towers, packing and distributors

Noram designed acid towers differ from the “standard” towers in four main areas:

1. The tower bottom is dished and not flat. This allows for a very stable brick lining shape.

2. The self-supporting dome does not exert stresses directly onto the floor of the vessel, thus allowing for an unobstructed tower floor area which assists with inspection and maintenance.

3. The acid distributor system allows for uniform acid distribution throughout the entire cross section of the tower. The design of the distributor maximises the area for gas flow reducing the risk of flooding and high pressure drop. The design of the down-comers is such that blockages are reduced and allows for ease of inspection and cleaning in significantly less time than before. The distributors are fabricated MONDI ductile iron piping and the nozzles from Lewmet material.

4. Noram’s patented CECEBE HP™ and FC™ packing. These enable a pressure drop which is typically half of that of conventional 3” saddles. The gas throughput in an existing acid tower can be increased by more than 25 percent! As such this type of packing is ideally suited to debottlenecking acid towers.
Anodically Protected Acid Coolers
Noram’s acid coolers combine results and improvements from a long history of developmental work in this area. Acid cooler failures were investigated and found to occur mainly in large acid coolers in hot service applications where the sulphuric acid concentration was outside the design parameters.

Noram evaluates each cooler for its specific duty using proprietary flow sheeting and heat exchanger rating programs. These programs result in designs that are thermally efficient and economically viable. The acid coolers are shell and tube units with the acid on the shell side and up to 4 passes on the water side (tube side). The acid area is constructed 100% of stainless steel. Large diameter bare metal cathodes are used for the anodic protection system. This allows for uniform current flow and improved corrosion protection of the acid coolers.

Radial flow heat exchangers
Traditionally, acid plant gas-gas heat exchangers are of the single or double segmental type. Both of these have some inherent problems in terms of pressure drop, heat transfer rate, acid condensation etc. Noram’s RF™ gas exchanger addresses these problems by adopting a radial flow pattern from the inner core across the tubes to the outside and then back again to the centre core.
In this approach, the heat transfer area is optimally used and the tube surface area reduced with a subsequent reduction in pressure drop. This type of exchangers typically require approximately 25% less surface area than conventional units and allow for nozzle orientations to be more flexible.

Stainless steel Converters
Traditionally, SO$_2$ gas converters were carbon steel vessels with brick-lining around the first (hot) bed of the catalyst and a complicated system of cast iron grids and supports of the catalyst beds.

Typical challenges encountered in converters of this type include gas distribution problems, temperature corrosion of the cast iron supports, scaling of the catalyst as a result of the materials of construction as well as long heat up and cool down periods as a result of the thermal inertia of the converters.

In the early 1980’s stainless steel converters became the industry standard and Noram has subsequently developed this concept further. Specifically important is the design of catenary plates for support of the catalyst bed. These plates are flexible and minimise stresses on the shell of the converter during start-up (at which time the shell and supports are at different temperatures).

Improved SO$_2$ conversion rates have been achieved as a result of reduced SO$_2$ leakage and reduced pressure drop. In addition, because the stainless steel converter has no need for brick lining, the unit has less mass and therefore heats up significantly faster than heavier, brick lined carbon steel units.
Noram has modelled this design extensively and has supplied a number of these units to acid plants.

**Figure 14**: Top bed of converter (with shipping bracing)

**Figure 15**: Converter internals during fabrication (with shipping bracing) showing the perforated catenary plates which support the quartz rock and catalyst

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**Innovative Sulphur Burner**

**Traditional Sulphur Burners**

Traditionally sulphur burning acid plants relied on large sulphur furnaces (operating at approximately 1100°C) to produce sulphur dioxide (approximately 11% by volume) from combustion of liquid sulphur with oxygen (in air).

The well established technology required to produce liquid sulphur comprise of a system of melting tanks, steam heating coils, filters and storage of liquid sulphur. Sulphur is melted in tanks fitted with agitators and steam heating coils. The melting temperature of sulphur is ~120 °C. The liquid sulphur is then pumped via steam jacketed pipes and special pumps to sulphur filters which remove ash, gypsum and excess lime (used to neutralise the free acid in the sulphur). The clean sulphur is then stored in large sulphur storage tanks prior to being pumped to the sulphur furnace.

The typical requirements of this traditional system include:

- The temperature of the liquid sulphur should be very carefully controlled as a small change in temperature can either cause the sulphur to solidify or to significantly increase its viscosity – both of which result in a blocked system which may take a long time to rectify
Steam is required continuously to keep the sulphur from solidifying as it is used as the trace medium in the jacketed pipes.

Hazardous working environment – hot, liquid sulphur, SO$_2$ and H$_2$S emissions (depending on sulphur source) need to be managed and addressed in the plant design and operations.

Equipment maintenance is difficult and required frequently

The possibility of fires in enclosed tanks necessitates the installation of steam quenching systems.

To eliminate some of these requirements, Bateman has developed a solid sulphur burner, allowing sulphur prills to be combusted directly to form sulphur dioxide without the need for prior liquefaction. This unit has been patented and preliminary test work from our pilot plant is proving promising.

The pilot plant at Bateman’s laboratory in South Africa comprises a sulphur feed hopper, refractory lined combustion chamber and caustic scrubber (in order not to release SO$_2$ to the atmosphere) as well as pumps, burners and blowers for combustion and fluidisation air.

The refractory lined main reaction chamber has two LPG burners which are used to heat the reactor to between 800 °C and 900 °C. Sulphur prills are then added pneumatically to the chamber from the bottom where it reacts. Once at temperature and after sulphur has been introduced to the reactor, the LPG is switched off as the reaction is self sustaining from this point onward.

SO$_2$ is removed from the vessel tangentially and is directed to a caustic scrubber for gas cleaning on the pilot plant but would obviously be routed to the converter in a real plant.
The unit has been tested at low sulphur rates (increased sulphur throughput results in slippage in the scrubber and emissions to atmosphere).

Bateman is currently investigating the temporary installation of the unit at an existing operating sulphuric acid plant for an extended campaign of test work. Following this, it is intended to develop a commercial burner design incorporating removal of ash and other solid impurities from the SO$_2$ stream before feeding it to an existing or new acid plant.

Figure 18 : Solid sulphur burner test unit
Bateman, with its technology supplier Noram, and other suppliers with whom Bateman has commercial relationships, offer a unique combination of sulphur and sulphuric acid technologies and expertise, and has been able to apply this on the Ambatovy project. In-house technology development may add new commercial opportunities for the full suite of technologies on offer.
Werner Vorster, Bateman Engineering Projects, Technical Manager : Acid Plants and Environmental

I completed my undergraduate studies at the University of the Witwatersrand in 1997. From 1998 to 2001 I studied toward a PhD in Chemical Engineering at the University of Birmingham with the topic “The effect of Microwave Radiation on Mineral Processing. I joined Bateman in January 2003 where I have fulfilled the role of process engineer on a number of arc furnace rebuild projects, chromite sintering projects as well as an commissioning engineer on a number of projects. Since August 2007 have been involved as process and project engineer on the Ambatovy Acid Plant project in Madagascar.