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Tenke Fungurume Mining – an update

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Synopsis

With the successful commissioning of a 600 t/d sulphuric acid plant as part of the new metallurgical complex in Lualaba Province in the DRC, Tenke Fungurme Mining (TFM) continues to develop this site and increase copper production using a systematic approach. This paper outlines the key challenges encountered and solutions adopted to reliably increase acid production in a remote location. Development of acid plants no. 1 and no. 2, including debottlenecking and environmental upgrades, is described.

Keywords

sulphuric acid plant, debottenecking, capacity expansion.

Introduction

With the successful commissioning of the 600 t/d sulphuric acid plant as part of the new metallurgical complex in Lualaba (formerly Katanga) Province in the DRC, Tenke Fungurume Mining (TFM) continues to develop this site and increase copper production using a systematic approach (Hayward, 2016). As of 2016, the facility produced 205 kt copper and 16 kt cobalt per annum. As the metal production capacity increases, the demand for sulphuric acid also continues to increase. It became apparent that the acid demand within the complex would continually exceed the existing acid plant (AP1) capacity, even with the plant being able to consistently operate at 660 t/d. Therefore, TFM has taken a staged approach to increase acid availability on site, with the first stage involving debottlenecking of AP1 and the second stage building a new acid plant (AP2) to complement the existing AP1.

Capacity expansion of AP1

In 2011 TFM engaged the services of Chemetics to study the potential for capacity increases in AP1. To ensure the expansion project would be executed with cost and technical certainty, the study was conducted in two phases:

Phase 1—A high-level study to identify capacity constraints of existing equipment, including a review of any areas of concern at current operating rates, and evaluation of two capacity increase options: a lower increase that could be implemented with limited change and capital, and a maximum capacity case considering additions to and replacement of equipment.

Phase 2—A detailed study that lists all the changes required to enable the plant to reach the capacity increase selected in phase 1 of the study. The scope included preparing PFDs and P&IDs for current and future operating cases, and a site visit to review the current operation and identify any operational constraints that could prevent the plant from reaching the new target in acid production.

For any sulphuric acid plant production increase, the key considerations that must be taken into account are as follows:

- SO_2 gas concentration and conversion
- Plant volumetric flow rate
- Gas side pressure drop across the system
- Additional heat load.

The SO_2 conversion and resultant gas concentration in the stack that must be achieved by the plant is usually as per statutory (permit) requirements and cannot be relaxed at any operating rates. Therefore, it becomes one of the main considerations in any capacity increase. In sulphur-burning applications, SO_2 gas concentrations of up to 12% by volume to bed 1 of the converter can now be achieved in new plant designs. For existing plants where higher throughput is desired, an increase in SO_2 gas concentration

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is a normal and often-used approach. Special care must be taken to address the lower oxygen to sulphur dioxide ratio that will be present for conversion.

Plant volumetric flow is a function of production rate and the design SO_2 gas concentration. The optimum plant design minimizes flow by increasing the SO_2 gas concentration while still meeting emission requirements.

Increases in flow will raise the overall gas side pressure drop by approximately a square ratio. The capacity of the main blower then typically becomes the plant limitation to further increases. Other large equipment such as the strong acid towers may also have hydraulic limitations that must be addressed.

Heat is generated from the combustion of sulphur, the oxidation of SO_2 to SO_3, and finally the absorption of SO_3 into strong acid and its subsequent dilution. The heat generated in each of these process steps is in direct proportion to the production rate. The heat produced by the combustion of sulphur is removed in the waste heat boiler, that from SO_2 oxidation by steam superheaters and economizers located between converter passes, and the heat from absorption of SO_3 and acid dilution by the strong acid coolers.

For phase 1 of the expansion study, the following key assumptions/design decisions were made:

- SO_2 emissions to atmosphere would not exceed the original design basis
- Converter with internal superheater and reheat exchanger would not be modified
- Blowers would not be replaced
- Strong acid towers would not be replaced or significantly modified
- Steam equipment would not be replaced
- Cold reheat exchanger would not be replaced
- Turbine generator set and dump condenser not to be limiting to any capacity increases
- The two capacities identified and evaluated were:
  - Option 1 - 750 t/d as 100% H_2SO_4
  - Option 2 - 825 t/d as 100% H_2SO_4.

This study resulted in the following key limitations to further production increases above current rates being identified:

- SO_2 conversion and emissions
- Inter-tower hydraulics
- Strong acid circulation and cooling.

At capacities above 825 t/d several equipment items, including the blowers, inter-tower, and mist eliminators reach their ultimate capacity limit and require replacement or significant modification.

One possibility to increase capacity was by raising SO_2 concentration at the furnace and boiler system to the original 14% SO_2 by volume design. However, raising the furnace temperature would potentially impact on materials and equipment maintenance requirements. After reviewing with TFM, it was decided that furnace operation SO_2 concentration would be increased to 12% SO_2 by volume in order to minimize volumetric flows downstream and keep the plant pressure profile and system hydraulics within acceptable ranges.

To improve inter-tower hydraulics and reduce pressure drop, low pressure-drop packing was used. This packing had more open area than conventional saddles while maintaining good SO_3 absorption efficiency. With the increase in plant rate the inter-tower acid outlet temperature will also increase, therefore an increase in acid circulation rate is also required to ensure that the acid outlet temperature is below the safe operating temperature of the SARAMET™ alloy tower.

The findings and recommendations of the phase 1 study were reviewed with TFM, which resulted in TFM engaging Chemetics to proceed with phase 2 of the expansion study with the selected target of 825 t/d acid production. The following tasks were completed.

- Develop PFDs for the current (650 t/d) and future (825 t/d) operation
- Review the BFW, deaerator, and LP steam system during a site visit to identify and solve bottlenecks
- Review cooling water system during site visit to ensure sufficient cooling water is available to handle the extra heat load after the expansion
- Review plant operation during site visit to identify any other operational constraints that would prevent the plant from reaching 825 t/d capacity
- Rate the existing boiler for expanded capacity using the observed in-service heat transfer coefficients during operation at 1200°C furnace temperature
- Summarize all plant changes required to enable TFM to execute the project.

As a starting point, the current plant operation was reviewed to develop an as-is flow sheet. From this starting point, the flow sheet for the expanded plant was developed. The combination of current plant operating data and the calculated requirements after expansion allowed for a detailed analysis of the critical equipment and verification of the recommended modifications identified in the phase I study.

At the conclusion of the phase 2 study, it was determined that the following items should be completed in order to reach the 825 t/d expansion target:

(a) Install new packing in the inter- and final towers
(b) Install new catalyst in the converter
(c) Replace underperforming inter economizer
(d) Modify the deaerator system to allow operation at higher temperature
(e) Install a new, larger acid cooler to increase acid cooling capacity
(f) Install a larger acid supply pipe to inter-tower and new distributor to inter-tower to allow inter-tower acid circulation rate to increase.

As with most plant expansion projects, the modifications were implemented during a planned plant turnaround. It was critical that the turnaround was completed on time as acid production was halted during this period, so any delays in the plant restart would have a significant impact on copper production. As part of the phase 2 study work, Chemetics provided a detailed procurement plan and shutdown works schedule to allow TFM's project team to implement all the changes in an organized, efficient, and safe manner. Furthermore, TFM engaged the services of Chemetics to provide site technical advisory services to support the

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September 2012 maintenance turnaround of the sulphuric acid plant. The main scope of services included performing internal visual inspections to assess the condition of the equipment and provision of technical assistance during the plant modifications. After the plant turnaround, the plant was restarted and proved able to consistently produce 825 t/d.

Development of second acid plant (AP2)

After successful completion of the AP1 expansion project, planning began for the second sulphuric acid plant (AP2). While AP1 was a successful project for TFM, nevertheless, TFM's project team, operations team, and technology provider (Chemetics) were brought together to conduct a formal 'lessons learned' session during the feasibility study stage for AP2. Key project team members from all three parties met to review all aspects of the design and generate ideas on what could be done to make AP2 better than AP1. The following recommendations were identified and implemented in the AP2 project:

- ➤ Larger platforms around the front end of the sulphur furnace to allow better access to sulphur gun changes
- ➤ Revamp DCS operator interface to improve usability; the number of screens was revamped to allow operators to see the 'core' of the acid in only two screens
- ➤ Addition of a continuously operating caustic scrubber to reduce SO_2 emissions to below 20 ppm, well within World Bank recommended emission guidelines.

Chemetics innovations

In addition to the above design changes to improve usability, Chemetics continues to build on their successful experience in AP1 and work with TFM operations to improve on the 'best in class' technology slated for the AP2 project. Although infrastructure in the DRC has been significantly improved since the first project, executing a large complex project in the country remains a challenge. Limited port access, long distances from ports to site, poor infrastructure and road conditions, and shortage of skilled labour within the country remain the top issues. In addition, the plant capacity in AP2 is more than double the original AP1 capacity, which results in larger equipment sizes and pushes the shipping constraints to the limits.

To address these challenges, the following strategies were developed in designing key equipment in the acid plant:

- ➤ Use of proven designs for critical process equipment
- ➤ Minimize field fabrication/installation
- ➤ Maximize off-site prefabrication
- ➤ Provide complete assembled equipment if deemed suitable for road transportation.

SARAMET™ acid towers, piping and ISOFLOW™ distributor

For the AP2 project, TFM has continued to use SARAMET™ acid towers in preference to conventional brick-lined towers after considering the advantages of prefabricating the entire tower, including internals, off-site. The general dimensions of the dry, inter-, and final towers are shown in Table I. The overall dimensions of these towers are within the shipping capability of ground transportation, thus the towers could be shipped to site in a single piece without further field assembly. Once the towers are lifted into position the tower packing and acid distributors can be installed immediately (Figures 1 and 2). This eliminates the cost premium required to bring in specialist contractors to complete the acid bricking installation on-site.

For the acid distributors, the newest generation of ISO-FLOW™ trough distributors were installed in AP2. In this innovative design, acid flows from the main header to the bottom of the trough, and then upwards via a series of calming plates which also filter out debris. Choking of flow orifices through downcomers is essentially eliminated (Figure 3). This innovation also reduces the number of parts, which reduces overall cost and simplifies installation and maintenance.

Table I

General dimensions for the Tenke acid towers (AP2)

Application	Diameter (m)	Overall height (m)
Dry tower	5.2	14.3
Inter-tower	5.6	18.3
Final tower	5.6	18.3

Figure 1—Completed SARAMET™ acid towers arrive at TFM site

Figure 2—SARAMET™ acid towers in installed position

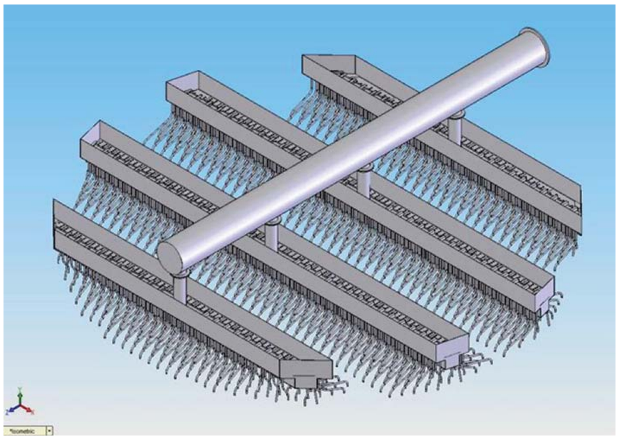

Figure 3—ISO-FLOW™ trough distributor

Figure 4—Sulphur furnace shell delivered to site

Prefabricated sulphur furnace

The sulphur furnace is a critical component for reliable acid plant operation. The furnace incorporates Chemetics' proprietary design features such as individual combustion air control to each sulphur gun for optimal air-sulphur mixing, no internal baffles or checker walls, insulated shell designed to ensure optimum shell temperature, and dual saddle support to minimize stress on the shell and refractory.

The furnace shell was fabricated off-site and shipped to site in a single vessel, followed by refractory installation and curing on-site under the supervision of the refractory supplier (Figures 4 and 5).

Internal heat exchangers and modular converter

The converter is the focal point of the sulphuric acid process. This vessel contains the series of catalyst beds that convert the sulphur dioxide gas to sulphur trioxide. The gas flows in series through these beds with intermediate cooling between each bed. The converter at Tenke AP2 is similar to that at AP1, which features Chemetics' patented all-stainless design. The Chemetics design incorporated an internal superheater inside the core of the converter, which eliminates the hot gas ducting between beds 1 and 2, which is well known to be a continual maintenance problem on many plants owing to the very high gas and metal temperatures (Figure 6).

To minimize field construction the converter was constructed using a modular approach. The converter was shipped to site as prefabricated modules and assembled on-site. This method greatly reduces construction time from 2 to 3 months for a conventional 'knock-down' build to less than 1 month. This unique approach also improved the overall quality of the construction, since the majority of the fabrication was completed off-site in a fabrication shop under ideal conditions (Figures 7 and 8).

Commissioning and operation

Although the basic design of AP2 is the same as of AP1, nevertheless the design went through a detailed hazard and operability (HAZOP) study, with particular emphasis on the impact of all changes that were implemented in the AP2 project.

Figure 5—Sulphur furnace internals

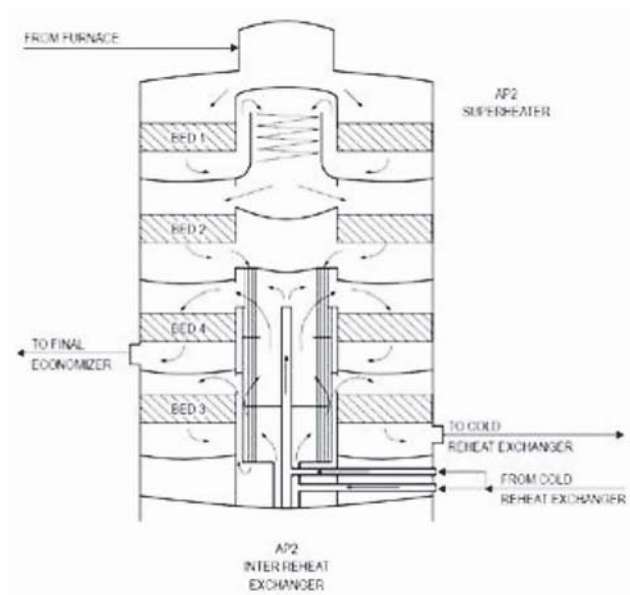

Figure 6—Tenke AP2 converter – process gas flow schematic

Figure 7—Prefabricated converter modules

Figure 8—Converter modules assembly on site

Before commissioning, TFM, Hatch GOBA, and Chemetics developed a joint commissioning plan with all teams actively participating in the development and execution of the plant startup plan. The startup plan was structured to meet a systems-based approach whereby the plant was broken down into systems. For each system, the individual tasks required to bring the status of the system from mechanical completion to commissioning were identified.

The sequence of steps to be taken for distinct tasks within each system was jointly developed between Chemetics' commissioning specialists and TFM's commissioning team and approved by TFM's Commissioning Manager prior to starting of the task. The integrated commissioning team also worked with commissioning/operations personnel where specific safety procedures such as confined space entry permits, lockout/tagout, line, and flange break permits were to be issued prior to start of commissioning.

During commissioning, daily meetings were held at TFM's site office to plan and coordinate tasks to ensure everyone was aware of what other teams were working on at the site.

Before commissioning a new process area or a piece of equipment, all Chemetics commissioning team members were required to complete a Safe Plan of Action (SPA). SPA is a safety system designed to systematically review all the potential hazards prior to the start of work in the field (Figure 9). This ensured that every team member involved in the task understood the work and all identified hazards were mitigated by appropriate control measures. The SPA system was designed to integrate with Tenke Fungurme's lockout/tagout procedures to ensure all commissioning tasks could be done safely.

With a detailed systematic plan in place, the integrated startup team worked with the construction team to prioritize resources to complete critical path items according to the commissioning schedule. The acid plant reached mechanical completion status in January 2016 and first acid production in early February. The plant has exceeded nameplate capacity of 1400 t/d since three weeks after the first acid production.

Summary

Increasing sulphuric acid production at Tenke Fungurume Mining while maintaining copper production presented some unique challenges. The staged strategy of first expanding the capacity of AP1 using a systematic approach, followed by execution of AP2 project using proven AP1 execution strategies as well as incorporating lessons learned from the first acid plant project, has proven to be a success. With the successful debottlenecking of AP1 and safe startup of AP2, TFM is able to increase copper and cobalt production as well as reduce overall production costs as reliable on-site acid production eliminates the need to import acid.

Reference

Hayward, K. 2016. Tenke Fungurume looks to the future with second acid plant. Sulphuric Acid Today, Spring/Summer 2016. ◆

Safe Plan of Action

CHEMETICS®

Review checklist while completing the SPA table. Check all that apply.

A new SPA is required if the job scope or work conditions change.

Required Permits
☐ Confined Space
☐ Critical Lift
☐ Hot Work
☐ Lock Out/Tag Out
☐ Soil Disturbance (Over 12")
☐ Utility Clearance
Required PPE
☒ Hard Hat, Class C
☐ Hard Hat, Class E *(Elect. Protect)*
☐ Ear Plugs/Ear Muffs
Eye Protection:
☒ Safety Glasses
☐ Face Shield
☐ Chemical Goggles
☐ Welding Hood
Hand Protection:
☒ Cut Resistant Gloves
☐ Welders Gloves
☐ Nitrile Gloves
☐ Surgical Gloves
☐ Rubber Gloves
☐ Elect. Insulated Gloves
☐ Arm Sleeves
Foot Protection:
☐ Sturdy Work Boots
☒ Safety Toe Boots
☐ Rubber Boots
☐ Rubber Boot Covers
☐ Dielectric Footwear
Respiratory Protection:
☐ Dust Mask
☐ Air Purifying Respirator
☐ Supplied Air Respirator
☐ SCBA
☐ Emergency Escape Respirator
Special Clothing:
☐ Tyvek ®
☐ Poly Coated Tyvek ®
☐ Fire Resistant Coveralls
☐ Rain Suit
☒ Safety Vest
Fall Protection:
☒ Harness
☐ Double Lanyard Required
☐ Anchorage Point Available
☐ Additional Anchorage Connector Needed e.g. Cross Arm Strap, etc.
☐ Retractable Device Needed
☐ Horizontal Life Line System Req'd.
☐ Fall Clearance Distance Adequate
☐ Fall Rescue/Retrieval Plan Set Up

Hazards	Safe Plan
☐ Overhead Utilities	☐ Power de-energization required ☐ Insulation blankets required ☐ Wire watcher required ☐ Required clearance distance = ______Ft. ☐ Safe work zone marked
☐ Crane or other Lifting Equipment	☐ Signalman assigned ☐ Tag lines in use ☐ Area around crane barricaded ☐ Lifting equipment inspected ☐ Personnel protected from overhead load
☐ Underground Utilities	☐ Reviewed as-builts ☐ Subsurface surveys ☐ Received dig permit ☐ Required clearance distance = ______ Ft. ☐ Safe work zone Marked
☐ Electrical	☐ Lock Out/Tag Out/Try Out ☐ Permit required? ☐ Confirm that equipment is de-energized ☐ Reviewed electrical safety procedures
☐ Excavations	☐ Permits ☐ Inspected prior to entering ☐ Proper sloping/shoring ☐ Barricades provided ☐ Access/egress provided ☐ Protection from accumulated water
☐ Fire Hazard	☐ Hot Work Permit ☐ Fire Extinguishers ☐ Fire watch ☐ Adjacent area protected ☐ Unnecessary flammable material removed
☐ Vehicular Traffic or Heavy Equipment	☐ Traffic Barricades ☐ Cones ☐ Signs ☐ Flagmen ☐ Lane closure ☐ Communication with equipment operator
☐ Noise >85 dB	Hearing protection is required: ☐ Ear plugs ☐ Ear Muffs ☐ Both
☐ Hand & Power Tools:	☐ Inspect general cond. ☐ GFCI in use ☐ Identified PPE required for each tool ☐ Reviewed safety requirements in operators manual(s) ☐ Guarding OK
☐ Hand Hazards	List sharp tools, material, equipment: ______ ☐ PPE gloves, etc. ☐ Protected sharp edges as necessary
☐ Manual Lifting	☐ Reviewed proper lifting tech. ☐ Identified material requiring lifting equipment ☐ Hand protection required ☐ Back support belts
☒ Ladders	☐ Inspect general cond. before use ☐ Ladder inspected with in last quarter ☐ Ladder tied off or held ☐ Proper angle and placement ☐ Reviewed ladder safety
☒ Scaffolds	☐ Inspect general condition before use ☐ Tags in place ☐ Properly secured ☐ Toe boards used ☐ Footings adequate ☐ Materials properly stored on scaffold
☒ Slips, Trips Falls	☐ Inspect for trip hazards ☐ Hazards marked ☐ Tools & material properly stored ☐ Extension cords properly secured ☐ Work zone free of debris
☒ Pinch Points	List potential pinch points: ______ ☐ Working near operating equipment ☐ Hand/Body positioning
☐ Working w/ Chemicals	☐ List specific chemicals involved and list hazards and precaution on front side. ☐ Reviewed MSDS ☐ Exposure Monitoring required ☐ Have proper containers and labels. ☐ Identified proper PPE (respirators, clothing, gloves, etc.)
☐ Asbestos or Lead Paint Potential	☐ Areas to be worked may contain asbestos or lead paint ☐ Asbestos controls incorporated ☐ Lead based point controls in place ☐ Exposure monitoring conducted.
☒ Heat Stress Potential	☐ Heat stress monitoring (>85°) ☐ Liquids available ☐ Cool down periods ☐ Sun Screen ☐ Reviewed Heat Stress symptoms
☐ Cold Stress Potential	☐ Proper clothing (i.e.. gloves, coat, coveralls) ☐ Wind chill <32° ☐ Reviewed Cold Stress symptoms ☐ Warm up periods
☒ Environmental	☐ Air emissions ☐ Water discharge ☐ Hazardous wastes ☐ Other wastes ☐ Pollution prevention ☐ Waste minimization
☒ Natural or Site Hazards	☐ Weather ☐ Terrain ☐ Adjacent operations or processes ☐ Biological hazards ☐ Animals/reptiles/insects hazards
☐ Adjacent Work/Processes	☐ Notified them of our presence ☐ Other workers adjacent, above, or below. ☐ Coordinated with adjacent supervisor/customer/operator ☐ Need barriers between.
☒ Barricades/covers	☐ Caution barricade tape required ☐ Danger barricade tape required ☐ Rigid railing required ☐ Covers over opening ☐ Warning signs required
	Additional Information:

0-FRM-8268-R1 SPA – Field Visit

Figure 9—Safe Plan of Action form (partial sample)