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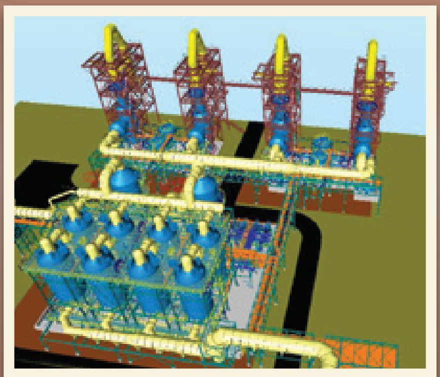
Fall/Winter 2015

First Quantum Minerals brings largest acid plant on-line in Zambia Page 7



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When you mine copper ore from a very productive source, you also need an efficient way to smelt all that ore and clean the off-gases from that smelting process. The Kansanshi mine in Zambia, the largest copper mine in Africa, is just such a source. But the nearest smelters were 180 kilometers away, in the county's Copperbelt region. That is, until a new copper smelter, complete with the world's largest single-train metallurgical gas cleaning and sulfuric acid facility, was built on site.

The Kansanshi mine, which is 80 percent owned by Kansanshi Mining PLC (KMP), a subsidiary of First Quantum Minerals Ltd. (FQM), has undergone several expansions since it began operating in 2005. But adding the new smelter together with a combined gas cleaning/acid manufacturing facility at the mine source makes for a complete and fully integrated operation, turning copper concentrate into anode copper.

First incorporated in 1983, FQM acquired its 80 percent interest in the Kansanshi mine in August of 2001. Besides its assets in Zambia, the mining and metals company holds assets in Spain, Mauritania, Australia, Finland, Turkey, Panama, Peru and Argentina. Today, FQM is an established and growing company producing copper, nickel, gold, zinc and platinum group elements.

Engineering on the Kansanshi smelter project began in 2011, with the contract for the gas cleaning/sulfuric acid manufacturing facility awarded to Outotec in March 2012. Smelting began in March 2015 with introduction of copper concentrate to the smelter and off-gas to the acid plant. The smelter's yearly capacity is greater than 300,000 metric tons anode copper. The acid plant's maximum capacity is 4,400 MTPD.

Prior to the new acid plant, the sulfuric acid necessary for leaching oxide copper had been either produced on site via sulfur burning plants, or purchased from smelters in Zambia's Copperbelt region. Now with the new plant, the Kansanshi operation is no longer constrained by limited acid capacity or fluctuating acid prices.

Construction of the Kansanshi new single-train 4,400 MTPD double absorption sulfuric acid plant.

Gas cleaning: a dual system

The design philosophy for the Kansanshi gas cleaning plant is to remove the impurities directly at the source of occurrence, rather than after mixing all of the off-gas sources. To that end, the core wet gas cleaning unit is specialized to treat two types of off-gas generated from the Kansanshi smelting operation: One type from an Isasmelt™ furnace and the other from Peirce-Smith converters (PSCs). The treatment technologies differ based on each gas type's distinct impurities. Isasmelt™ furnace gas contains condensable metal fumes, such as arsenic, selenium, lead or halides. Converter gas, however, contains mostly mechanically entrained solids. The initial impurity removal step is tailored to the composition of the off-gas, ensuring efficient and reliable gas cleaning at low operating and maintenance cost. Another feature of this approach is that copper-containing dust can be easily separated from the PSC scrubber and recycled back to the smelter facilities. Following the initial separate gas cleaning processes, the gases are then combined for further gas cleaning.

The experience of Outotec with similar plants was one of the key reasons FQM selected Outotec to engineer and supply the project, as per FQM officials.

Outotec's well proven gas-cleaning technology using high efficiency scrubbers on the Peirce-Smith converters and overall experience executing projects of this size were also important contributing factors.

The brick lined towers are equipped with Outotec's Film Distributor (FIDI™) to minimize acid entrainment and are constructed with Edmeston SX® material.

Cleaning Isasmelt™ off-gas (primary cleaning)

The gas from the Isasmelt™ furnace is cooled in a waste heat boiler and evaporative gas cooler, and then cleaned in a hot-ESP before entering a brick lined quench tower. In the quench tower, the gas is adiabatically cooled to below 80 degrees C and then directed to a variable throat scrubber to remove solids and condensed fumes by applying a high pressure drop at the variable throat. The variable throat is adjustable to keep a fixed pressure drop under all operating conditions and also to be able to adjust the pressure drop based on the required scrubbing efficiency. This scrubber is made entirely of high alloyed stainless steel.

Both quench tower and variable throat scrubbing stages are equipped with two operating and one standby weak acid circulating pump. The piping is arranged such that the operating pumps discharge into independent spray systems, so that they are fully redundant, while a single such circuit is sufficient for the cooling duty. Additionally, the quench tower has an independent emergency water system. The emergency water is supplied from a gravity head tank, so in case of a power failure, sufficient cooling is maintained while smelting is stopped to protect the downstream FRP equipment. Fig. 1 shows the independent pump systems.

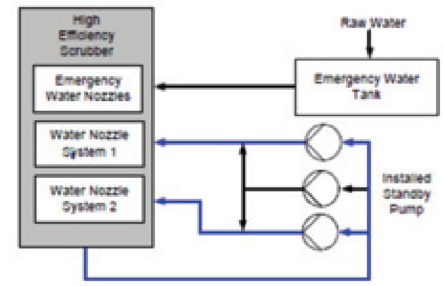

Fig. 1: Schematic of independent scrubber pump systems.

Leaving the scrubber, the gas is directed through a droplet separator to remove large entrained droplets. A wet ID-fan provides the necessary suction through the scrubber. This fan's speed is adjusted to control the gas pressure at the quench tower inlet.

Cleaning PCS off-gas (primary cleaning)

Off-gas from each individual Peirce-Smith Converter is cooled first in an evaporative spray chamber and then directed into a high efficiency scrubber with integrated upper quench section. The quench section is brick lined, while the lower variable throat scrubber section is made of high alloyed stainless steel, similar to the smelter scrubber.

Downstream of the scrubber, the gas route is identical to the smelter gas cleaning. The scrubber is followed by a droplet separator and a wet ID-fan. The PSC-Scrubber systems are equipped with settling tanks to allow copper dust from PSC off-gas to be recovered in a downstream filter plant.

Cleaning common gas (secondary cleaning)

After receiving their separate treatments, the PSC off-gas and the Isasmelt™ furnace off-gas are combined before entering two parallel packed gas cooling towers (PGCT), operated with weak acid to reduce the moisture content and remove halides. The circulating weak acid for each packed tower is cooled by two parallel plate heat exchangers, with a third heat exchanger installed as standby. Fig. 2 shows a schematic of the common gas cleaning system.

The gas is then finally cleaned by four trains of wet-ESPs, each with two ESPs in series. The casing and collection tubes are made of plastic, while all other internals are made of high alloyed stainless steel. No lead or leaded materials are applied. The clean gas is then directed into the drying tower of the sulfuric acid plant.

The acid plant offers more flexibility

The 3+1 double absorption acid plant design accommodates the fluctuating SO_2 concentrations and varying gas flows typically occurring in Kansanshi's smelting operation.

While the smelter is a constant strong gas source operating between 50-100 percent of its design load, the batch-operated Peirce-Smith Converters have two major modes: slag blow with weaker SO_2 off-gas and copper blow with a stronger off-gas. During a blowing cycle, the converters roll in and out several times for charging, skimming, adding reverts, etc. The Kansanshi acid plant is designed to treat the off-gas from the Isasmelt™ furnace plus up to two blowing PSCs.

Regarding flow rates, the acid plant is designed for minimum operation with one PSC on slag blow at 110,000 Nm^3/h (dry) with about 4.5 percent SO_2 by volume. The maximum design case is with the Isasmelt™ furnace on full load plus two PSCs on copper blow, resulting in up to 320,000 Nm^3/h (dry) with a SO_2 concentration of 13.0 percent SO_2 by volume.

Acid plant's catalytic section

Given variations in gas concentrations and flow, the catalytic section features two process gas coolers for the rejection of excess heat at times where the feed SO_2 concentration is high. At low SO_2 concentrations where no excess heat is to be rejected, all gas heat is kept within the catalytic section and consequently those gas coolers are bypassed. Fig. 3 shows the basic arrangement.

The two hot heat exchangers (hot and hot re-heat) are integrated inside the SO_2 converter to ensure uniform and radial gas distribution to all beds at all operating conditions and also to keep the catalyst at striking temperature during extended idle time or temporary shutdown of the plant. Both internal heat exchangers and the fully welded converter are made of stainless steel. Fig. 4 shows a section of the converter.

The design philosophy for the Kansanshi gas cleaning plant is to remove the impurities directly at the source of occurrence, rather than after mixing all of the off-gas sources. Pictured is the wet gas cleaning section.

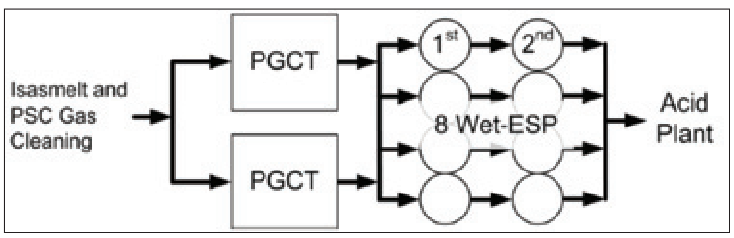

Fig. 2: Common gas cleaning system.

All external heat exchangers (cold heat and cold re-heat) are of the radially symmetric disc and doughnut type and made of carbon steel. The cold re-heat exchanger employs Outotec's horizontal stainless steel part (CORD™). This increases the temperature of the gas originating from the intermediate absorber by approximately 20 degrees C, which promotes conditions that help minimize corrosion. This ensures that no iron sulfate formation and subsequent plugging of the gas path can occur, which may occur due to potential carry over from the intermediate absorber.

Gas inlet temperatures to each bed are controlled by the addition of cold bypass gas and are kept constant at all operating conditions. With the large size of the plant vessels, the risk of uneven gas distribution and varying gas temperatures must be avoided. To ensure adequate gas mixing was achieved, Outotec's design phase included extensive CFD modeling to simulate gas mixing devices.

In a typical scenario, the first bed inlet temperature might contain a mixture of hot SO_2 gas leaving the hot heat exchanger (~460 degrees C) and the cold bypass (~100 degrees C). These gases must be mixed within a very short time to arrive at a uniform entry temperature to bed 1 catalyst of 400 degrees C. The location of the gas mixing device is depicted in Fig. 4.

The mixing device is shown in Fig. 5 along with the results of the CFD modeling showing that a good control temperature (400 +/- 5 degrees C) was achieved.

Treating off-gas from a single PSC on slag blow, with only ~4.5 SO_2 percent by volume, the plant would operate below the autothermal point and hence require energy input from the preheater. However, since this situation only occurs for a relatively short time, the acid plant can maintain acceptable catalyst temperatures, utilizing the thermal mass of the plant without using the preheater.

Two electrically driven SO_2 blowers operate in parallel. The blowers are equipped with inlet guide vanes for flow control. Also, a recycle line is installed from the blower discharge to the inlet of the drying tower so that the blowers can remain operating without rapidly cooling the catalyst during short periods where no gas is offered from the smelter. The recycle line also keeps the plant ready to receive off-gas at any time, rather than struggling with frequent stopping and starting of the large blower motors.

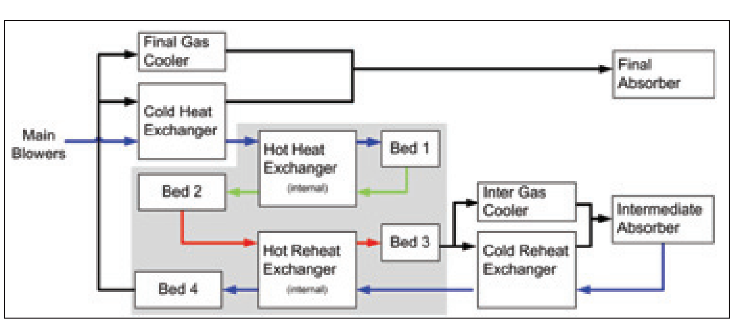

Fig: 3: Catalytic section of Kansanshi sulfuric acid plant.

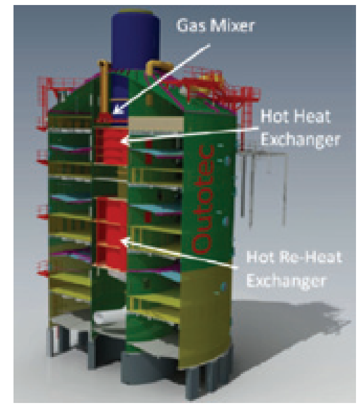

Fig. 4: SO_2 converter with integrated heat exchangers.

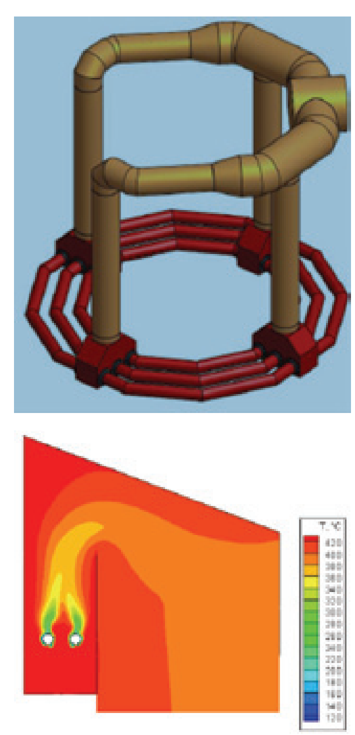

Fig. 5: Bed 1 by-pass mixing device (top) and CFD model showing proper temperatures achieved.

Acid plant's strong acid section

The strong acid section employs Outotec's flowsheet where both the intermediate and final absorber acid circuits are operated with a common pump tank, while the drying tower is equipped with a separate pump tank. The brick lined towers are equipped with Outotec's Film Distributor (FIDI™) to minimize acid entrainment. The distributors are made of Outotec's proprietary Edmeston SX® material. The acid temperature to the absorbers is controlled by means of an acid bypass around the coolers.

During periods where very low SO_2 concentration gas is processed for a longer time or while preheating, the water balance of the plant cannot be kept when producing 98.5 percent H_2SO_4. Increased flexibility is provided, therefore, by optionally exporting drying tower acid to the product acid tanks.

All acid coolers are shell and tube type with anodic protection. The absorber coolers operate in co-current flow while drying tower and product coolers are in counter current arrangement. All strong acid piping is made from Outotec's Edmeston SX® material.

Final product acid is stored in four 7,500-tonne storage tanks located south of the acid plant and then transferred a distance of 1.9 km to the existing Kansanshi mine storage tanks where it is used for leaching operations.

Training operations staff

Virtually all the operators had previous experience as operators in sulfuric acid plants either in KMP's own sulfur burning acid plants or from acid plants in the Zambian Copperbelt. However, many of the operators had experience only with sulfur burning acid plants and were unfamiliar with metallurgical acid plants, particularly with the gas cleaning systems.

Operator training began in October 2014, well in advance of the start-up. Training began with classroom sessions and presentations prepared by supervisory staff. After each classroom session a visit was made to the plant to view the equipment and system presented. In many cases the system was still under construction, which gave the operators an opportunity to see inside the equipment. Testing of the operators' comprehension and knowledge was done after each section to ensure that the key principles were understood.

Acid plant operators were also extensively involved during the commissioning of the acid plant as part of their hands on training.

Optimization through integration

Because smelters and acid plants are typically designed separately by different groups, their operations are often only loosely linked. KMP and Outotec recognized that the operation of the overall plant could be optimized by tightly integrating the sections. The key objectives of the integration were:

- Steady pressure control at the inlet of the gas cleaning plant, so that gas sources starting and stopping don't cause off-gas flow fluctuations for the other sources.
- Automation of dilution air control based on the calculated off-gas flows and compositions, to achieve steady SO_2 concentration at the acid plant converter.
- Automation of the starting and stopping of off-gas from each source, to minimize fugitive emissions.
- Ensuring the controlled shutdown of gas sources when acid plant upset conditions occur, minimizing the chance of fugitive emissions. Where possible, gas sources should stop prior to an acid plant trip, to avoid fugitive emissions.

Steady wet gas cleaning pressure control was achieved by implementing feed-forward control for each off-gas source. Feed-forward control is particularly important for the PSCs, which frequently start and stop generating off-gas. Control of SO_2 blower throughput (via IGVs and recycle line) and wet ID-fan throughput are automatically linked so that as the flow increases/decreases through the wet ID-fan, the SO_2 blowers automatically adjust without waiting for a change in gas cleaning pressure.

Gas cleaning section of Isasmelt™ off-gas.

Packed gas cooling towers with plate type weak acid coolers.

Dilution air is controlled automatically based on calculated dry flowrates and SO_2 content of each gas source. The dry flowrates are calculated using wet ID-fan power consumptions and off-gas temperatures. The SO_2 contents are calculated based on the concentrate composition and converter blowing rate (with different factors for slag and copper blows). Based on the input off-gas, the required dilution air flowrate is calculated. In addition to the automatic wet gas cleaning pressure control, and the sophisticated dilution air control system, sequences were implemented to enable easy starting and stopping of each off-gas source. The sequences allow an off-gas source to start (if the acid plant is ready for additional off-gas) or stop without operating intervention. The acid plant control room operator simply gives permission for each source to operate, and monitors the plant.

Typically the acid plant control system (software and safety systems) protects the acid plant during upset conditions by tripping the SO_2 blowers and/or wet ID-fans. For example, if the off-gas temperature leaving a wet gas scrubber is excessively high, the wet ID-fan will trip to prevent damage to the gas cleaning plant. Tripping the SO_2 blowers and/or wet ID-fans creates an emergency situation at the furnaces, as the generation of off-gas must cease immediately. In many situations the upset acid plant condition (which would lead to a SO_2 blower or ID-fan trip) can be avoided by stopping the off-gas flow. Although stopping the off-gas flow leads to short term production losses, avoiding emergency situations and keeping equipment running (i.e. avoiding trips) leads to faster restart times, and avoids the possibility of fugitive emissions. To ensure that the off-gas source is stopped before acid plant equipment trips, an extra control system alarm was implemented for critical parameters. For example, for a scrubber exit temperature, the following alarm levels were configured:

- High Alarm: trips an operator warning.
- High High Alarm: automatically stops the off-gas source. As the off-gas source is stopped before a loss of suction from the acid plant, a normal controlled shutdown can be performed, rather than an emergency shutdown.
- High High High Alarm: trips the wet ID-fan.

Successes and challenges

In contrast to many plants of its size, hot commissioning of the overall smelting operation took just two months. FQM officials credit excellent construction and equipment quality along with a well-trained workforce. Having the acid plant on site, cleaning gas at the source, was also instrumental to a quick start-up.

Having a tightly integrated smelting/gas-cleaning/acid system on site also ensures compliance with SO_2 emissions mitigation. In the unlikely event that the acid plant becomes unavailable, the smelter off-gas sources shut down automatically before any SO_2 emissions occur. In fact the overall smelter/acid plant operation has proven to be reliable enough that Kansanshi has mothballed its sulfur burning acid plants, relying only on the acid produced in the new plant to feed their oxide leach operation.

Naturally, the project was not without its challenges, principally time constraints and distance. An aggressive schedule meant pre-ordering materials, such as stainless steel, before equipment design was complete. Fortunately, Outotec's longstanding relationships with its manufacturing partners enabled a reduction in project duration of about three months.

Another hurdle involved moving equipment and supplies some 2,700 kilometers from the main supply harbor. The long travel distance was a major impact to the timetable, and costs were high because of transport restrictions. To offset these expenses, Outotec and FQM collaborated on optimizing the dimensions of prefabricated items to minimize the overall installed cost.

And then the usual technical issues came up during testing and commissioning. Fortunately none of these problems delayed commissioning or halted production later. Some of these include:

During cold commissioning with water, the header of the distributor pipe inside a packed gas cooling tower came apart. The failure was attributed to excessive water flow, due to oversized circulation pumps. The distributer was repaired and a valve adjusted on the pumps to restrict flow with reliable results. Parts of the distributer will be changed in the future, but the function of the cooling towers is not affected.

In testing wet-id fans and their associated droplet separators, the vanes of the droplet separator detached from their central hub. The failure was caused by a flow rate that was much higher than the design was meant to handle. The flow was generated because the ID fan's pressure drop was significantly lower in the test because the gas was taken through a nearby man hole rather than through the normal gas path. The normal gas route was isolated from the gas cleaning system because of preheating the brick work in the PSC. After identifying the cause, the flow was reduced to within actual operating conditions and the droplet separators worked normally.

During hot commissioning, distribution caps on cold bypass discharge nozzles caused excessive pressure drop in the cold bypass, restricting the cold gas flow, which resulted in an elevated bed 4 inlet temperature. The temperature to bed 4 could not be lowered even though the bypass was fully open. The solution identified is to open up the distribution caps to allow more gas flow.

Since hot commissioning last March, acid production at Kansanshi has been steadily increasing. Moving forward, the focus is to maintain optimal working order and continue with operating improvements. ❑