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Number 422

January | February 2026

SULPHUR

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Battery technologies and acid demand

Sulphuric acid catalyst

Zero emission sulphuric acid production

The sulphur market in deficit


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Middle East Sulphur

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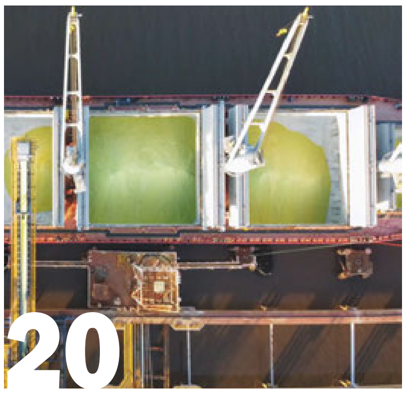
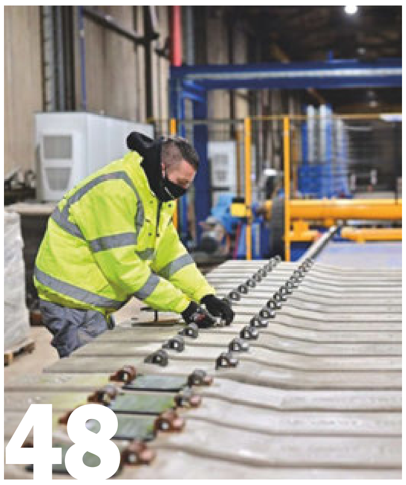
Cover: *Abstract Battery supply digital concept.*
Photo: MF3d/ istockphoto.com



Sulphur markets

Market tightness likely to continue.



Sulphur concrete sleepers

Thiotrack sleepers offer high fatigue endurance with a truly reversible circular binder.

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CRU

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REGULARS

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Melting sulphur

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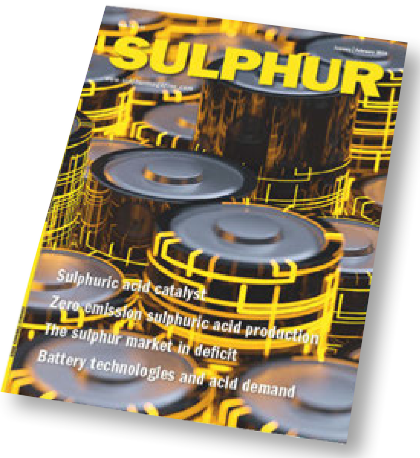
Melting sulphur



The deficit in the sulphur market has led to a new focus on melting down and selling stockpiles of sulphur around the world. From Kazakhstan to Canada, stocks of sulphur have been shrinking.

The sulphur market has always been a slightly strange one. Since the 1990s, supply has been almost completely from involuntary sources, primarily oil refining and sour gas processing, and so has been the main alternative source of sulphuric acid – metal smelting. In few cases is the sale of sulphur or sulphuric acid a key determinant of whether a project proceeds or continues to operate. Conversely, demand, dominated by the fertilizer industry, has been to a large extent dependant on sulphur prices being relatively low – high sulphur prices lead to lower use of phosphates by farmers, which helps balance the market. Logistical constraints tend to determine which sulphur gets to market, and where there is a surplus, stocks build up. These stocks can then be sold when prices are higher, during times of shortage, but with a wrinkle – where the stocks exist as piles of formed sulphur, it is relatively quick and easy to access them. Sulphur stored over long periods, however, especially block sulphur, must be remelted, requiring energy inputs which influence the cost, and leading to a delay in responding to market signals - one must be sure that prices will remain elevated for a significant period to start melting down a sulphur block. This leads to a degree of delay and inelasticity in the market which can lead to price spikes. And, as we note in our articles in this issue, phosphates are no longer the dominant factor in new sulphur demand – battery metals processing is surpassing them in terms of incremental demand, and the price response of battery producers is quite different from fertilizer producers.

> **"From Kazakhstan to Canada, stocks of sulphur have been shrinking..."**

Overall sulphur demand overtook global production during 2024, and the shortfall was made up for with a drawdown of stocks, primarily in Kazakhstan and Saudi Arabia. Kazakhstan operators face persistent pressure from government to reduce stocks, and in fact had been drawing down stocks since 2023, but in 2024 this accelerated considerably, with more than 1 million tonnes of stock sold. From 2023 to mid-2025, Kazakhstan sold an additional 1.7 million tonnes of sulphur, keeping global prices relatively on an even keel when combined with additional stock sales from Saudi Arabia. Kazakh stocks are, however, now largely depleted.

In 2025, Canada also moved to destocking, and this will continue this year. The increase in remelting capacity at the Heartland Sulphur forming unit from 700 t/d to 1,700 t/d is a symptom of this. Other stocks are likely to come from Turkmenistan and potentially even Iran. Set against this, Chinese port stocks have remained relatively high, and generally above 2 million tonnes, though there are some signs of a draw down of these as sulphur prices have climbed and with continuing restrictions on phosphate exports.

Overall, relief is not expected until the start up of large sour gas projects in the Middle East from around 2027, and it is therefore estimated that over the period 2024-2028, around 4.1 million tonnes of sulphur will have to be drawn from stocks to keep the market supplied. At present, global sulphur stocks remain relatively high at around 32 million tonnes, around one third of this in Canada, and this is not a problematic situation. However, as battery use increases and fossil fuel use decreases, this cushion could find itself being eaten away over the longer term, and the sulphur industry may need to start considering what will happen when the stockpiles start to run dry.

Richard Hands, Editor

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Price Trends

SULPHUR

The global sulphur market's bullish momentum from late 2025 has firmly carried over into the New Year, with prices pushing forward across most key regions despite a slow return to spot trading after the holiday break. With spot prices now past their 2022 highs and testing levels not seen since the 2008 peak, affordability has become the market's central theme. The market remains divergent, with some buyers forced to accept the rally due to tight supply, while others, particularly in China, are showing clear signs of demand destruction.

The upward trend was largely driven by the official confirmation of higher forward prices from Middle Eastern producers. This firming price environment has also set a tense backdrop for Q1 contract negotiations, which are still under discussion in key markets. The Middle East market concluded 2025 on a powerful note, with spot prices reaching a 17-year high of $505-525/t f.o.b. after climbing 200% over the year. The latest monthly prices from the Middle East have maintained the market's bullish sentiment, with leading producers announcing increases of $21-25/t, a more moderate hike compared to the steep $80-95/t jump recorded from November to December. The move, which was widely anticipated, brings Adnoc's price to $520/t f.o.b.,,Qatar's QSP to $517/t, and KPC's to $516/t. These hikes reflect the significant run-up in spot prices that occurred throughout December. While no new spot sales were confirmed from the region, these f.o.b. levels were supported by notional netbacks from prevailing prices in India and Brazil.

It has been confirmed that the supply constraints from Russia will now extend further into 2026, following the government's decision to extend its ban on technical sulphur exports until the end of March. The move, which was largely expected by the market, removes any prospect of Russian export volumes returning in the first quarter, maintaining a key pillar of support for global prices. The initial ban, which followed drone strikes on key gas plants in September, had already turned Russia into a net importer in late 2025. While the extension is bullish, the confirmation that transit volumes from Kazakhstan are unaffected prevents a wider supply disruption. In contrast, the supply picture is improving in Iran, where an easing of regional tensions has improved the logistical situation, allowing both domestic exports and previously constrained Turkmen transit volumes to return to the market.

The Chinese sulphur market is now being dictated by a new domestic price control policy. State-owned refineries have begun supplying core phosphate producers with sulphur at a significantly reduced price of around RMB2,000/t ex-works, which reflects a three-year historical average. While phosphate producers are maintaining stable operating rates to ensure domestic supply, their need for expensive seaborne cargoes has evaporated in the short term. This provides them with a temporary shield from high international prices, allowing them to delay spot purchases and wait for a market correction.

Bullish sentiment returned to the Chinese market with force after the holidays. Delivered c.fr prices firmed to $520-530/t, supported by a pre-holiday Canadian cargo sale and the new Middle East postings. The key driver, however, was a significant drop in port inventories, which fell to their lowest level since May 2025 at 1.95 million tonnes. This tightening domestic supply, combined with a two-tier pricing system where many buyers must compete for high-priced spot cargoes, has underpinned the market's strength. Although deals were concluded in the high $520-530s/t in late December, buying interest has remained slow, leaving the last formal assessment at $510-515/t c.fr. Chinese spot prices are forecast to peak in January at $533/t c.fr before declining steadily to bottom out at $298/t c.fr in October, followed by a slight recovery to $310/t c.fr by the end of the year.

Vancouver prices ended 2025 at a multi-year high of $485-495/t f.o.b., supported by firm netbacks from Brazil as Chinese demand remains limited. This price surpasses the 2022 peak but is still well below the 2008 record. Negotiations for quarterly liquid sulphur contracts in Tampa for Q1 2026 were not yet concluded at time of writing. Broader market chatter has recently coalesced around $475–520/t f.o.b. Tampa for Q1, though no settlement has been

Price Indications

Table 1: **Recent sulphur prices, major markets**

Cash equivalent	August	September	October	November	December
Sulphur, bulk ($/t)					
Adnoc monthly contract	265	285	324	415	495
China c.fr spot	285	334	415	478	513
Liquid sulphur ($/t)					
Tampa f.o.b. contract	252	252	310	310	310
NW Europe c.fr	290	290	340	340	340
Sulphuric acid ($/t)					
US Gulf spot	163	120	128	135	145

Source: various

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reached. Downstream affordability has been a key focus given firmer sulphur values versus softer fertilizer pricing. DAP has retreated from earlier highs, increasing buyer sensitivity to feedstock costs and tightening margin headroom for phosphate producers.

Market participants also pointed to recent Brazilian developments as an example of downstream margin pressure amid higher sulphur costs. Mosaic said in December it was idling SSP production at its Fospar and Araxá facilities and suspending future sulphur purchases following a sharp rise in sulphur prices. Brazil c.fr prices finished 2025 at an average of $535/t.

Indonesia's sulphur imports have continued at a record-breaking pace, surging 42% year on year to reach 4.8 million t/a in the first eleven months of 2025, according to Global Trade Tracker (GTT) data. This is up from 3.4 million t/a in the same period of 2024.

SULPHURIC ACID

Prices for global sulphuric acid pushed higher at the start of 2026, as the market's bullish underlying tone overshadowed a slow return to spot trading after the holidays. This upward momentum was driven not by a surge in new spot demand but by the inclusion of firmer forward-month indications in pricing windows and by tight supply fundamentals in key export hubs.

The clearest driver was Northwest Europe, where prices firmed to $110-120/t f.o.b. This was supported by an active forward market, with sources indicating a few deals for February loading have already been concluded at the $120/t f.o.b. level, confirming the market's upward trajectory. This strength in Europe directly rippled across the Atlantic. The US Gulf assessment also firmed to $140-155/t c.fr, with delivered cost calculations from Europe supporting the increase.

In Chile, the market's upward shift was clear. Annual contract talks are reportedly wrapping up in the $162-175/t c.fr range, a significant increase from last year, though these numbers are not yet formally assessed. In the spot market, while quiet, notional ideas have jumped to $180-195/t c.fr, tracking higher European f.o.b. prices, which have become a more competitive supply source.

In Brazil, prices rose to $160-165/t c.fr, finding support from a firm tender award in neighbouring Argentina, which set a strong regional benchmark in recent weeks. Brazil's sulphuric acid imports contracted by 2% in 2025, with full-year arrivals totalling 540,479 tonnes, according to Global Trade Tracker (GTT) data. Spain solidified its position as the top supplier, with its shipments growing 22% year on year to 201,183 t. In contrast, volumes from the second-largest supplier, Belgium, fell by 31% to 86,811 t.

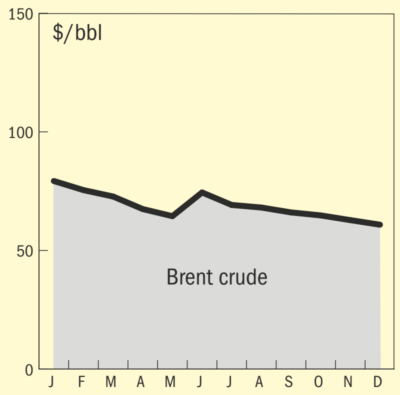
The Chinese sulphuric acid market was thrown into significant uncertainty in December following a series of conflicting government interventions. An initial halt on phosphate fertilizer exports prompted acid producers to sell out Q1 availability and raise offers to high levels of $140-160/t f.o.b. However, a subsequent government directive instructed producers to cap prices at early December levels and prioritise domestic supply. This created a wide gap between unworkable producer offers and market reality, effectively paralysing the export market as participants await clarity. This policy confusion represents the primary upside risk to the forecast, as the true volume of available Chinese exports for 2026 remains uncertain. Export assessments for both China and Japan/South Korea rose by $5/t, reflecting the inclusion of higher-priced February indications. The underlying supply in Asia remains tight; South Korean producers are reportedly sold out on contract, Japanese suppliers are holding back offers amid production uncertainty, and the Chinese market is paralysed by a standoff between high producer offers at $140-160/t f.o.b. and a lack of buying interest.

As a result, market participants report that most available spot cargoes are now in the hands of traders. Looking ahead, traders expect more offers to begin emerging for March-April loading. A 20,000 t sale to India from South Korea was reported at $148/t c.fr for early March delivery.

This buyer-seller impasse was most evident in India, where prices held stable at $145-155/t c.fr as the market stalled. Traders need $150-160/t c.fr to cover high sulphur costs, but importers are resisting any level above $150/t, freezing spot activity and forcing a reliance on inventories. ■

END OF MONTH SPOT PRICES

oil



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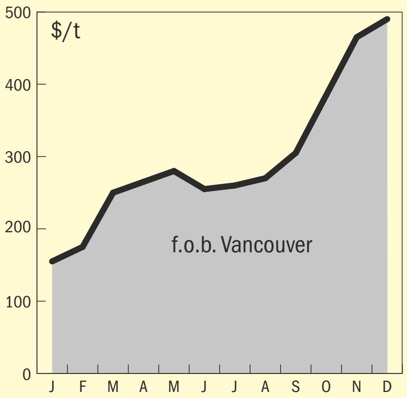

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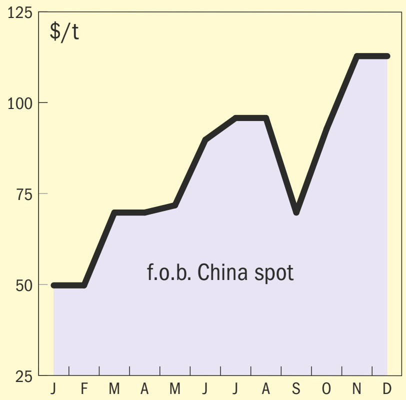
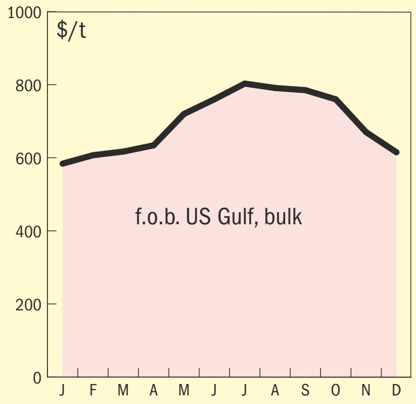


diammonium phosphate



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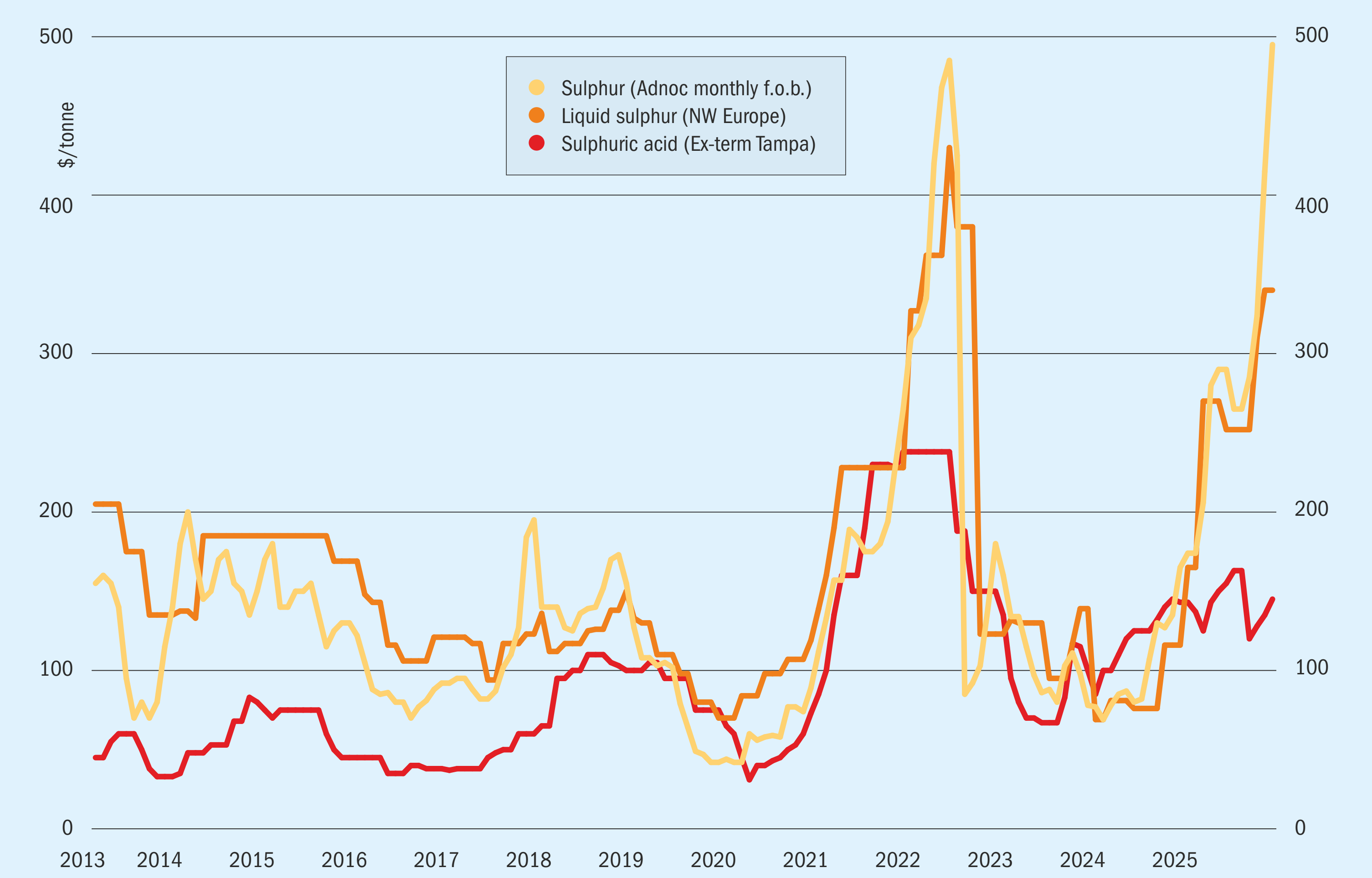
Market Outlook

Historical price trends $/tonne



Source: CRU

SULPHUR

- CRU's latest global sulphur forecast is for a January price peak before a decline, with the key downside risk being a sharper correction if the supply deficit closes faster than expected. The global sulphur market's upward momentum has been slowing, with attention shifting to geopolitical risks in Iran. Despite limited physical disruption being reported, the upside risk to prices could be substantial. Following the US bombing of an Iranian nuclear facility back in June, supply from Iran became bottlenecked, despite good production levels, as vessel owners became unwilling to call at ports like Bandar Abbas due to the increased risk.
- More political risk emerged on 12 January when the Trump administration threatened a 25% tariff on goods from any nation with commercial ties to Iran. This is creating uncertainty for key sulphur buyers, who may now hesitate to commit to future cargoes, such as China and India.
- Otherwise, markets have quietened in Brazil and the Middle East, where the market's attention was captured by the unusual absence of a February spot tender from QatarEnergy.
- In China, bullish sentiment is strong, fuelled by rising domestic prices and geopolitical tensions. However, with international offers climbing to $560-570/t c.fr, buyers are resisting fresh purchases and drawing down port inventories.

SULPHURIC ACID

- CRU's latest forecast suggests sulphuric acid prices will peak in January before trending lower for the remainder of the year, with the primary upside risk remaining expectations that Chinese government policy will cap January-April exports at 50% of last year's volumes, compounding existing tightness in the region. This has created major uncertainty over whether prior term contract commitments will be honoured, let alone if any spot volume will be available. This situation is amplified by ongoing tightness in Japan and South Korea, which has lifted the regional FOB assessment to $110-120/t this week.
- This supply-side concern has overshadowed quiet spot activity in most markets, with the exception of a burst of buying from Indonesia. In Europe, underlying momentum remains bullish, underpinned by a tight supply situation in the region. In turn, this strength in European f.o.b. prices has lent clear support to delivered prices in key import markets such as Chile and the US Gulf.
- In contrast to quiet spot activity elsewhere, Indonesia has emerged as a demand hot spot. The recent issuance of import licenses has reportedly triggered a wave of buying, with prices reported in the $145-155/t c.fr range.
- On the contract front, negotiations are drawing to a close, with assessments yet to be updated. In Chile, annual 2026 contracts are understood to be largely concluded, with market indications pointing to a range of $162-175/t c.fr.

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Sulphur Industry News

RUSSIA

Sulphur ban extended

At the end of December, the Russian government extended its ban on the export of technical sulphur until at least the end of March 2026. The move prolongs the initial restrictions, which were first reported on 4 November and which were set to expire at the end of 2025. The initial ban was widely expected and followed early September drone strikes on the Astrakhan and Orenburg natural-gas plants. The official justification for the extension remains to "stabilise shipments of raw materials to the domestic market" and maintain production volumes for mineral fertilizers, according to the government's press service Interfax.

The restrictions apply to liquid, granulated, and lump sulphur. A number of exemptions to the ban remain in place. Deliveries to fellow Eurasian Economic Union (EAEU) members, Abkhazia, and South Ossetia are still permitted. The decree also clarifies that the restrictions do not apply to humanitarian aid, international transit shipments, or supplies for Russian operations on the Svalbard archipelago. Crucially, the specific exemption for international transit means that shipments of material from other origins, such as Kazakhstan, passing through Russian ports, have not been affected by the ban. ■

GERMANY

DOMO files for insolvency

Three German subsidiaries of the Belgian chemical group DOMO Chemicals have filed for insolvency, following weak demand in the European chemicals sector, high energy costs and a significant increase in imports of polyamide resins from outside the European Union, in particular from China. Court appointed administrator Prof. Lucas F. Flöther said that day-to-day operations would continue for the time being. Around 585 employees are affected across the three companies; DOMO Chemicals GmbH and DOMO Caproleuna GmbH in Leuna and DOMO Engineering Plastics GmbH in Premnitz.

The DOMO Group, headquartered in Ghent, Belgium, manufactures and markets polymers, engineering plastics and high-performance fibres. It produces ammonium sulphate from caprolactam at DOMO Caproleuna with 420,000 t/a of AS capacity and sulphur consumption of up to 100,000 t/a. DOMO had already been running at reduced capacity, so the loss of AS supply and sulphur demand will be less but may still represent a significant shift if it does fully shut down.

CANADA

Capacity increase at Heartland Sulphur

Heartland Sulphur says that it has debottlenecked its crushed bulk sulphur remelting operations, increasing capacity by 40%. Heartland says that the increase boosts the company's sulphur handling efficiency and service capability for producers and buyers. It has also completed a full feasibility study and retained engineering partners to add an additional 1,000 t/d of sulphur remelt capacity, slated to be fully operational by year-end 2026. Heartland Sulphur can form 4,500 t/d for offshore markets, transport molten sulphur by tank car to destinations across North America, and accept and condition sulphur in both molten and solid states. The company's existing remelt capacity stands at 700 t/d and is projected to reach a total of 1,700 t/d (560,000 t/a) by the end of 2026.

ROMANIA

SRU commissioned at Petrobrazi refinery

Romanian oil and gas group OMV Petrom has commissioned a new sulphur recovery unit at its Petrobrazi refinery, near the southern city of Ploiesti. Development work on the new SRU began in 2023, and represents the second at the site, treating acid gas produced during the refining process. The euro 45 million investment is part of euro 2 billion of improvements that have been made over the past 20 years as part of the company's strategy to modernise its refining capabilities, aiming to reduce environmental impact. Last year, the company said it would invest around euro 750 million to build several sustainable fuel plants at the refinery, which are expected to become operational in 2028.

"This 45 million euro investment marks an important step in reducing emissions and improving operational adaptability. We delivered the project safely and efficiently. The new unit allows Petrobrazi to process a wider range of crude oils," said Radu Caprau, member of OMV Petrom's Executive Board, responsible for Refining and Marketing.

PHOTO: OMV PETROM

The Petrobrazi refinery, Ploiesti.

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AUSTRALIA

Low sulphur refinery upgrade for Viva Energy

Viva Energy has commissioned a new ultra-low sulphur gasoline (ULSG) plant at its Geelong refinery to meet Australia's updated fuel standards, which came into effect on December 15. Under the standards, all gasoline grades must contain a maximum of 10 parts per million (ppm) sulphur, a so-called Euro-V standard. The ULSG plant was officially opened by the Minister for Climate Change and Energy, Chris Bowen MP, alongside Viva Energy Chairman Robert Hill and CEO Scott Wyatt.

Speaking at the commissioning ceremony, Wyatt said the project was a major milestone for the refinery. "This investment not only keeps local manufacturing thriving but also enables us to produce the cleanest petrol we've ever manufactured in Australia, reducing vehicle emissions and supporting the latest in vehicle technology. We are proud to play a leading role in ensuring Australia's energy security and contributing to a cleaner environment for future generations."

The project was part of an A$400 million refinery upgrade over a 27-month period. Sulphur removed during the process is converted to elemental sulphur and sold for use in fertiliser products for the Australian agricultural market.

UNITED ARAB EMIRATES

Financing in place for Hail and Ghasha

The Abu Dhabi National Oil Company (ADNOC), working in partnership with Italy's Eni and Thailand's PTT Exploration and Production, has completed a structured financing transaction of up to $11 billion for its huge Hail and Ghasha sour gas development. Dr. Sultan Ahmed Al Jaber, UAE's Minister of Industry and Advanced Technology and ADNOC's Managing Director and Group CEO, commented: "This landmark transaction builds on ADNOC's successful track record of global energy partnerships and unlocks capital to drive progress at Hail and Ghasha, one of the world's most ambitious offshore gas projects. The exceptional demand from over 20 leading global and regional financial institutions reinforces confidence in ADNOC's value creation strategy, innovative approach to financing, and expertise in delivering mega projects. Hail and Ghasha is an important contributor to ADNOC's gas strategy and is on track to generate significant value for ADNOC, our partners, and the UAE, while unlocking important new gas resources for our customers."

Chinese lenders Industrial and Commercial Bank of China, Agricultural Bank of China and Bank of China were part of the deal, which also saw participation from seven local banks. Funds from the deal will be available in "staggered phases" to help build gas processing plants, which would include sulphur separators for the ultra-sour gas concessions.

The Hail and Ghasha concessions are expected to produce up to 1.8 billion scf/d of gas, with first gas from the project expected by the end of the decade. It is described as the world's first offshore gas project of its kind that aims to operate with net zero emissions, capturing 1.5 million t/a of carbon dioxide (CO_2). ■

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Sulphuric Acid News

NAMIBIA

First production from Kamoa-Kakula smelter

Ivanhoe Mines says that the first copper anodes were produced by Kamoa-Kakula's 500,000 t/a direct-to-blister copper smelter on December 29, 2025, approximately five weeks after the commencement of the smelter's heat-up and one week after the first feed of concentrate.

Ivanhoe Mines' Founder and Executive Co-Chairman Robert Friedland commented: "The first production of copper anodes from our world-class smelter is a defining moment for Kamoa-Kakula... This achievement is the culmination of a $1.1 billion investment, 18 million man-hours of disciplined execution, and an outstanding health and safety record that reflects the professionalism and commitment of everyone involved. This facility will proudly deliver the highest-quality Congolese copper anodes to the international markets, setting a new global benchmark for scale, efficiency, and sustainability. I want to extend my sincere thanks to the extraordinary Kamoa Copper team, as well as our contractors and partners from across the world whose expertise, innovation, and teamwork made the design and delivery of this state-of-the-art facility possible. Together, we have built something exceptional that will serve global consumers for generations to come."

The Kamoa-Kakula copper smelter, Namibia.

PHOTO: KAMOA COPPER SA

Smelter ramp-up is under way to achieve a steady-state rate of 500,000 t/a of 99.7%-pure copper anode, making it the largest copper smelter in Africa, and will continue throughout 2026, with completion expected towards year-end. Kamoa-Kakula's copper production is estimated at between 380-420,000 t/a of copper in 2026, with the mid-point of 400,000 t/a of copper representing approximately 80% of the smelter's total capacity. Kamoa-Kakula's operating margins are set to expand due to reduced logistics costs from the smelter, as well as sales of by-product sulphuric acid. The smelter is expected to produce up to 700,000 t/a of high-strength sulphuric acid at steady-state operations, which will be sold locally. Sulphuric acid is in high demand by other mining operations across the Central African copper belt, especially following the export ban of acid by Zambia in September 2025. Spot acid prices have reached as high as $700/t in Kolwezi in recent months. The first sale of acid by Kamoa-Kakula has already taken place, with the first delivery expected in the coming weeks. ■

UZBEKISTAN

Metso books third part of Almalyk order

Metso has booked the third part of its order for JSC Almalyk Mining and Metallurgical Complex's copper smelter project based on the equipment and project services delivery contracts announced on August 9, 2024. The first parts of the order, worth €146 million were booked in 4Q 2024, and the second part, worth €50 million in 1Q 2025. The order value recorded in 4Q 2025 is €70 million.

Almalyk MMC is the main copper producer in Uzbekistan. The company produces refined copper, gold, silver, zinc, molybdenum, lead concentrate, and other products. Metso's scope of delivery to Almalyk MMC's new copper smelter complex includes flash smelting and flash converting, gas cleaning, and sulphuric acid production technologies. The planned production capacity of the new copper smelter, which will be integrated with the company's existing operations in Almalyk, is 300,000 t/a of copper cathodes and 1.8 million t/a of sulphuric acid. Metso's scope of delivery includes flash smelting and flash converting, gas cleaning and sulphuric acid production technologies.

IRAQ

New phosphate project

Iraq's Ministry of Industry and Minerals confirmed on Wednesday its intention to proceed with the construction of a new phosphate plant in Al-Qaim district, Anbar province, to use 10 billion tonnes of phosphate reserves. The ministry also revealed the expected production volume and the total value of the project. Ministry spokesperson, Duha Al-Jubouri, told the Iraqi News Agency (INA): "This project aims to revive this sector after the near-total destruction of the phosphate plant due to terrorist operations." She explained that "the project is being implemented in partnership with the private sector and is considered one of the mega-projects that reflects the significant potential Iraq possesses."

Al-Jubouri added that the project's production capacity will be 500,000 t/a of triple superphosphate (TSP) fertilizer and 1.0 million t/a of diammonium phosphate (DAP) fertilizer. She explained that "the project is based on strategic assets, as the western Anbar desert contains one of the largest phosphate reserves in the world, estimated at about 10 billion tons," noting that "the total cost of the project is about $2 billion."

CANADA

Arianne to receive government support

Arianne Phosphate says that the government of Canada has approved contribution funding of up to C$735,000 to support the company's ongoing work on processing phosphate rock and optimising its purified phosphoric acid (PPA) process. The funding, provided through Natural Resources Canada's Critical Minerals Research, Development and Demonstration programme, is part of a C$80.3 million investment announced by Prime Minister Mark Carney to help build secure critical minerals supply chains

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in Canada. Phosphate was added to the Canadian critical mineral list in 2024. Arianne's Lac à Paul project is the only fully permitted phosphate mine in the country. Arianne is now actively pursuing opportunities for the downstream production of PPA, a necessary ingredient for lithium-iron-phosphate batteries.

"Investing in initiatives like Arianne Phosphate's Technology Centre reinforces Canada's position as a global leader in critical minerals. This commitment drives innovation, strengthens supply chain resilience, and creates good jobs for Canadians," said Tim Hodgson, Minister of Energy and Natural Resources. "By harnessing our natural resources responsibly, we are ensuring Canada remains at the forefront of the clean technology transition—advancing the priorities we set with our G7 partners in Kananaskis and building a cleaner, more secure future for all."

UNITED STATES

Mixed smelter for Tennessee

Korea Zinc says it will partner with the US government to construct a critical minerals smelter in Clarksville, Tennessee, producing zinc, lead, and copper. Korea Zinc will begin site preparation next year, followed by phased commercial operations from 2029. The plant is planned to process around 1.0 million t/a of raw materials and turn out 540,000 st/a of finished products. Processing of gold, silver, and key strategic minerals such as antimony, indium, bismuth, tellurium, cadmium, palladium, gallium and germanium, are also planned in what is being touted as a "state-of-the-art" facility. Sulphuric acid and semiconductor-grade sulphuric acid will also be produced. The output will include 300,000 t/a of zinc production, 200,000 t/a of lead, 35,000 t/a of copper and 5,100 t/a of rare and strategic metals. Development will be through Korea Zinc's US subsidiary, Crucible Metals.

Core capex is put at $6.6 billion, plus $800 million in working capital and financing costs, giving a total of $7.4 billion. The US Department of War is conditionally investing $1.4 billion in the project and arranging around $2.15 billion of smelter construction costs with investors. The new unit's design will be based on Korea Zinc's Onsan smelter in Ulsan, South Korea. The project is also backed by the US Department of Commerce. The US will also have preferred access to a portion of Korea Zinc's expanded production in South Korea, US Secretary of State for Commerce Howard Lutnick said.

"Establishing a production base in the United States, where investment, regulatory and policy predictability are high, is expected to effectively transform geopolitical volatility, export restrictions and logistics disruptions into strategic opportunities," Korea Zinc said, adding that sourcing raw materials and scrap directly from the US will diversify the global supply chain and enable more flexible corporate responses.

CRU assesses that even if the construction of the smelter were to go ahead, imports from neighbouring countries Canada and Mexico, which typically provide around 70% of the imports into the country, would not be significantly impacted. Still, imports from countries further afield, such as Peru, Australia, Spain, and South Korea itself, may experience reduced demand for refined zinc in the US in the future. The potential new Korea Zinc smelter would also have an interesting impact on the zinc concentrates market. CRU assesses that there are only 3-7 years' worth of reserves left at the East Tennessee and Middle Tennessee mines, and even before they close, the new zinc smelter might only be able to obtain just one third of its raw material feed requirement from these mines. Korea Zinc will be heavily reliant on the custom market for concentrate feed and will seek to source material from nearby mines, likely including Teck Resources' Red Dog mine in the US.

Acid leak into ship canal

Around 1 million gallons of sulphuric acid was released from an industrial facility, some of it into the Houston Ship Channel, in late December. A pipeline ruptured when an elevated walkway collapsed at the BWC Terminals facility in Channelview, east of Houston. Two people were transported to a hospital and subsequently released, while 44 others were treated and released at the scene. BWC Terminals said in a statement the majority of the sulphuric acid released was into a designated containment area, with a smaller, unknown amount entering the ship channel.

Ecovyst sells AMC to Technip

Ecovyst Inc, a provider of sulphuric acid, sulphuric acid regeneration services and catalyst activation services, has announced today that it has completed the sale of its Advanced Materials & Catalysts segment to Technip Energies. The company expects net proceeds after taxes and transaction expenses to be approximately $530 million.

"We believe the sale of our Advanced Materials & Catalysts segment creates significant value for our stockholders by allowing us to realize the intrinsic value of the business," said Kurt J. Bitting, Ecovyst's Chief Executive Officer. "Net proceeds from the sale will provide for significantly reduced leverage and enhanced financial flexibility that we believe will support the implementation of our growth strategies as well as the active return of capital to stockholders through our existing stock repurchase authorisation," added Bitting. "We want to thank the Advanced Materials & Catalysts team for their valued contributions to Ecovyst, and we wish them continued success as part of Technip Energies."

Arnaud Pieton, CEO of Technip Energies, commented: "Closing this transaction is an important milestone in the evolution of Technip Energies. With Advanced Materials & Catalysts, we are combining a differentiated catalysts and advanced materials platform with our process technologies and engineering expertise, creating an integrated offering that helps our customers to improve efficiency, reliability and emissions performance across their assets. We are very happy to welcome Advanced Materials & Catalysts teams and look forward to working together to deliver the next phase of growth for our customers and stakeholders."

NEW ZEALAND

Chatham Rock Phosphate sells Australian subsidiary

Chatham Rock Phosphate has agreed to sell its wholly-owned Australian subsidiary Avenir Makatea Pty Ltd to Austure Industries Pty Ltd for A$1.4 million, including A$900,000 in cash over a 24-month period, and a 20% shareholding in Austure Phosphate AU Pty Ltd, a newly-formed subsidiary of Austure, to establish a mono- and dicalcium phosphate manufacturing plant in Cloncurry. Colin Randall, Chatham Executive Director has been appointed a Director of Austure Phosphate AU Pty Ltd.

This agreement provides the Korella North mine with a local market for its mined rock phosphate which will be supplied to the DCP/MCP manufacturing plant. Austure Industries Pty Ltd has developed a

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technology that enables a manufacturing plant to produce both dicalcium phosphate (DCP) and monocalcium phosphate (MCP). Australia imports all of the estimated 100,000 t/a of DCP/MCP/MDCP for use as supplements and in feed rations for cattle, pigs and broiler chickens.

Ma'aden's phosphate complex, Saudi Arabia.

PHOTO: MA'ADEN PHOSPHATE COMPANY

SAUDI ARABIA

Feedstock allocation for fourth phosphate plant

The Saudi Arabian Mining Company (Ma'aden) says that the Ministry of Energy has approved the allocation of feedstock for its fourth phosphate project. This project aims to produce approximately 1.1 million t/a of ammonia and increase the production of phosphate and specialty fertilizers by about 2.5 million t/a, raising the company's total production capacity to nearly 12 million t/a. This will further solidify Ma'aden's position as one of the world's largest producers of phosphate fertilizers, according to a company statement. Ma'aden will now commence engineering studies and obtain the necessary approvals.

ASIA

Metso to supply copper smelter

Metso says it has won a €180 million order for the delivery of engineering and key process equipment for a new primary copper smelter investment at an undisclosed location in Asia. The planned production capacity of the copper smelter complex is 300,000 t/a of copper cathodes and 1.1 million t/a of sulphuric acid, based on licensed Outotec® Flash Smelting, PS Converting and Lurec® technologies. It includes the design and supply of key process equipment for the main areas of the smelter complex, and the gas cleaning and sulphuric acid plant, copper electrolytic refinery, and precious metals refinery. The delivery also comprises site services and spares.

MOROCCO

Safi floods likely to impact phosphate supply from OCP

Flash floods in the Moroccan port city of Safi killed at least 37 people in December and injured many others, with knock on effects also likely to impact exports from phosphate producer OCP. Jorf Lasfar is the phosphate giant's main export hub for phosphate fertilizers and phosphoric acid, while Safi exports smaller volumes of phosphoric acid, TSP and animal feed products. Phosphate rock exports are largely concentrated at the port of Casablanca further north. OCP produces around 420,000 t/a triple superphosphate and 1.63 t/a phosphoric acid at Safi, as well as around 62,000 t/a dicalcium phosphate and 70,000 t/a monocalcium phosphate.

INDIA

Approval for phosphate expansion

Madhya Bharat Agro Products has announced board approval for a major capacity expansion at its Dhule manufacturing facility. The expansion represents a comprehensive enhancement of the company's fertilizer production capabilities, including 330,000 t/a of diammonium phosphate and NPK fertilizer, a 66,000 t/a phosphoric acid plant, and a 396,000 t/a sulphuric acid plant. The expansion plan is part of a strategy of vertical integration in fertilizer production. The addition of phosphoric acid and sulphuric acid production capabilities will support the primary DAP/NPK manufacturing operations, creating operational synergies and potentially reducing input costs, according to the company.

BRAZIL

Mosaic suspends Brazil SSP production as sulphur surges

Mosaic has started activities to idle single super phosphate (SSP) production at its Fospar and Araxá facilities in Brazil due to the recent sharp increase in sulphur prices, the company said 16 December. The company said it has also suspended future purchases of sulphur, and it may review these decisions after 30 days. Sulphur spot prices in Brazil were assessed by CRU at $515/t c.fr at the time, representing the highest level since June 2022, and a staggering 180% increase from the figure of $182/t c.fr at the start of 2025. Prices for SSP, however, have been relatively stable, with only slight increases in recent weeks. CRU's assessment for 18-20% SSP was at $200-245/t c.fr Brazil in December, up from $190-240/t in November, though it remains below the $230-265/t of June.

SYRIA

Syria restarts Sharqiya phosphate washing and drying plant

Syria restarted a phosphate production site in Homs province after a decade-long shutdown, according to local media reports 25 November. The washing and drying facility is part of Syria's Al-Sharqiya mine. The Syrian government has indicated that it plans to increase its presence in global phosphates market as part of efforts to support the country's economy.

"I am pleased to announce today the Phosphate Wash and Drying Lab has reopened after a ten year hiatus," Syria's energy minister Mohammed al-Bashir said on his Facebook account. "This achievement comes to constitute a strategic step in boosting and improving phosphate production, opening up broad horizons for global markets and strengthening the status of the national economy."

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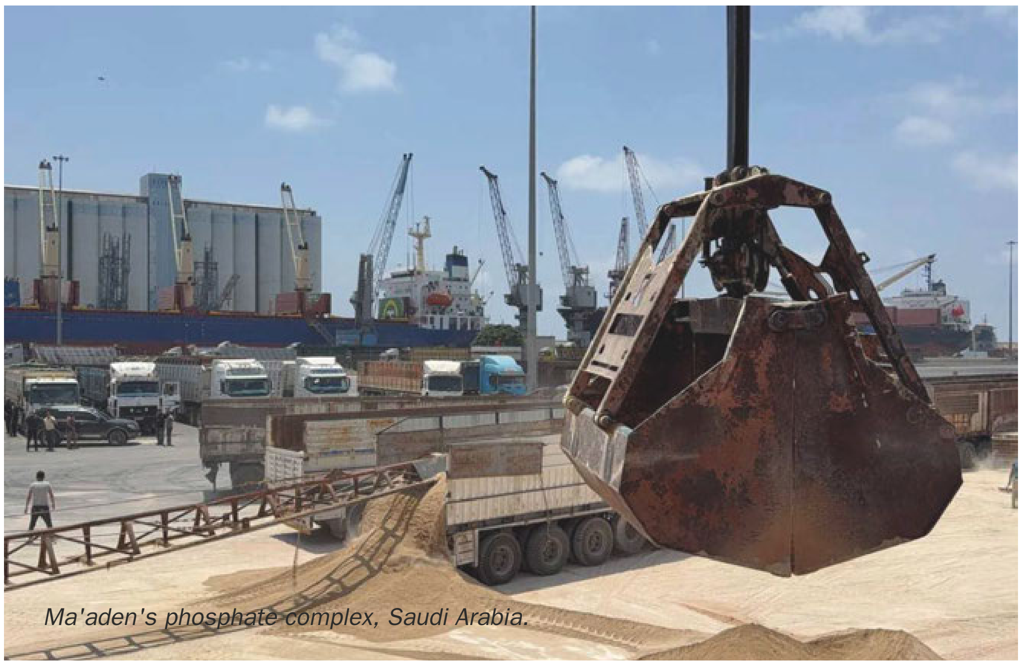
PHOTO: MA'ADEN PHOSPHATE COMPANY



Ma'aden's phosphate complex, Saudi Arabia.

The ousting of Bashar Al-Assad's government in December 2024 brought an end to Syria's 13-year long civil war but also renewed risks to the country's phosphate rock industry. Exports have slumped in 2025, stalling a recovery in output seen during the 2020s. Syrian exports decreased by almost 80% in 2025 H1 as the new government struggles to increase output. Although more limited Syrian supply may pose challenges to some key buyers, global phosphate rock export availability has improved since 2023.

Phosphate investment deal

Syria's Geological and Mineral Resources Authority has signed an agreement with Teryaq, a subsidiary of Serbia's Exlixir Group, aimed at exporting 1.5 million t/a of phosphate by the end of 2026. The agreement marks a significant step in Syria's efforts to expand international partnerships and optimise its mineral resources for economic gain. Elixir Group owns the largest phosphoric acid plant in Europe and operates three fertilizer plants in Serbia.

Syria's Director-General of the Geological and Mineral Resources Authority, Siraj al-Hariri, told local media that the deal will cover the entire phosphate process, from exploration and extraction to export. The first phase aims to export 1.5 million tons of phosphate by 2026, with potential for further cooperation, including the establishment of phosphate processing plants tied to related industries.

"This is the first step in entering global markets," al-Hariri said, adding that Syria plans to ramp up phosphate production to 5 million t/a in the coming year, with the possibility of increasing output to 7 or 8 million t/a.

INDONESIA

Indonesian nickel shutdown signals risk for sulphur demand

PT QMB New Energy Materials, a major Chinese-owned nickel smelter in Indonesia, is temporarily cutting production due to mounting waste management challenges, according to a 24 November report from local news source Sina, a move expected to temporarily impact regional sulphur demand. The facility, located in the Morowali Industrial Park, will reduce output for at least two weeks as its tailings ponds are nearing capacity while it awaits approval for a new facility. The shutdown may have implications for the sulphur market, as QMB is a major consumer.

The company, which accounts for 12% of Indonesia's nickel-based acid demand, expanded its sulphur-burning capacity to 1.6 million t/a in 2025. The two-week production halt may curb its sulphur consumption and may place downward pressure on regional demand. While significant, QMB is one of several major HPAL producers in the country, with PT Lygend (30%), Huafei (26%), and Huayue (18%) holding larger shares of acid requirements.

The situation at QMB may set a precedent that concerns sulphur market players. Stricter government enforcement of waste disposal rules means other Indonesian HPAL producers could easily face similar disruptions, introducing a major new uncertainty for the market.

Autoclaves arrive for Pomalaa HPAL project

PT Vale Indonesia Tbk says it has officially received the first two autoclave units for the Pomalaa high-pressure acid leaching (HPAL) project, a key component of the Indonesia Growth Project (IGP) Pomalaa. This delivery marks a critical milestone in preparing Indonesia's high-tech nickel processing facility for operation. The welcoming ceremony was attended by PT Vale and PT Kolaka Nickel Industry (KNI) management, along with strategic project partners including Indonesia Pomalaa Industrial Park (IPIP), Huayou Southern Construction Command, MCC20, and other stakeholders.

The Pomalaa HPAL facility is designed to produce up to 120,000 t/a of mixed hydroxide precipitate, reinforcing Indonesia's role as a strategic player in the global battery industry. Three additional autoclaves are scheduled for delivery soon, with timelines being finalised by the KNI team.

Muhammad Asril, Chief Project Officer at PT Vale Indonesia, stated: "The arrival of these two autoclaves is a major milestone for the Pomalaa HPAL Project. Autoclaves are the heart of the HPAL process, enabling the conversion of laterite ore into high-value products like MHP. Through this technology, we are not only enhancing the value of Indonesia's mineral resources but also strengthening the country's role in the global EV battery supply chain. We appreciate the collaboration of all partners and remain committed to advancing construction with a focus on safety, sustainability, and long-term benefits for local communities."

Sphere to buy stake in HPAL project

Australia's Nickel Industries is to sell a 10% share of the Excelsior Nickel Cobalt high-pressure acid leach (HPAL) project in Indonesia to South Korea's Sphere Corp. The $240 million price tag represents a $2.4 billion valuation for the company. Sphere will acquire the stake from Hong Kong-based Decent Resource, while Nickel Industries will retain its 44% stake in the project, according to Nickel Industries.

The ENC HPAL project, being built in Indonesia's Central Sulawesi, will be the first HPAL project with the capacity to produce mixed hydroxide precipitate (MHP), nickel sulphate, and nickel cathode, according to Nickel Industries. ■

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People

BP plc appointed **Meg O'Neill** as its next chief executive office, effective 1 April 2026. **Murray Auchincloss** stepped down from his position as CEO and director of the Board, as of Thursday, 18 December. **Carol Howle**, current executive vice president, supply, trading & shipping of bp, will serve as interim CEO until O'Neill joins as CEO. Auchinloss will serve in an advisory role until December 2026 to ensure a smooth transition.

Meg O'Neill currently serves as CEO of Woodside Energy. Since her appointment as CEO in 2021, she has grown Woodside Energy into the largest energy company listed on the Australian Securities Exchange, including overseeing the acquisition of BHP Petroleum International. Before joining Woodside Energy in 2018, she spent 23 years at ExxonMobil in technical, operational and leadership positions around the world.

Albert Manifold, Chair of bp, said: "We are delighted to welcome Meg O'Neill to the bp team. Her proven track record of driving transformation, growth, and disciplined capital allocation makes her the right leader for bp. Her relentless focus on business improvement and financial discipline gives us high confidence in her ability to shape this great company for its next phase of growth and pursue significant strategic and financial opportunities."

Meg O'Neill said: "bp plays a critical role in delivering energy to customers around the world. I am honoured to serve as the company's next CEO. With an extraordinary portfolio of assets, bp has significant potential to reestablish market leadership and grow shareholder value. I look forward to working with the bp leadership team and colleagues worldwide to accelerate performance, advance safety, drive innovation and sustainability and do our part to meet the world's energy needs."


Meg O'Neill, new CEO of bp

PHOTO: BP

Phospholutions has announced multiple leadership appointments. **Justin Archibee** has been appointed Chief Financial Officer to lead financial strategy and scaling efforts. **Michael Castiglione** and **Steve Levitsky** have been promoted to expanded executive roles. **Weston Heide** has joined the company's Board of Directors, bringing agribusiness operating experience. The changes come amid rising focus on phosphorus as a critical mineral with supply constraints. The company stated that the changes are intended to strengthen its management team as it enters a new phase of commercial and operational growth.

Aguia Resources has appointed CEO **Tim Hosking** to the board as Managing Director, while **Warwick Grigor** transitions from Executive Chair to Non-Executive Chairman, formalising a leadership structure aligned with the company's current growth phase. Hosking, who is based in Brazil and has already initiated operational improvements at the Santa Barbara Gold Project in Colombia, will oversee Aguia as it enters the final stages of development at the Tres Estradas Phosphate Mine, with first mining operations targeted for 1Q 2026 and initial phosphate deliveries expected in the second quarter of 2026; his updated contract includes a fixed salary, director fees, and incentive structures to be set in line with comparable ASX junior miners, underscoring the company's efforts to strengthen governance and execution capacity across its Brazilian and Colombian operations. ■

Calendar 2026

FEBRUARY

5-6

SulGas Conference, MUMBAI, India
Contact: Three Ten Initiative Technologies LLP
Tel: +91 96766 11950
Email: admin@sulgasconference.com
Web: sulgasconference.com

17-20

Laurance Reid Annual Gas Conditioning Conference, NORMAN, Oklahoma, USA
Contact: Lily Martinez, Program Director
Tel: +1 405 325 4414
Email: lmartinez@ou.edu

APRIL

13-15

CRU Phosphates+Potash Expoconference, PARIS, France
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

13-15

World Copper Summit, SANTIAGO, Chile
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

28-30

TSI Sulphur World Symposium 2026, VANCOUVER, Canada
Contact: The Sulphur Institute, Washington D.C., USA
Tel: +1 202 331 9660
Email: sulphur@sulphurinstitute.org

27 – MAY 1

RefComm Expoconference, GALVESTON, Texas, USA
Contact: CRU Events
Tel: +44 (0) 20 7903 2444
Email: conferences@crugroup.com

JUNE

Date TBA

49th Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference, ST. PETERSBURG, Florida, USA
Contact: Michelle Navar, AIChE Central Florida Section
Email: vicechair@aiche-cf.org
Web: www.aiche-cf.org

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Acid demand for battery production

The switch towards battery technologies like lithium iron phosphate (LFP) is leading to major growth in demand for sulphur and sulphuric acid.


PHOTO: LG ENERGY SOLUTIONS

LG Energy Solutions lithium iron phosphate battery plant at Holland, Michigan, USA.

Sulphuric acid is the key to battery production. Cathode materials need sulphuric acid to make cobalt, manganese, aluminium and nickel sulphates which form the active material that are the foundation of these battery technologies. Soluble sulphates allow precise control over deposition to form cathode active materials (CAM) during nickel cobalt aluminium (NCA) or nickel manganese cobalt (NMC) cathode processing. Sulphuric acid is also used for the purification of graphite to 99.95% for battery use, and in, recycling, both hydrometallurgical and pyrometallurgical processes use sulphuric acid to recover metals from black mass and convert them back into sulphates for reprocessing into new cathodes. Lithium sulphur batteries offer further potential use for sulphur.

Battery markets

Progressive electrification of power trains is leading to a huge increase in demand for these materials. Global battery demand is projected to double between 2025 and 2029, from 2,000 GWh to nearly 4,000 GWh. While electric vehicle demand has softened recently outside China due to policy rollbacks in both Europe and the United States, and there are high inventories that will require a drawdown, there has been strong growth in the battery energy storage system (BESS) sector. Growth of energy storage is primarily being driven by the economics of power storage, arbitrage, and grid balancing needs.

The majority of BESS demand will be at the utility-scale to support deployment of renewable energy, but there will be rising demand for standalone battery installations, and residential and commercial and industrial (C&I) storage. Despite isolated policy disruptions in several regions, CRU's outlook remains bullish, under the assumption that it still makes sense to build out solar and BESS, especially in regions with supportive solar profiles; solar and BESS costs and prices will stay low; and by and large, global policies remain supportive to BESS build-out. New demand hotspots are emerging across the world, notably Europe and the 'global south', where there is a surging number of PV and BESS mandates, funding, and large-scale project announcements.

Energy storage also remains at the core of China's power transition plans. In November alone, 45 new provincial battery storage policies were unveiled across China to aid pricing of electricity from renewable and battery energy storage, with over half of them coming from 12 provinces.

Electric vehicles

The shift to battery electric vehicles is forecast to accelerate, driven by more affordable vehicles due to declining battery costs, stronger competition, and tighter emission targets. However, the pace of change outside China is now at risk as policy support suffers attrition, and legacy automakers are push for more time to adapt.

In Europe, despite a dilution of emissions standards this year, BEV demand has remained strong, driven by high-volume model launches and intensified competition. Plug-in hybrid electric vehicle (PHEV) sales have also increased, supported by stronger model offerings and heightened competition from Chinese brands, which are leveraging their PHEV portfolios. These are subject to lower import duties than BEVs. Further changes to future emission standards in 2030 and 2035 have been announced, providing upside for other powertrain types, such as PHEVs. To boost BEV sales, several countries have introduced new incentives. Italy and France recently launched favourable incentives to support BEV uptake, while Germany plans to roll out a subsidy scheme from 2026. In the UK, a BEV grant is available, and over 25% of BEVs sold currently qualify. Some automakers excluded from the scheme have responded with price cuts. However, despite these positives, manufacturers have ongoing concerns about the region's competitiveness, and about whether future emissions targets are realistic without further support – especially given the headwinds facing the industry. As a result, the European Commission has responded with an Automotive Package, which proposes a range of measures to support European manufacturers and soften future emissions standards. A central proposal is to relax the 2035 mandate for a 100% tailpipe emissions reduction (versus 2021 levels), replacing it with a 90% target. The remaining 10% could be covered through compensatory mechanisms, such as the use of green steel or renewable fuels, allowing some non-BEV powertrains to remain in the mix. Even so, CRU's view is that BEVs will still become the dominant powertrain.

In the US, policy rollbacks will slow BEV adoption. Tariffs, the removal of IRA consumer tax credits, the rescission of California's Clean Air Act, and the elimination of emissions-standard fines will reduce demand for BEVs, with some OEMs falling back on their ICE and hybrid portfolios. There could be further cutbacks to emission policy, with the US administration taking steps to water down the emission standards. These policy changes are set to reduce BEV demand, as OEMs will face less regulatory pressure to prioritise BEV offerings and lean more on their ICE and hybrid portfolios. Pure-play BEV makers will be disproportionately affected, not only by weaker demand but also by the loss of revenue from selling emissions credits to OEMs struggling to meet targets.

However, the Chinese market remains robust, supported by strong consumer sentiment, attractive promotions, and both local and national incentives. These include the ongoing trade-in policy and the NEV purchase tax subsidy, which will decrease from 10% to 5% in 2026. Competitive pressures are expected to persist, ultimately leading to further consolidation. BEV demand has strengthened as product improvements, faster charging technology, and an expanding charging network ease range anxiety. BEV exports continue to strengthen as Chinese automakers expanded their EV footprint abroad. PHEV exports also grew, aided by new model launches in Europe and lower import duties than BEVs.

Changing technology

Active support for battery technologies continues in China, and elsewhere lithium iron phosphate technology is maturing quickly and still expanding outside China, including high compaction density 4th and 5th generation routes. This supports cheaper cells for BESS and many battery electric vehicle (BEV) segments. Given its superior cycle life, LFP is now the dominant chemistry in BESS, but there is a niche for sodium-ion technologies in future. In China, LFP is expanding its presence in all vehicle segments due to advancements in fast charging and energy density.

Faster-charging LFP, and semi-solid and solid-state chemistries with increased lithium per kWh, as well as changes in anode/cathode routes will shift future lithium and precursor demand profiles. The first mass-produced electric vehicle with a semi-solid battery technology was launched last year by Chinese automaker SAIC, using lithium manganate (LMO), which has surpassed the performance and cost of lithium-iron-phosphate (LFP). All-solid-state batteries (ASSBs) are often touted as the "holy grail" technology as they promise rapid charging speeds, super-long EV ranges and high safety all in one. However, developers have yet to overcome challenges in ASSB cycle life (how many times a battery can be charged/discharged before its capacity plummets). The poor cycle life arises from solid-solid interfaces breaking apart during use with no liquid to fill the gaps, resulting in lost capacity. Producers have turned to using high pressure clamps to maintain interface contact, but this adds too much weight and volume to warrant adoption.

Semi-solid batteries (SSBs) are a compromise technology that could render ASSBs redundant. SSBs are similar to ASSBs but retain some liquid content. The added weight is a trade-off, but it substantially increases the cycle life and improved performance on current liquid electrolyte cells. SAIC's semi-solid pack will contain cells from startup Qingtao Energy and announced use of a manganese-based chemistry, with very few other details. The SAIC-Qingtao joint venture has published three patents relating to semi-solid battery technologies, focused on halide solid-electrolytes combined with a polymer gel or liquid electrolyte.

These SSBs change the anode from graphite and silicon-containing graphite to lithium metal. Lithium metal can store more charge per gram than graphite – 3,860 mAh/g vs. 372 mAh/g respectively – while enabling faster charging cells. This transition will increase the amount of lithium contained per cell and therefore raise overall lithium demand, shifting processing and feedstock needs toward production routes for lithium metal and its precursor compounds. Semi-solid batteries are expected to account for 25% of total battery-grade lithium demand by 2033.

The lack of an LFP supply chain outside China is the main barrier to more profound growth in those markets, but this will expand sufficiently in the long term. Based on the lead time for new projects outside China and for battery development and certification, CRU expects an acceleration in LxFP's market share in EVs from 2027. Meanwhile, nickel-based chemistries are driven by markets that remain heavily invested in the NMC-based supply chain. NMC will not disappear entirely, but its market share and advantage is being eroded by improvements in LFP. Manufacturers are also reverting from super-high-nickel to medium-nickel high-voltage variants.

Lithium

Significant supply growth is anticipated across all major regions, particularly in 2026. China will lead the growth, adding over 100,000 t/a of lithium carbonate equivalent capacity this year. It will become the largest producer of lithium, surpassing Australia for the first time. Elsewhere, African supply keeps coming, supported by Chinese investment, with countries including Mali and Nigeria rapidly increasing output. Supply in Argentina, Australia and Chile will add a combined 450,000 t/a LCE by 2030, while secondary supply from recycling continues to accelerate, anticipated to account for 9% of total supply by 2030, up from 5% in 2025.

The US is moving into lithium extraction on a large scale. The Thacker Pass project in northern Nevada, being developed by Lithium Americas, will be the largest single-unit lithium operation in the US in more than 30 years. The project has a phase 1 capacity of 40,000 t/a of lithium carbonate, which is sufficient for 800,000 EVs or one-third of Texas's 2023 stationary storage additions. Sulphur consumption will be 250,000 t/a of liquid sulphur, burned on-site to produce sulphuric acid for clay leaching; the clay is potassium-based and highly basic and hence requires significant volumes of acid. The acid extracts magnesium, and potassium ions; excess acid is neutralised post-leach, producing magnesium sulphate as a neutral by-product, with no acid mine drainage. Heat recovery from the acid production will generate around 50 MW of electricity to power the plant. Longer term, the site could expand up to 160,000 t/a of lithium carbonate, multiplying sulphur demand by five. Each phase is a "cookie-cutter" design interlaced on the same facility. CRU expects US lithium extraction to be consuming 950,000 t/a of sulphuric acid by 2030.

Nickel and cobalt

Nickel processing has been one of the largest growth areas for sulphuric acid consumption. Nickel HPAL (high-pressure acid leach) operations consume 12-18 tonnes of acid per tonne of refined nickel, similar to lithium clays and rare earths, and sulphuric acid represents 19% of all-in operating costs - the single most expensive input. Indonesian sulphur imports surged from zero in 2018 to 4.8 million t/a in 2025, and are projected to grow to an estimated 8 million t/a by 2030. Indonesian nickel operations remain profitable even at $450/tonne sulphur and $15,000/tonne nickel, thanks to low labour, energy, and environmental compliance costs. Evolving Indonesian regulations could be a supply risk, however. A recent directive aimed at boosting downstream processing will require nickel intermediate producers (including HPAL) to commit to higher-value products to obtain a business license. Over the next five years, Indonesia is expected to increase its total sulphuric acid production from 13.5 million t/a in 2025 to 27.2 million t/a in 2030. Supply will be a mix of sulphur-burnt acid (80% share by 2030) and smelter acid (13%), with some additional pyrite roasting capacity.

On the cobalt side, the DRC remains the key player. After a US-backed DRC-Rwanda peace deal, a US-DRC strategic partnership, and a Gécamines-Mercuria JV (backed by the US Development Finance Corporation) have been signed which will give the US priority access to DRC projects and offtake. At present however DRC export quotas have tightened the cobalt market. Some relief could come from Indonesian cobalt exports. Indonesian low cost projects will drive almost all non-DRC mined cobalt growth to 2030, adding 15-20,000 t/a of cobalt in both 2027 and 2028. By 2029, Indonesian MHP production could top 100,000 t/a of cobalt. However, policy and regulatory risks are rising. Low nickel prices are prompting Jakarta to tighten supply, mandate higher-value products, require annual RKAB approvals and scrutinise tailings management, putting most planned HPAL capacity at risk, if not advanced before 2029.

Rare earths

Like nickel production, rare earth element (REE) extraction uses 12–18 tonnes of acid per tonne of separated oxide. If all North American REE demand for EVs and wind turbines were produced domestically, it would consume 200,000–300,000 tonnes of acid by 2035. The US sees domestic onshoring as a geopolitical imperative, since China currently controls around 70% of rare earth processing, although US sulphuric acid availability could be a bottleneck.

Table 1: **Acid demand for metals production, 2025-2030, million t/a**

Metal	2025	2030
Nickel	18.1	30.5
Copper	19.2	21.7
Lithium	2.4	5.1

Source: CRU

Phosphates

While most phosphate demand is for fertilizer, high purity phosphates are in increasing demand for lithium iron phosphate demand. The vast majority of LxFP CAM is manufactured via the creation of an FP (iron phosphate) precursor. The main production routes for FP utilise either purified phosphoric acid or technical grade monoammonium phosphate. CRU assesses the LxFP demand share in China will peak just shy of 80% in 2025, and projects its share of CAM demand outside China to grow substantially, displacing mostly nickel-based chemistries. Consequently, LxFP's global demand share of the battery market is expected to continue to grow to around 67% by the early 2030s. The additional phosphate that will be required will consume a further 4 million t/a of sulphuric acid over the period 2025-2029.

Metals to the fore

Increased demand for battery metals is leading to a major boost to sulphuric acid demand, as shown in Table 1. This year, it is expected that metals-based demand growth will actually exceed phosphate based demand growth for the first time, and over the next few years they will be roughly on par. The energy transition cannot happen without sulphuric acid. From lithium clays in Nevada to nickel laterites in Indonesia, from NMC cathodes in China to copper foil in every battery on Earth, acid is the invisible enabler, and we are looking towards a future where metals demand may rival fertilizers. The question is no longer whether battery metals will drive acid demand – it is whether the world can build enough capacity, fast enough, to keep pace. ■

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The sulphur market in deficit

Sulphur prices have risen rapidly in recent months as the market moves into a period of deficit which is likely to last until 2028.

PHOTO: BRUKS SIWERTELL

Sulphur loading at Beaumont, Texas

The sulphur market moved into a period of pronounced deficit in 2025. CRU estimates that total global demand for sulphur in 2025 was 72.8 million t/a, and supply 70.8 million t/a, leaving a structural deficit of about 1.9 million t/a. The reasons for this were an acute underperformance of supply, combined with concentrated import demand, particularly in Indonesia, Morocco and parts of Latin America, which has triggered a sharp price rise during 4Q 2025, with Middle Eastern and Vancouver prices rising past 2022 peaks. A partial price correction is expected in 2026, driven primarily by demand destruction and some recovery in production, but over the medium term it is expected that prices will remain at relatively high levels while the structural deficit continues. A complete rebalancing of the market is not forecast until the startup of major sour gas projects in the Middle East, around 2028.

In the interim, there has been a drawdown of sulphur stockpiles in Canada, Saudi Arabia and Kazakhstan, and additional sales from Turkmenistan, but further drawdown will be required to maintain traded market flows until new supply arrives.

The developing deficit

The sulphur market in fact had moved into a structural deficit by early 2024, but this was largely masked that year by proactive stock releases from Kazakhstan and Saudi Arabia. During the first half of 2025, however, a recovery in demand, particularly in the phosphate fertilizer sector emerged. A ramp up in demand from nickel HPAL projects also increased sulphur consumption. Indonesian sulphur imports reached 4.6 million t/a in the 11 months to November, up 1.2 million t/a year on year. By 3Q 2025, supply disruptions became acute, with operational issues and unplanned outages reducing output in several regions, notable the CIS and parts of the Middle East. At the same time, strong import buying from Indonesia and robust Chinese domestic activity kept demand high. This confluence of restricted exports, including a temporary Russian export ban allowing only transit shipments, and stock depletion triggered the Q4 price spike.

Signs of demand curtailments began to appear in 4Q 2025, e.g., China delaying phosphate exports until August 2026; and Mosaic pausing SSP purchases in Brazil, signalling affordability issues. Middle Eastern f.o.b. prices have risen from $295/t in 2024 Q4 to $515/t by the end of 2025; Vancouver f.o.b. prices similarly rose from $275/t to $490/t, with delivered prices to key destinations rising to $480–550/t c.fr in markets such as Indonesia, China and Brazil (with Indonesia approaching $550/t). This means that sulphur's share of the raw material cost of phosphate fertilizer production rose to historic highs (72–82% in some markets), exceeding the 2022 peak. This squeezed margins for producers of DAP/MAP and other fertilizers, especially in China and Brazil. China's response has been to impose export restrictions, and CRU believes that this will trigger a price correction this year.

Supply

Overall, CRU expects supply to recover gradually from 2026, with a large acceleration from 2027 as large scale gas projects in the Middle East commission. Near term supply impacts have come from, e.g. Ukrainian drone strikes at the Astrakhan gas plant in Russia, which caused major production losses during the second half of 2025. Output from Astrakhan fell by an estimate 300,000 tonnes over the period,

Table 1: **Sulphur demand by end-use, million t/a**

	2025	2030	Chg
Phosphoric acid	38.5	43.2	+4.7
Ammonium sulphate	4.8	5.3	+0.5
Single superphosphate	1.4	1.4	-
Nickel	4.7	8.7	+4.0
Copper	1.7	1.7	-
Uranium	0.5	0.9	+0.4
Lithium	0.0	0.5	+0.5
Industrial uses	13.9	15.0	+1.1
Non-acid uses	9.1	9.6	+0.5
Total	**73.4**	**84.8**	**+11.4**

Source: CRU

leading to Russia's export restrictions in Q4. In the Middle East, a fire at the Al Zour complex in Kuwait and temporary curtailments in other Gulf operations contributed to Q4 tightness. Lower sulphur content in crude processed in the US, together with some refinery closures or conversions to biofuel processing at Phillips66 in Los Angeles, LyondellBasell in Houston, and Valero in Benicia have also reduced oil derived sulphur availability. Mexico's Dos Bocas refinery ramp-up has increased oil-sourced sulphur production south of the border, and PEMEX will continue to lift domestic supply through 2025–2030.

European refinery throughput has trended down since 2015 due to conversions and closures. Mined sulphur output in Poland provides a partial offset, but remelt capacity projects (e.g., Aglobis/Rhenus) are being developed to meet domestic demand.

Stock drawdowns have been the balancing factor. Kazakhstan and Saudi Arabia previously drew down large stocks in 2023–2024 and continued into 2025; Canada has likewise ramped up remelting of its considerable stocks at Fort McMurray to supply the traded market - these flows have been critical to sustaining traded availability despite production shortfalls.

In the medium term, CRU projects global supply growth of ~3.0 million t/a for 2026, split roughly 45% from gas projects and 55% from refineries. Major new projects that will be commissioning include new refinery capacity in India and China (~1.1 Mt combined for 2026) and multiple gas project increases in the Middle East. Looking further forward, ADNOC's Ghasha project will add about 3.5 million t/a of new sulphur capacity, beginning in late 2027, while expansions to Qatar's North Field will boost output by 700,000 t/a. In Saudi Arabia there are the Al-Fadhili and Tanajib expansions. By 2030 CRU expects the Middle East to account for 67% of incremental global supply growth (+8.9 million t/a).

Demand

Fertilizer demand via phosphoric acid production, as well as ammonium sulphate and single superphosphate (SSP) remains the single largest consuming sector. CRU forecasts that phosphoric acid demand will rise from 37.7 million t/a in 2024 to over 43 million t/a by 2030 in terms of sulphur tonnes consumed.

China's supply increased in 2025 due to new refinery capacity (e.g. the Yulong refinery) and production recovery at existing assets. Gas-based supply from the Puguang gas field also lifted slightly. Increased supply has reduced import dependence, and CRU projects Chinese production to continue rising to 2030, lowering import dependency from the late 2020s, although industrial demand from ammonium sulphate (see the article elsewhere in this issue) and other chemical outputs have remained resilient.

Morocco has seen capacity expansions from new sulphur burners at Jorf Lasfar leading to increases in demand capacity. Morocco's import pattern in 2025 also reflected stock drawdown initiated in earlier years.

Brazil's phosphate sector has seen a recovery plus new plants (EuroChem's Serra do Salitre) which have supported steady demand, and the country remains reliant on seaborne imports.

India is also seeing increasing sulphur consumption from expanded phosphate burners (Iffco, PPL, CIL) and limited domestic supply increases which will create ongoing import requirements over the next few years.

The metals industry also continues to expand rapidly, with nickel and lithium production for batteries and also (in the case of nickel) stainless steel production. Indonesia has been the centre for nickel production growth via large Chinese backed high pressure acid leach (HPAL) projects. HPAL plant ramp-ups (e.g., Huayue, PT Lygend, ENC, PT Meiming) have lead to a major expansion in sulphur-burning capacity, and many of these projects will continue to ramp through 2026 and beyond. Cobalt credits have mitigated HPAL sulphur cost pass-through in 2024–2025, reducing near-term demand destruction from high sulphur prices, but policy (Indonesia requiring downstream refining) and project viability could alter future demand. Overall, metals consumption is expected to increase its share of demand notably from 2026 onward. CRU forecasts nickel-related sulphur demand doubling or more through the later 2020s. Phosphate remains dominant in absolute terms, but metals constitute a larger share of incremental demand.

Trade flows

Global trade remained large (39-40 million t/a in 2025) but origin and destination patterns are changing. Kazakhstan historically fed Morocco and China, but after an aggressive stock drawdown in 2023–2024, Kazakh exports fell in 2025 to more typical levels of 3.3-3.5 million t/a as inventories depleted. Canada increased its seaborne export volumes in 2025 as stock remelting ramped to supply tight market, although remelt/logistics costs (ca. $180–200/t for oil sands remelt to Vancouver) affect competitiveness and set a floor on export volumes. Middle East exports remained central, and CRU expects the region to expand export capacity post-2026.

China's port inventories began declining in Q3–Q4 2025; northern river stocks fell more rapidly than southern port stocks. Chinese policy measures to stabilise domestic prices, including discouraging long positions by traders, have influenced inventory drawdown patterns. Global inventories are projected to fall to 30–33 million tonnes as stock drawdowns continue. This places the market below the recent five-year average and heightens vulnerability to further supply shocks.

Near-term outlook

CRU expects a moderation in demand in 2026 Q1 as affordability constraints bite and some consumers formally restrict purchases. This is the primary mechanism for a short-term price correction from late-2025 peaks. A supply recovery due to new project commissioning, and production repairs is expected to start contributing from 2026 H1-H2, but material relief will also come further down the line in (2027–2028) when major gas projects start up. Even so, the market will remain in deficit through 2026 and into 2027; therefore, while prices may fall from Q4 2025 highs, they will remain elevated vs historical norms until structural supply additions fully arrive. Producers in deficit regions can expect robust pricing into 2026 if supply disruptions persist; however price volatility is high and dependent on stock releases and short-term demand changes. Fertilizer producers face squeezed margins; some (e.g., Mosaic) are already curtailing purchases/production - this may feed through to fertilizer product availability/pricing. Nickel producers (HPAL) currently see sulphur cost exposure offset by metal credits (cobalt) but persistent high sulphur may influence project economics and downstream integration decisions. ■

PHOTO: MARSULEX

Ammonium sulphate production from coke oven gas.

China's ammonium sulphate boom

The Chinese ammonium sulphate industry continues to see rapid growth, with exports rising to record levels, against increasing demand coming from Brazil and India.

Ammonium sulphate is still the largest sulphur fertilizer by volume. Global ammonium sulphate production was 35.0 million t/a in 2024, with the 2025 figure expected to reach 35.8 million t/a. Figure 1 shows the geographical distribution of capacity. As can be seen, most is in East Asia, and 95% of that figure is represented by China, where there is a great deal of involuntary production as a by-product of caprolactam manufacture for nylon fibres, methylmethacrylate (MMA), acrylonitrile, methionine production etc.

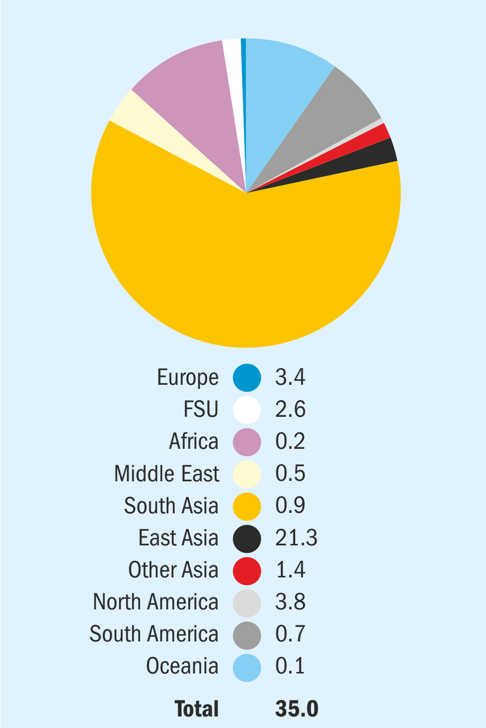
Production

Chemical sources of ammonium sulphate are shown in Figure 2. About half of all ammonium sulphate production comes as a by-product of caprolactam production, but that figure is much higher in China, where the rapid increase in artificial fibre production has led to a major increase in caprolactam production there, and concomitant demand for sulphuric acid. Other major involuntary sources of AS production are ammonia scrubbing of coke oven gas, and as a by-product of lithium iron phosphate production, the latter again increasingly important in China due to the rapidly expanding battery manufacturing industry for electric vehicles. Indeed, China is the single largest and fastest-growing source of traded AS. Capacity expanded rapidly over the last decade as caprolactam and lithium iron phosphate (LFP) industries increased co-product AS output. Chinese AS production reached record levels in 2024 (20.1 million t/a) and exports continued to break records into 2025

Overall, about 70% of AS capacity is based on by-products from other production, and in China this figure is 83%. It is also 90% in Europe and 73% in North America. However, in the Middle East, Africa and South America, the opposite is true, and on-purpose production predominates, between 75% of production (in South America) to 95% (in the Middle East).

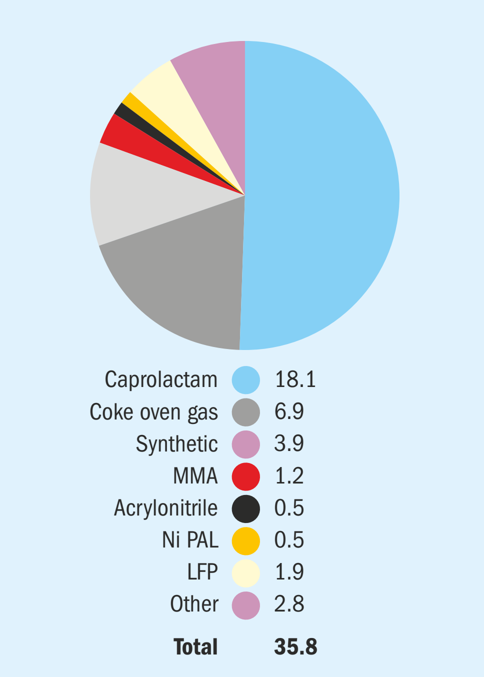
By-product routes drive most of the growth. Caprolactam-derived AS and LFP-related production account for the majority of incremental capacity additions over the period 2024–2026. Voluntary, ammonia-based routes picked up in regions such as Russia where new projects and restarts increased granular and synthetic capacity through 2025.

Fig. 1: **AS production by region, 2024, million t/a**



Source: CRU

Fig. 2: **AS production by source, 2025, million t/a**



Source: CRU

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56

Consumption

AS consumption is virtually all (95%) as a fertilizer, with its sulphur content becoming increasingly relevant. Consumption is more widely distributed than production, with the strongest demand in Asia (though not China, which uses relatively small quantities) and Latin America – particularly Brazil. There are some exports from Europe, but low operating rates for caprolactam production there means that there are also imports, but the AS trade is dominated by China, which is by far the largest exporter. Because much of AS production is involuntary, a striking amount of AS is traded across borders; 21.8 million t/a in 2024. Chinese exports represented 17.1 million t/a in that year, or more than 75% of all traded AS.

Sulphur deficiency in soils remains a structural demand driver for sulphur-containing fertilizers. Areas with pronounced sulphur deficits – South Asia, East Asia, and parts of Africa – are long-term addressable markets for AS. The global sulphur deficit has been gradually reducing but remains elevated, supporting incremental AS uptake where agronomic and price conditions allow.

Recent developments

During 2025 the global ammonium sulphate (AS) market has been characterised by a dominant and growing supply surge from China, ongoing structural shifts in demand – notably large-scale substitution toward AS in Brazil and gradual uptake in India – and a weakening AS premium versus urea as nitrogen product prices evolve. China's exports rose strongly in 2024 and continued through 2025, reaching 19.0 million t/a, putting pressure on prices and forcing traditional exporters and regional producers to reposition their sales strategies. However, this has been complicated in recent months by port congestion in Brazil and other logistical issues, and temporary supply disruptions in sulphur and ammonia markets that supported input costs, and pre-buying ahead of regulatory measures in Europe (CBAM).

Compacted granules and improved agglomerated/crystalline products from China have allowed Chinese exports to compete in markets that historically preferred granular product (for blending and mechanised application). This shift reduced the granular premium in importing markets like Brazil and Europe.

Brazil

Brazil was the single most important demand story in 2025, representing over 1/3 of all global imports. Robust substitution of urea and ammonium nitrate by AS (especially granular AS used in bulk blends) and expansion of farmed areas pushed Brazilian AS demand sharply higher: imports into Brazil hit record levels and granular demand dominated the import profile. Shipments to Brazil were up 11l% during 2025.

Brazil's agricultural economics - corn/cotton/soy/pasture rotations and the value placed on S for yield/soil conditioning - combined with favourable AS pricing created a sustained surge in imports, almost entirely sourced from China in 2024–25. In Brazil the AS premium to urea declined to historically low levels in 2025 Q2–Q3; in some snapshots AS traded at a discount to urea for the first time on record, which catalysed substitution and import demand. The result is Brazil's AS consumption rising substantially, from 1.9 million t/a in 2017 to 6.0 million t/a in 2024, with forecasts pointing towards 9.7 million t/a of imports by 2029.

India

India showed substantial import growth and rising acceptance of AS in 2025. Imports have risen markedly, from 140,000 t/a in 2020 to 600,000 t/a in 2025, and the updated Nutrient-Based Subsidy (NBS) policy for 2025–26 incorporated domestic and imported AS – a significant policy signal that can underpin longer-term demand growth. Nevertheless, AS still represented a small share of India's total nitrogen demand in 2025, and structural change will be gradual.

Elsewhere

Southeast Asian demand in 2025 experienced affordability pressure. Price relationships versus key crops (rice, palm oil) matter: falling rice prices in Thailand and Vietnam and higher AS prices reduced affordability for farmers, slowing purchases in 2025 H1. Indonesia and Malaysia (palm oil) remained more supportive, but overall regional imports from China increased share at the expense of Far East suppliers.

Europe imported more AS in 2025, partly driven by buyers front-running CBAM implementation and sourcing cheap Chinese volumes. Domestic caprolactam-based production in Western Europe remained subdued because of low caprolactam operating rates and structural chemical industry weakness.

Price developments

AS price trends during 2025 were shaped by a tug of war: abundant Chinese supply and logistics pushed delivered prices lower in many markets, while input cost shocks including episodic sulphur and ammonia tightness such as downtime at Ma'aden in Saudi Arabia temporarily supported production costs in some regions. However, these cost pressures did not fully offset the market effect of rising global by-product supplies.

Looking ahead

China remains the dominant producer and exporter; domestic consumption weakened as urea became more attractive domestically in 2025, and AS was exempt from export inspection which allowed volumes to move abroad freely. Provincial export hubs (e.g., Fujian, Hubei) contributed heavily to the export surge. Forecasts show continued export growth through 2026–29 absent major policy changes.

Conversely, Brazil was the major importer and the primary demand engine in 2025; granular adoption and substitution trends are reshaping the nitrogen import basket. China supplied essentially all incremental Brazilian needs in 2024–25, forcing legacy suppliers (Europe, US) to seek alternative markets.

Uncertainties for 2026 are whether new urea capacity and urea price moves and potential trade policy responses, including tariffs, inspection rules, and in Europe CBAM implementation, will alter farmer economics and restore stronger premiums to AS or accelerate further substitution and import growth.

Acid consumption

Overall, the world consumed around 18.6 million t/a of sulphuric acid in 2025 to make ammonium sulphate, or about 6% of all acid demand. China represented just over half of that acid demand (9.4 million t/a). Sulphuric acid use for AS production is expected to grow to 20.8 million t/a in 2029, with China representing around 55% of incremental production, but increased production is expected in western Europe, the US, India and elsewhere. ■

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SULPHUR index 2025

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PHOTO: HUAYUE

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Country	SULPHUR INDUSTRY NEWS	Issue	Pg
Argentina	Desulphurisation united installed at Lujan refinery	Sep/Oct	11
Azerbaijan	Baker Hughes partners with SOCAR on flaring	Jan/Feb	11
Canada	Gas plant startup delayed	Sep/Oct	11
	Northern Nutrients restructuring and expansion	Jul/Aug	9
	Oil sands production to reach record this year	Jul/Aug	9
	Start-up for Albright gas plant	Nov/Dec	10
China	Production begins at Dukouhe-Qilibei	Jul/Aug	9
	Topsoe technology chosen for SAF project in Guangxi	Mar/Apr	11
	Topsoe technology chosen for SAF plants	Jul/Aug	9
France	TotalEnergies to decarbonise its European refineries	Mar/Apr	10
	Uhde gasification selected for biomass to SAF project	May/Jun	10
Germany	Green hydrogen to decarbonise Leuna refinery	May/Jun	10
	New sulphur remelter for Duisburg	Jan/Feb	10
Hungary	MOL co-produces HVO and SAF	Mar/Apr	11
India	Anti-dumping duty on insoluble sulphur	Jul/Aug	11
Iraq	CPECC to build Ar-Ratawi gas processing plant	Jul/Aug	10
	Gas treatment plant for Basra	Mar/Apr	10
Italy	Stellantis and Zeta to develop lithium sulphur batteries	Jan/Feb	10
Kazakhstan	Agreement signed for gas separation complex	Sep/Oct	10
	KazZinc to invest in increased SO_2 recovery	Jul/Aug	11
	TCO starts up future growth project	Mar/Apr	12
	Work progressing on Kashagan	May/Jun	9
Kuwait	Bids invited for gas sweetening facility	Mar/Apr	12
	Contract expected on oil project	Mar/Apr	12
	SRU contract awarded for gas sweetening facility	Nov/Dec	10
Mexico	Samsung ends contract with PEMEX	May/Jun	10
Morocco	QatarEnergy signs sulphur supply deal with OCP	Jan/Feb	10
Nigeria	Dangote cleared of breaching fuel sulphur limits	Nov/Dec	10
Philippines	Philippines introduces 0.5% bunker fuel sulphur cap	Jan/Feb	11
Poland	Grupa Azoty to produce sulphur enhanced fertilizer	Mar/Apr	11
Russia	Attack on sour gas plant	Mar/Apr	11
	Fuel exports suspended following drone attacks	Nov/Dec	10
Saudi Arabia	Axens expands TGT catalyst production	May/Jun	9
	BlackRock signs $11 billion deal for gas plant	Sep/Oct	10
	NextChem awarded refinery improvement contract	Mar/Apr	12
South Africa	Glencore invests in sulphur removal	May/Jun	9
Uganda	New refinery construction agreed	May/Jun	9
UAE	ADNOC awards design contract for Bab gas facilities	Jan/Feb	11
	ADNOC Gas posts record profit	Sep/Oct	11
	First production from Ghasha within months	Nov/Dec	11
	Sultech to supply micronized sulphur technology	Nov/Dec	11
	Tenders for Ruwais sulphur terminal	Nov/Dec	11
	Tender launched for SARB expansion	Mar/Apr	11
UK	NextChem to conduct study on SAF plant	Nov/Dec	10
US	AMETEK and Worley collaborate on burner control	Jul/Aug	10
	Deer Park contractors died from H_2S poisoning	May/Jun	9
	Hazardous area certification for wall mount analysers	Jul/Aug	10
	IPCO buys New Era Converting Machinery	May/Jun	9
	Lyten acquires Northvolt	Sep/Oct	11
	Sulphur supply agreed for battery manufacturing	Mar/Apr	10
	Topsoe technology selected for Indiana refinery	Sep/Oct	10
World	OPEC+ postpones oil supply relaxation	Jan/Feb	11

Country	SULPHURIC ACID NEWS	Issue	Pg
Algeria	Major new phosphate project	Jan/Feb	14
	Sonatrach awards Saipem phosphate FEED contract	Jul/Aug	13
Australia	Ammaroo phosphate project secures mineral leases	May/Jun	13
	Feasibility study on copper expansion project	Mar/Apr	14
	Glencore looking to extend life of Mt Isa	Mar/Apr	14
	Glencore prepares to idle Queensland smelter	Sep/Oct	15
	Investment to boost phosphate project	May/Jun	14
	Kalgoorlie secures major project status renewal	Nov/Dec	12
	Mining license approved for Ammaroo	Nov/Dec	13
	Nyrstar to reduce output at Hobart	May/Jun	13
	Sulphuric acid from pyrite tailings	Jan/Feb	12
Bangladesh	BADC signs DAP import agreement	Jan/Feb	14
	BADC signs import deals	Sep/Oct	14
Brazil	Acid tanker spill after bridge collapse	Jan/Feb	14
	Yara to suspend acid, phosphate production	Mar/Apr	15
Bulgaria	Aurubis completes major maintenance at Pirdop	Sep/Oct	13
Canada	Arianne to use Travertine technology	Nov/Dec	13
	First Phosphate to license Prayon acid technology	Jan/Feb	12
	Nutrien considering phosphate sell-off	Nov/Dec	14
Chile	Anglo and Codelco to combine operations	Mar/Apr	16
	Codelco charged over smelter pollution	Jan/Feb	14
	Codelco warns copper output could stagnate	Sep/Oct	12
	Copper at a crossroads	May/Jun	11
	Glencore to test new leaching process	Jan/Feb	14
	Marimaca to acquire acid plant	Sep/Oct	12
	Metso expands technical service centre	Nov/Dec	14
	Operations halted at El Teniente mine	Sep/Oct	12
	Permit agreed for smelter revamp	Nov/Dec	14
	SMAC to list on Toronto stock exchange	Nov/Dec	14
	Upcycle launches potassium sulphate project	Sep/Oct	12
China	Acid exports rose in 4Q 2024	Jan/Feb	13
	Attempts to rein in smelter overcapacity	Mar/Apr	14
	Nornickel to send concentrate, acid for processing	Jan/Feb	13
	Production cuts at Chinese smelters	May/Jun	11
	Smelters process Chilean concentrate for free	Jul/Aug	12
	Work begins on Kaiyang LFP project	Jul/Aug	12
Egypt	KMCJNC to fund new phosphate project	May/Jun	15
	MoU signed for exploration of phosphate production	Jul/Aug	13
	New phosphoric acid plant	Jul/Aug	13
	Sino-Egyptian phosphate cooperation deal	Sep/Oct	14
Finland	Metso launches sustainable copper leaching process	Mar/Apr	16
Germany	Aurubis earnings up 17%	Mar/Apr	15
India	CIL to increase BMCC stake	Sep/Oct	14
	CIPL to build phosphoric acid plant by 2027	Jul/Aug	13
	Paradeep plans additional phosphoric acid capacity	Nov/Dec	13
	PPL signs MoU for phosphate expansion	Mar/Apr	16
	Start-up for Adani smelter	May/Jun	11
Indonesia	Deal signed for new HPAL plant	Sep/Oct	14
	Fatal dam collapse at nickel facilities	May/Jun	14
	GEM and Vale in HPAL project	Jan/Feb	13
	Government to limit new nickel projects	Nov/Dec	14
	Major smelter faces supply issues	Nov/Dec	14
	Merdeka Battery to build new HPAL plant	Mar/Apr	14
	Royalty rates not expected to affect nickel production	May/Jun	14
Jordan	Foundation stone laid for new acid plant	Mar/Apr	16
	JPMC and APC expand fertilizer production	Sep/Oct	13
	Metso awarded beneficiation plant contract	May/Jun	14
	Sulphuric acid leak at Aqaba	Nov/Dec	13
Kazakhstan	Karatu expansion onstream next year	Jul/Aug	12
	Major acid plant part of new fertilizer complex	Jan/Feb	12
Morocco	OCP certifies low cadmium phosphates	Jul/Aug	13
	OCP Nutricrops surpasses 5 million t of TSP	Sep/Oct	14
New Zealand	Balance to end phosphate manufacturing	Jul/Aug	12
Philippines	Glencore's copper smelter put into maintenance	Mar/Apr	15
	Government looking to emulate Indonesia	May/Jun	14
	Nickel Asia sells its stake in Coral Bay	Mar/Apr	15
Senegal	Indorama to boost phosphate fertilizer production	Nov/Dec	12
	Major phosphate expansion announced	Mar/Apr	16
Saudi Arabia	Saudi Arabia agrees $9 billion of mining deals	Jan/Feb	12
South Korea	Korea Zinc completes smelter upgrade	Jan/Feb	14
Sweden	LKAB begins work on phosphate demonstrator plant	Mar/Apr	15
	Lyten to buy lithium sulphur assets	Sep/Oct	15
Tunisia	Cabinet aims to boost phosphate production	May/Jun	11
Turkmenistan	Casale awarded fert plant PDP contract	Jul/Aug	13
	Daewoo to build phosphoric acid plant	May/Jun	15
	Turkmenabat reports production figures	Jul/Aug	12
US	Aurubis looking at US smelter	Nov/Dec	12
	Copper output begins at Rio Tinto backed project	Sep/Oct	13
	Cornerstone sells sulphuric acid operations	May/Jun	12
	Travertine starts operation of demonstration plant	Nov/Dec	12
	US tariff pause brings relief to fertilizer exporters	May/Jun	12

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PHOTO: CRU

Sulphur + Sulphuric Acid 2025

CRU's annual Sulphur+Sulphuric Acid Expoconference was held from November 3rd to 5th, at The Woodlands, Texas.

The sulphuric acid energy transition panel, Monday afternoon.

The main section of the conference was preceded as usual by a morning of troubleshooting clinics, one on SRU operation, and the other on sulphuric acid plants. There were also technology showcases by Recalibrate, Wylton (China) Chemical Co and Sulphurnet.

Commercial sessions

Lisa Connock, Managing Editor of Sulphur Magazine at CRU, opened the conference, framing the event as a pragmatic, forward-looking gathering for an industry that powers global agriculture, manufacturing, and critical value chains.

The opening paper, delivered by CRU economist Maria Garcia, began with a discussion of US tariff chaos – rates spiking to 35% in April before settling near 18%. US customs revenue doubled to $113 billion in fiscal 2025's first nine months, making tariffs "one of the largest revenue sources for the federal government" and thus "likely to remain sticky". Brent crude, anchored in the mid-$60s, reflects "policy friction, not shortage", but sanctions on Rosneft and Lukoil – half of Russia's crude exports – are rerouting sour barrels eastward through "darker, longer, and more expensive routes". For US Gulf refiners configured for heavy, high-sulphur crudes, the result is feedstock scarcity: Maya and WCS discounts to Light Louisiana Sweet have collapsed, and sulphur recovery is "stalling" even as refiners stay busy.

Maria's paper was followed by a keynote panel discussion chaired by Willis Thomas of CRU, which explored sulphur and sulphuric acid's critical role in the energy transition, focusing on battery metals and lithium recovery. Andrew Nissan (Lyten) demonstrated that sulphuric acid is "the unsung hero" of lithium-ion batteries, essential for converting nickel, manganese, cobalt, and aluminium into sulphates for cathode active materials. He also presented Lyten's lithium-sulphur battery technology, which offers 350 Wh/kg energy density – 40–60% lighter than nickel-based chemistries, with superior thermal stability and a 100% North American supply chain. Rene LeBlanc and Christopher Larson (Lithium Americas) detailed their Thacker Pass project in northern Nevada, which will produce 40,000 t/a of lithium carbonate using 250,000 t/a of liquid sulphur to generate sulphuric acid for clay leaching. Frank Nikolic (CRU) contextualised the broader battery metals landscape, noting that sulphuric acid represents 20% of all-in costs for Indonesian nickel operations, with North American demand for lithium potentially reaching 200–300,000 t/a by 2035; he emphasised that China's dominance across the battery value chain from mining to refining requires urgent US policy action and onshoring. The panel concluded that sulphur and sulphuric acid are indispensable to the energy transition, with Willis Thomas saying: "the ultimate winner here is sulphur and sulphuric acid, no matter how we want to put it."

Sulphur and sulphuric acid markets

Dr. Peter Harrisson's global sulphur market outlook framed 2025 as an unprecedented supply crisis, with prices surging from $120–150/t in early 2024 to $450 by late 2025; a rally driven not by speculation but by fundamental supply failure. Kazakh inventory liquidation (1.5–1.7 million tonnes) masked underlying tightness through Q1 2025, but persistent demand collided with collapsing supply. Russian drone strikes on Astrakhan and Orenburg gas facilities removed over 500,000 tonnes per quarter, while US refining sulphur content declined by 0.25%, eliminating up to 900,000 t/a of sulphur due to lighter crude slates. Indonesian nickel demand surged by 1 million t/a, while phosphate affordability collapsed: China's sulphur-to-DAP price ratio approached 1:1, "fundamentally challenging and breaking parts of the industry in Asia." He projected persistent high prices through Q1 2026, potentially reaching $500, before correction toward long-run marginal cost of $180–200 f.o.b.

The subsequent keynote panel addressed three themes: trade policy and tariffs, supply chain resilience, and long-term demand security. Craig Jorgenson of TSI reported intensive advocacy since January 2025. Jorgenson highlighted TSI's push to designate sulphur as a critical mineral in both US and EU frameworks, emphasizing that "without sulphur, you can't get to those critical minerals." Al Foley (InterAcid) noted tariffs add $15–20/t to seaborne imports, making Mexican/Canadian supply more competitive, though some customers resist tariff pass-through. Jay Davis of Chevron described operational flexibility managing lighter crude slates – US refineries have mothballed sulphur plants as crude sulphur content declined by 0.25%. Dan Deaver of Georgia Gulf emphasised supply diversification as "absolutely critical," noting agriculture demand will curtail as sulphur prices rise.

The last paper of the day, CRU's Viviana Alvarado's sulphuric acid market outlook highlighted that acid prices have decoupled from sulphur's rally, remaining "broadly reasonable" despite tight supply. Prices rose from H2 2024 through August 2025 due to Chilean smelter disruptions, then briefly corrected to $150/t in September before rebounding on renewed tightness. The acid premium over sulphur collapsed to $22/t in October, explaining why China's record exports in 2025 came almost entirely from smelter acid (up 106% year-on-year), filling gaps in Chile and Saudi Arabia. But the global copper concentrate deficit also forced smelter curtailments.

Sulphur technology

Tuesday opened with presentations on amine technologies for effective H_2S removal. Rodolfo Gonzales from BASF presented a case study on ExxonMobil's Flexsorb technology, demonstrating how a Middle Eastern refinery achieved improvements by switching from MDEA to Flexsorb. The facility increased acid gas processing capacity by 60-70% while reducing H_2S in treated gas from over 100 ppm to less than 50 ppm, and tail gas H_2S from 300-500 ppm to under 100 ppm, without major equipment modifications.

Prashanth Chandran from Optimized Gas Treating introduced rate-based simulation models for liquid-liquid extraction in LPG treating, moving beyond traditional ideal stage models. This represents a significant advancement in predicting actual performance, particularly for COS and mercaptan removal, where the model validated against 15 commercial LPG treaters showed good agreement with plant data.

New technologies presented included a paper by Sebastien Duval from Aramco, who presented a revolutionary approach using diluted wet sulphuric acid for tail gas treatment. Operating at 60°C with hydrogen peroxide injection, this system could achieve near-zero SO_2 emissions while reducing the carbon footprint by 80-90% compared to conventional amine systems. The technology produces weak sulphuric acid as a byproduct.

Elmo Nasato discussed catalytic incineration as an alternative to thermal oxidation, demonstrating 67% reduction in operating temperature, 40% less fuel consumption, and 82% lower stack flow rates. With CO_2 becoming the molecule of concern rather than SO_2, catalytic systems offer significant advantages in reducing carbon footprint.

Joe Weiner from 8 Rivers Capital introduced the SEPARATE process – a low-temperature distillation system for ultra-sour gas that eliminates amine requirements by using CO_2 itself as the stripping solvent. Economic analysis showed 30% reduction in levelized costs for high H_2S gas (16 mol%) compared to conventional MDEA systems.

Topsoe demonstrated how WSA (Wet gas Sulphuric Acid) technology can transform sulphur plants from energy consumers to exporters. Two refineries, one in India and one in South America, reported fuel savings by implementing WSA, while achieving 99%+ sulphur recovery.

Reliability and maintenance

SGS Sulphur Experts presented eight case studies on making it to turnaround under challenging conditions. Logan Muehlstein demonstrated creative solutions including bypassing entire Claus stages, conducting sulphur washes without traditional methods, and managing waste heat boiler failures. A key takeaway: "The key to managing abnormal operating conditions is understanding process chemistry, corrosion mechanisms, and process limitations".

Tammy Chan from Worley Comprimo shared a case study on reusing existing amine and sulphur plants for SAF (Sustainable Aviation Fuel) projects. For a North Dakota refinery processing bio-feedstocks with only 1,300 lb/d sulphur production, the study compared multiple technologies. Despite the small scale, reusing the existing amine/SRU system proved most economical, with lowest CapEx and competitive OpEx, particularly when considering a 15 year life cycle.

Motiva Port Arthur and Zeeco presented critical findings on thermal oxidiser trip scenarios. The presentation highlighted flammability concerns when tail gas is used as purge gas during incinerator trips. Using ISO 10156 methodology, they demonstrated that while the method can determine if gas is flammable, it cannot definitively prove it is safe as inert purge gas due to temperature, mixing, and composition variables.

Elmo Nasato presented CFD modelling of Claus reactors, emphasising that catalyst displacement is a far more common problem than generally recognised. The simulation work demonstrated that proper inlet distribution and stress calculations are critical KPIs – not just conversion efficiency. "Catalyst movement is hard to conceptualise, but it happens over and over again," Nasato noted, describing cases where catalyst was replaced every nine months due to unrecognized displacement.

Aramco engineers shared "seven deadly sins" of thermal reactor and furnace design, covering everything from thermal growth management to thermowell installation. One finding was that weather shrouds, traditionally considered standard equipment, can actually increase shell temperatures in hot climates by trapping radiant heat. Removing shrouds reduced shell temperature by 184°C in one Saudi case.

Environmental footprint

Marco van Son opened Wednesday with a case study on resolving high SO_2 emissions at ENAP Bio Bio refinery in Chile. The facility experienced 20,000 ppm SO_2 events affecting a nearby school. Investigation revealed the root cause wasn't the new DCS system as suspected, but incorrect air-to-acid-gas ratios and improperly tuned tail gas analyser controllers. Operator training using Worley's dynamic simulation tool (EMERGE) proved critical in preventing future events.

The subsequent emissions panel provided comprehensive coverage of CO, NOx, and CO_2 alongside traditional H_2S and SO_2 concerns. CO destruction requires 750-800°C in thermal oxidisers for 400 ppm outlet targets, with residence time being critical. Tail gas hydrogenation can reduce CO to hundreds of ppm in refineries but thousands in gas plants due to higher CO_2 content. NOx formation increases linearly with temperature but decreases with lower temperatures – the opposite trend from CO.

CO_2 footprint increases as emission specs tighten, creating tension between environmental goals Christopher Lavery from ASL presented kinetic data showing CO is the most difficult tail gas component to oxidise, requiring the highest temperatures.

Ametek addressed the challenging question of measuring COS and CS_2 in sulphur plants. Michael Gaura demonstrated that UV spectroscopy faces severe interference from H_2S, SO_2, and sulphur vapour at most measurement points. The best location is after the amine absorber outlet, where concentrations are low enough for reliable measurement, though this doesn't help diagnose upstream catalyst bed issues.

Nuberg Engineering presented an economic analysis for coal gasification projects

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in India, comparing sulphur recovery versus removal. For lean gas on a short life cycle, removal may be attractive, but for longer lifecycles or high-sulphur gas, recovery becomes economically superior. Disposal costs are increasingly driving decisions toward recovery even at small scales.

Product handling

The final session focused on safe sulphur handling. Trimeric Corporation emphasised that hazards in molten sulphur systems are always present, even during normal operation. Key recommendations included using sweep air rather than nitrogen blanketing (to avoid pyrophoric iron sulphide formation), implementing proper degassing to reduce H_2S below 10 ppm, and recognizing that even degassed sulphur can evolve lethal H_2S concentrations in closed headspaces.

Elessent Clean Technologies demonstrated the DynaWave scrubber for sulphur vapour treatment, achieving <5 ppm H_2S, <5 ppm SO_2, and low particulate from melting operations handling 1,920-3,720 short tons/day. The technology continuously washes the inlet barrel, preventing sulphur buildup – a critical feature for reliability.

Sulphurnet concluded with best practices for sulphur melting and filtration, emphasising lime addition for acid neutralisation, proper pre-coating procedures, and the advantages of cellulose over diatomaceous earth as filter media. Online turbidity monitoring between filter stages enables immediate detection of filter breakthrough, preventing contaminated sulphur from reaching storage.

Sulphuric acid technology

The acid technology papers began with a series of presentations on operations and best practises. Ben Senyard of Worley kicked off with a look at ways of maximising return on investment in an acid plant; by reducing downtime via high reliability components, and optimising plant design for less thermal and chemical stress; unlocking by-product value via low grade energy recovery; and evaluating the total cost of ownership when comparing technical options.

Justin Thiems of Elessent looked at the challenges in producing ultra-pure SO_3 for the semiconductor industry, while Ethan Schrader of CG Thermal explained the use of ceramics to resist corrosion in SO_2 scrubbers and quench gas coolers. Steve Puricelli of EXP OG&C Group tackled the age old question of brick vs alloy-lined acid towers, with a comprehensive look at the benefits and drawbacks of each.

Collin Bartlett of Metso discussed maintaining acid quality from metallurgical off-gases, stressing increasing impurity loads as ore grades decline and the need for robust gas-cleaning. He presented digital process optimisers, tail-gas scrubbing options, pilot test capabilities, and emphasised proactive maintenance and upgrades to protect acid plant performance.

Michael Labbe of REMA outlined integrated surface-protection and reliability services for sulphuric-acid assets: acid-resistant coatings/linings, predictive maintenance workflows, engineering, conveyor/tire repair solutions and global service capacity.

PegasusTSI reviews hydrogen generation and accumulation risks in sulphuric acid plants (e.g., IPA/HRS towers), showing how hydrogen can accumulate in dead-spaces and reach flammable concentrations. They outline CFD-backed vent-sizing methodology for buoyancy-driven high-point vents, empirical validation, and recommend layered safeguards (venting, automation, administrative controls) to mitigate ignition risk.

Clark Solutions presented the SAFEHX heat-recovery concept for sulphuric-acid plants: a three-fluid exchanger using an inert buffer to recover SO_3-absorption heat safely without exposing water to acid. They detailed retrofit requirements for existing double-absorption trains, expected steam and cooling-water savings, safety advantages and practical adaptation steps for brownfield installations.

Operations

Operator experiences included PT Petrokimia Gresik, who discussed the use of silica by-product as a sustainable alternative to diatomaceous earth for sulphur filtration; and Alvaro Jara from Southern Peru Copper who described steps taken to improve reactor performance at the Ilo metallurgical acid plant by improving filtration and gas cleaning. Stuart Hintze of JR Simplot explained the repairs and improvements that Simplot had taken to keep a 40-year old converter operating efficiently, including a new steam superheater and changeout in catalyst loading. Finally, Blake Stapper of Messer describes debottlenecking a spent acid regenerator using strategic O_2 injection into the spent-acid decomposition furnace.

Catalysts

Leading off a section of papers on acid catalysts, Wylton (China) described the optimisation of its CHP75B-Plus catalyst via better diatomite carrier selection, optimised dispersant and binder dosages and a new mixing/process method. Characterisation showed higher porosity, improved dispersibility, more oxygen vacancies, lower activation energy and up to ~10% higher activity at test temperatures.

P&P Industries promote platinum-promoted honeycomb catalysts as an alternative to bulk V_2O_5, with the advantages of lower ignition temperature, higher activity and surface area, much lower pressure drop and attrition, and easier platinum recovery.

Topsoe described a catalyst upgrade project with Ma'aden Phosphate where the new VK38+ catalyst and increased dust-protection layer depth enabled a safe, tailored de-bottleneck that raised capacity toward 5,000 t/d. The solution balanced pressure-drop and emission constraints, and enabled longer campaign expectations.

BASF summarised the evolution from conventional vanadium shapes to Quattro and additive manufactured X3D catalysts, the latter with the benefit of higher surface area, lower pressure drop, improved SO_3 conversion, energy and caustic savings, and CO_2 and cost reductions from early commercial references.

Monitoring and control

ControlRooms.ai introduced an AI troubleshooting agent that uses multivariate models, pattern matching and explainable reasoning to detect anomalies early, surface probable causes, and integrate into operator workflows. Case studies show earlier detection than alarms.

Ohio Lumex presented the Ei4200 dewpoint/acid condensation probe that detects onset of acid condensation via electrodes on a cooled sensor tip. The device improves sensitivity, supports basic and advanced detection protocols, and includes installation, remote diagnostics and tuning guidance for site-specific thresholding and DCS integration. Finally, Anton Paar presented inline and lab measurement solutions for concentrated H_2SO_4 and oleum, showing field case studies where traditional conductivity or refractive-index meters failed. ■

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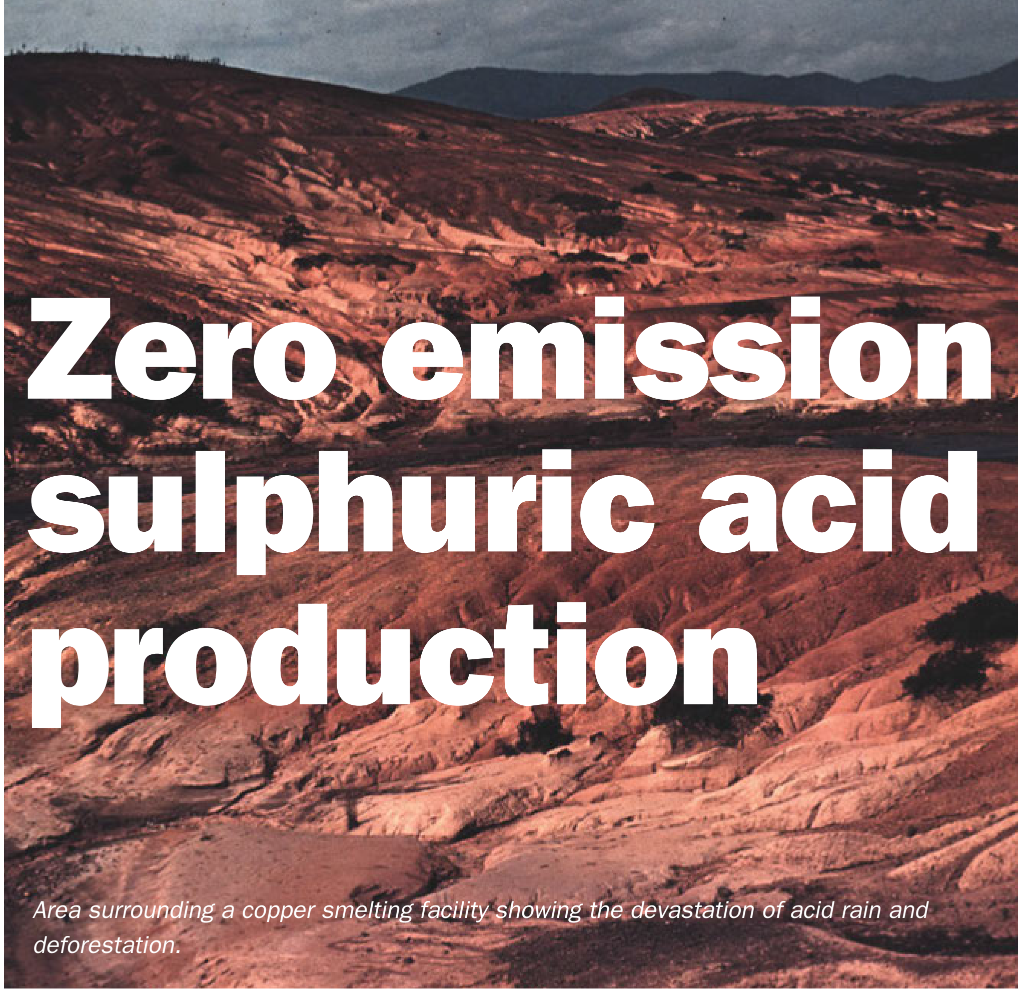
Zero emission sulphuric acid production



Area surrounding a copper smelting facility showing the devastation of acid rain and deforestation.

Recalibrate™ has developed a next generation sulphur burning plant to produce sulphuric acid with ultralow SO_2 and zero NOx emissions, designed to derisk the permitting process and increase speed to market for new sulphuric acid plants. In addition, the proprietary process minimises the added capital cost and operational expenses typically associated with pollution control strategies.

Sulphuric acid production maintains its position as one of the most produced chemicals in the world. With an installed base of over 750 units worldwide, these plants process a variety of sulphur sources including solid sulphur (S), metallurgical off gas (MET), hydrogen sulphide (H_2S), and spent acid (SAR) to produce over 300 million tonnes of sulphuric acid (H_2SO_4) annually. Sulphuric acid is used in large industries critical to human growth, including:

- making fertilizer to grow our food;
- mining metals such as copper, nickel, and lithium critical to making everyday items;
- making steel and other materials used to build our buildings;
- making silicon chips that are the foundation for computers and AI.

As demand grows for these items critical to global infrastructure, demand for sulphuric acid must grow with it.

Regulatory standards challenge new plants

The recent economic climate and the impact of government regulations have caused regional differences in how acid producers conduct operations while staying competitive under new emission standards. Building a new sulphuric acid plant in most of the world has become a formidable challenge. For decades, few new plants have been constructed in the United States. The last large sulphuric acid plant in the US was for fertilizer production and was completed in 2010. A new wave of mining, semiconductor, and re-industrialisation projects is now driving demand for domestic sulphuric acid capacity. From lithium extraction for EV batteries to rare earth processing, semiconductor manufacturing, and fertilizer expansion, industry players need new acid plants quickly but face stringent emissions regulations and lengthy permitting processes that delay and often derail projects.

Current information from industry and environmental consulting firms indicates five to ten years for application approval times. These delays have a profound financial impact: project returns (IRR) can drop by 30% to 50% before production even begins, eroding project value (NPV) by up to 70% compared to initial forecasts.

As an example, the Rosemont Copper Mine in Arizona lost an estimated $3 billion in value after eight years of permitting delays. Certain project components face even greater regulatory challenges. Permitting for sulphuric acid production facilities is known to be particularly challenging.

Learning from the past

Understanding the past can be an important way to understand our future. The US has a rich history with sulphuric acid and shaped many of the technologies and standards used today around the world.

Ducktown Sulphur, Copper and Iron Company

The need for regulatory oversight arose from the manufacturing practices of the 1800s and 1900s where industrial off gases were directly emitted to atmosphere. One of the most well-known cases was the copper smelting operations of the Ducktown Tennessee basin by the Ducktown Sulphur, Copper and Iron Company (DCS&I, 1890-1936, shown overleaf). DCS&I operated an open-roast heap smelting process whereby large quantities of crushed copper ore containing chalcopyrite ($CuFeS_2$), chalcocite (Cu_2S) and covellite (CuS) were piled onto a bed of combustible wood soaked in fuel oil. The company would ignite the bed, leaving it to burn for several weeks to drive off the sulphur as sulphur dioxide SO_2, leaving a concentrated ore for further processing.

SO_2 released by heap smelting, ~80,000 ppm, would react with water in the atmosphere to form acid rain that devastated the surrounding ecology. Following the US Supreme Court ruling in Georgia v. Tennessee Copper Co (1907), DCS&I immediately implemented technology to capture and convert SO_2 vapour into liquid sulphuric acid. The sulphuric acid stream quickly became a major co-product and eventually influenced the decision to restructure the Ducktown Sulphur, Copper and Iron Company into Ducktown Chemical and Iron Company (DC&I) in 1925. DC&I went on to pioneer the advancement of wet scrubbing, leading to technologies still in use today.

Ducktown Copperhill smelter owned and operated by the Ducktown Sulphur, Copper and Iron Company (1939).

How the industry navigated new regulatory standards in the US

The next regulatory evolution was the implementation of the US Clean Air Act which established New Source Performance Standards (NSPS), capping SO_2 emissions at 4 lb per ton of acid produced (approximately 2 kg/t) and acid mist at 0.15 lb/ton. These limits, equivalent to roughly 99.5% sulphur conversion efficiency, were the baseline that all new plants had to meet. In response, the acid industry adopted the double contact double absorption (DCDA) process commercialised in the 1960s and 1970s. The DCDA process uses four reaction beds to achieve the target 99.5% conversion rate. This process was designed to re-route ~2-3% unconverted SO_2 gas from the converter (bed 3) through a new interpass absorber tower to remove most of the sulphur trioxide (SO_3) as H_2SO_4. Gas exiting the interpass absorber would be sent back to the converter (bed 4) at conditions far from equilibrium to reach an overall SO_2 conversion approaching 99.5%. Today companies that operate in regulated nations have adopted the DCDA process as standard technology; however, this decision comes with increased capital and operational costs from the second absorption tower and supporting equipment. Following the US Clean Air Act, regulators further increased standards though two additional enhancements: (1) the introduction of Best Achievable Control Technology (BACT) criteria, and (2) the ability of US State environmental agencies to enforce stricter limits than the federal NSPS regulation. Under the Clean Air Act's amendments, BACT means a new plant can be required to hit the lowest emission level "economically demonstrated" anywhere in the industry. In response, many US States have set permit limits well below the federal 4 lb/ton SO_2 standard to protect local air quality. While the federal SO_2 limit has not changed in over 50 years, meeting only that standard today would fall woefully short of what US state regulators expect.

Improved catalyst to meet lower US state emissions standards

While federal law sets the floor, US states like North Carolina and Nevada have effectively set a higher bar through their permitting. North Carolina's regulators allowed the large Aurora, NC sulphuric acid plant to be built on the condition it use advanced catalyst to cut SO_2 emissions well below 4 lb/ton. The acid industry responded with subsequent enhancements to the DCDA process with the introduction of higher activity catalyst compositions.

Here caesium (Cs) and other proprietary elements are added to the vanadium pentoxide (V_2O_5) base catalyst to lower the starting temperature for a sustained reaction by ~40-60°C. Because the SO_2 oxidation releases heat and the reaction is limited at high temperature, this lower starting temperature enables more SO_2 to be consumed per bed. For example, a caesium promoted catalyst would reach 64% SO_2 conversion in the first pass where the previous generation catalyst would only reach 57% conversion (see Fig. 1). These catalysts enable modern plants to obtain conversions as high as 99.7% SO_2.

Adding equipment for even lower emissions

In Nevada, the new Thacker Pass DCDA acid plant had to include a tail-gas scrubber unit to achieve SO_2 emissions far under the federal limit. For highly regulated environments, tail gas scrubbers are the last line of defence for meeting stringent emission requirements and have been selected as a lower cost alternative to retrofitting single absorption plants with double absorption technology. They are also used in regulatory environments where emissions must be tightly controlled during abnormal plant operations such as upsets, start-ups, or in cases where high SO_2 feed gas compositions must be processed. Tail gas scrubbers are offered in several variations whose selection depends on the plant operator's tolerance for capital costs, operational expenses, and operability. Ultimately, tail gas scrubbing does not eliminate waste SO_2, it only transfers a gaseous pollutant into a liquid or solid stream that must be treated appropriately. For a 1,000 t/d acid plant, caustic costs for the tail gas scrubber could exceed \$600,000 per year. This is equivalent to \$30 million over the life of a 50-year plant.

Case studies

In the following section three modern US case studies are detailed to illustrate the role of environmental regulation on acid plant construction, operation, and the pollution control technology owners choose to adopt.

Freeport McMoRan

The earliest modern acid plant construction project took place at the Freeport-McMoRan Copper & Gold Mine in Safford, (AZ) between 2007 and 2011. The \$150 million project was implemented on remote privately held land ~250 miles east of Phoenix AZ. This facility burns elemental sulphur to supply 1,250 t/d acid for leaching operations and produces power that enables the site to run completely isolated from outside sources. Peroxide tail gas scrubbing was selected early in the design process to target SO_2 levels below 20 ppm

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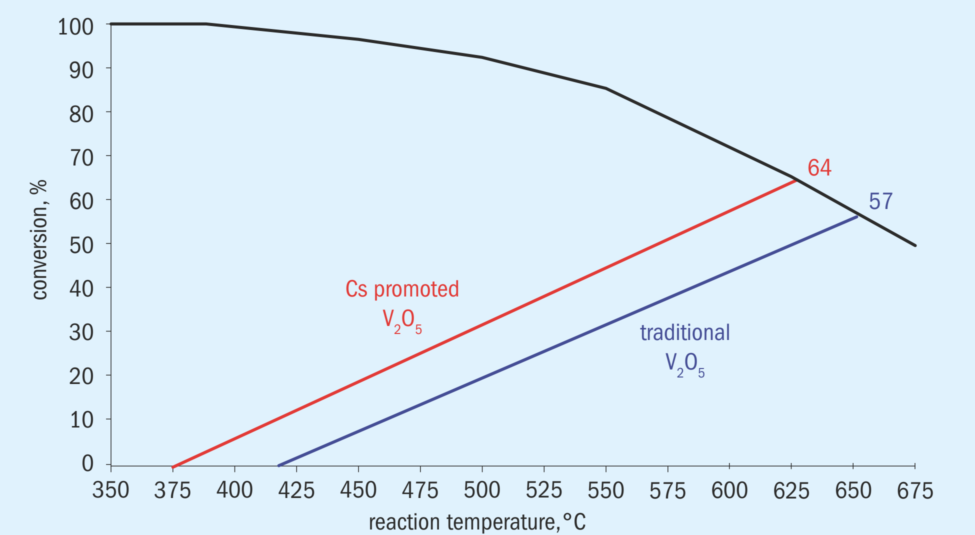
Fig. 1: **SO_2 conversion as a function of temperature rise in the adiabatic reactor for a model traditional and Cs promoted catalyst.**



Source: Recalibrate

and permitting was completed between 2007 and 2009. Two years is a remarkably fast permit time and a testament to what is possible when operators select BACT and are supported by regulators to implement that technology. The site continues to operate and has upgraded its acid capacity to 1,550 t/d as of this writing.

Nutrien Aurora

Near the end of the Freeport project, Nutrien Aurora, NC, formerly Potash Corp of Saskatchewan (PCS), was beginning work to replace its No. 3 and 4 sulphur burning units which were nearing the end of their ~40-year lifetime. The new No. 7 plant was planned to produce 4,500 t/d of acid for downstream manufacturing of phosphate fertilizer and carbon free power for the grid. Like the Freeport facility, Nutrien also chose to operate BACT in the form of caesium (Cs) promoted catalysts and DCDA to reach emission levels below federal and state regulation. Project permitting was simplified due to the site having existing acid plants and the project resulting in a net reduction in total emissions. The No. 3 and 4 plants relied on less efficient 1970s technology and were replaced with a modern unit using BACT. Nutrien continues to operate the No. 7 unit with world class environmental standards to this day.

Lithium Americas Thacker Pass

Most recently, Lithium Americas announced a 2,250 t/d plant in Thacker Pass in Nevada. This first unit is phase one of four planned for the location as part of a $2.23 billion loan from the US Department of Energy. Each phase will use 2,250 t/d of sulphuric acid for leaching operations to produce 40,000 t/a of Li_2CO_3. The high-profile project has attracted numerous challenges from local objectors including cattle ranchers, indigenous tribes, and environmental groups resulting in immense pressure on regulators. Tail gas scrubbing and DCDA were just some of the many elements that contributed to satisfying air quality requirements and ultimately, presidential power under Donald Trump was required to authorise the permit in a timely manner. Unlike the Nutrien or Freeport sites which had existing industrial operations, greenfield sites like Thacker Pass must often meet even more stringent requirements to operate.

Regulations drive sulphuric acid plant technology

The common thread is that each project had to push emissions as low as feasible at the time of construction. Freeport's peroxide scrubber; Aurora's caesium-promoted catalyst; and Thacker Pass's scrubber, were responses to the same underlying pressure – meet or exceed BACT requirements. History has shown that US federal and US state regulators will continue to pass more stringent regulations to further reduce emissions as a result of public pressure.

The next solution: ultralow emission

Recalibrate is offering a next generation sulphuric acid plant with zero NOx and part per billion (ppb) SO_2 and emissions. This is achieved by integrating an air separation unit (ASU) with a patented acid plant of reduced footprint but equivalent acid output. The Recalibrate technology uses pure oxygen from the ASU instead of air. Where enhanced oxygen combustion is a known strategy for lowering emissions, the technology has not been widely adopted due to the cost of generating elemental oxygen (O_2). Through direct integration of the air separation unit (ASU) with the sulphuric acid plant, both processes have been concurrently optimised lowering ASU costs while maximising acid output, steam, and power generation from the acid plant. In a standalone ASU, energy is converted into cryogenic capacity used to separate purified streams of nitrogen (N_2), oxygen (O_2), and argon (Ar) by distillation. Both product purity and composition can be tuned for a trade-off in capital costs and power consumption – the main cost driver for oxygen from the ASU. Furthermore, heat and steam losses have been reduced by integrating the operations together, instead of operating as separate processes.

Recalibrate technology versus a traditional DCDA design

Producers can expect comparable outputs to a traditional DCDA process with heat recovery, and the ratio of outputs can be varied depending on user preferences or geographical requirements. Operators conditioned for today's state-of-the-art DCDA process will find the Recalibrate process easy to adapt and can expect competitive steam, power, and acid outputs. Investors will find an increase in speed to market for new plants due to lower environmental barriers.

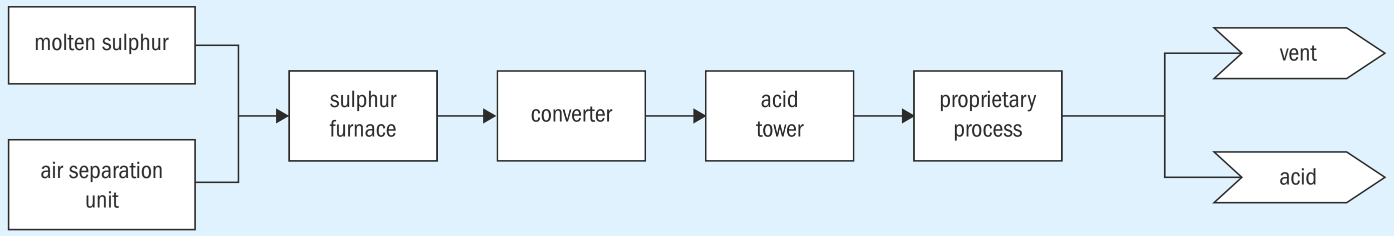
Equipment comparison

Equipment for the acid process remains similar in function to traditional plants (Fig. 2). Operators can still expect a process that feels familiar although the plant layout and unit operations have been modified for an improved design.

Improved operations: Single pass converter and lower catalyst costs

Recalibrate's next generation converter has been engineered to provide better kinetics for SO_2 conversion and improve heat transfer efficiency. The new converter can be expected to cost half that of traditional plants. In conjunction with a proprietary catalyst, an operation can save ~$15 million over 50 years in catalyst for a 1,000 t/d plant.

Fig. 2: **The Recalibrate process showing main equipment**



Source: Recalibrate

Low emissions for better operations and public relations

Any experienced acid plant owner will say that the appearance of the stack is one of the key factors in maintaining good public relations, and there are numerous operational issues contributing to poor stack visibility. The most common problems are stack spitting and acid mist formation. Stack spitting occurs when solid sulphate deposits are formed on carbon steel and then dislodged by fast flowing gas. This is often recognised by the surrounding community when discoloration is noticed on buildings and vehicles. That damage must then be repaired by the plant operator at both a financial and political loss. Acid mist formation is the phenomenon whereby a visible cloud of acid vapour is emitted and usually results from high moisture contents in stack gases. Moisture can be introduced from several upstream operations in the dry section of the plant including:

- mist eliminator damage or gasket leaks;
- poor performance in the drying tower;
- acid mist formation from hot gas entering the absorber tower;
- poor performance of the absorber tower due to an out of balance acid concentration;
- mechanical failure of tower packing;
- steam leaks from economisers, coolers, and other acid / water contact points in the process.

These issues are often difficult to identify and even more difficult to correct. Some problems may require a prolonged reduction in rates or sustained downtime to perform repairs. Like stack spitting, acid vapour results in negative externalities for the surrounding community and will come at an immense cost to plant owners. Recalibrate's technology eliminates the risk of visible stack emissions as the process emits strictly oxygen, nitrogen, and trace argon. There is little risk for SO_2 and acid mist, and no risk of stack spitting or NOx emissions as these are eliminated elsewhere in the process. Even a small traditional DCDA technology plant has a stack with a diameter several feet wide. Recalibrate's technology is much smaller, roughly four inches in diameter for the same capacity plant. Recalibrate's stack visibility is greatly reduced, reducing concerns from the public. Several other key pieces of process equipment have also been engineered with the goal of reducing the visible operating footprint for surrounding communities. Recalibrate's technology enables companies to be persuasive to regulators on technical merits where projects are proposed that beat the strictest emissions rules in the country. Early adopters of this technology will likely find that regulators become allies rather than adversaries. This means faster permitting times, reduced project risk, and faster speed to market.

Steam output comparison

Steam and power are both important coproducts of sulphuric acid production. The process is highly exothermic, so capture and use of that energy as steam or power is critical to the economics of a plant. Two, simplified, base case scenarios are presented comparing the Recalibrate technology against the traditional DCDA design using a 1,000 t/d acid plant basis where either power or steam is the desired coproduct. Steam and power are compared by first addressing the power generation for each case and comparing them. The net power is calculated as the "net power export". The steam only case assumes the only power generated is what is needed to supply both the ASU and acid process (Table 1), resulting in net power export of zero (consumption equals production). The rest of the steam is exported at lower pressure, which can be used as process heat on site.

Here the steam output from the standard technology is nearly identical to the Recalibrate technology, but a cost for higher conversion efficiency is paid in steam pressure. Operators in regions with lower energy costs or with high value use for thermal steam will find the Recalibrate process flexible to fit their needs.

Table 1: **Modelled outputs for a 1,000 t/d acid plant using the Recalibrate process and standard DCDA process with heat recovery maximising thermal steam as the main output**

1,000 t/d sulphuric acid process	Thermal steam (MWt)
Recalibrate technology	57.0 (LP)
Traditional DCDA with heat recovery	57.6 (MP)

Source: Recalibrate

Table 2: **Modelled outputs for a 1,000 t/d acid plant using the Recalibrate process and standard DCDA process with heat recovery maximising power as the coproduct (zero steam export)**

1,000 t/d sulphuric acid process	Net power export (Mwe)
Recalibrate technology	11.4
Traditional DCDA with heat recovery	14.6

Source: Recalibrate

Power output comparison

Table 2 also uses the net power export to compare the technologies for the power only case: all high-pressure steam from the acid plant is converted into electrical power using a steam turbine.

The net power export shows a net power penalty of 3.2 MWe for the Recalibrate process from operating the ASU and resulting higher conversion rate. However, consideration should be given to the scenario where oxygen is already available onsite or where a traditional plant is undesirable due to emissions regulations. The cost of operating the ASU can be offset if oxygen is needed for other onsite processes. Another consideration to remember is speed to market. Speed to market is a significant concern as obtaining mining permits can take eight to nine years on average, and often longer for complete operations. As stated earlier, these delays can cause project returns (IRR) to drop by up to 50% before production begins, eroding project value (NPV) by up to 70% compared to initial forecasts. The Rosemont Copper Mine in AZ lost an estimated $3 billion in value after eight years of permitting delays. The benefits from faster permitting processes offset the impact of reduced power production.

Conclusion

Recalibrate has developed a next generation sulphur burning plant to produce sulphuric acid with ultralow SO_2 and zero NOx emissions. The main features of the technology are:

- smaller and simpler acid plant with a single adsorption tower;
- no NOx emissions from the pure oxygen;
- higher SOx conversion from the pure oxygen and proprietary process and catalyst, leading to almost no SOx emissions;
- small stack (4-inch diameter compared to 4 ft diameter for a 500 t/d sulphur burner);
- no acid mist concerns due to small SOx emissions;
- lower failure risks due to low amount of SOx gas in the system;
- thermal efficiency from integration with an ASU or other form of pure oxygen compared to other enhanced oxygen methods;
- the design scales linearly, no big jumps in capital cost for larger scale systems;
- flexibility to design the plant to tailor the steam or power output to customer requirements;
- potential additional byproduct sales (nitrogen, argon, oxygen) with an integrated ASU.

Recalibrate is actively looking for partners for a demonstration plant, plant number one. The plant is currently configured only for sulphur burning. However, there is a product development pipeline that expands the sulphur feeds to H_2S, sulphuric acid recovery, metallurgical off gas, and industrial SOx.

Recalibrate's development pipeline also includes the ability to produce ultrapure acid and add core elements of the technology to retrofit existing plants to reduce SOx emissions and enhance conversion rates instead of adding a scrubber. The company is also looking for operators in these areas interested in supporting these product development efforts.

This article is based on the white paper "Recalibrate™ – to zero emission sulfuric acid production" by Ben Egelske, Rick Davis, Ron Cloud, Tony Miles, Gerry d'Aquin, Billy Barron, Kris Van Damme, Bob Gulotty, Lee Mitchell.

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Neutralisation of heat stable salts – Part 2

Joel Cantrell of Bryan Research & Engineering (BR&E) and **Clay Jones** of INEOS GAS/SPEC continue their review of neutralisation of heat stable salts. Part 2 focuses on how caustic (NaOH) affects amine chemistry and corrosion and the effects of adding too much NaOH.*

NaOH effects on amine chemistry and corrosion

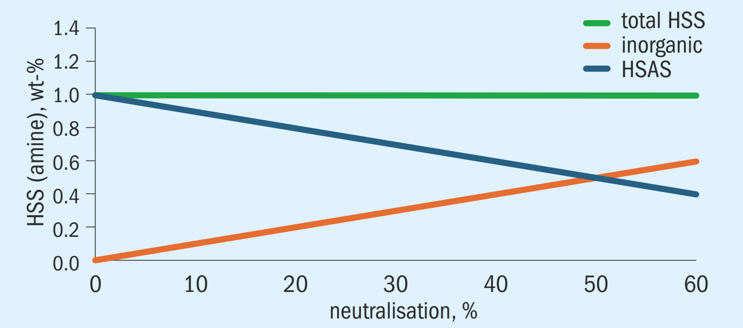
Simulation study

A ProMax® simulation study was used to investigate what happens to ionic speciation when NaOH is added to an amine solution with HSS. The example uses a 34 wt-% MDEA solution with acetate as a contaminant. To simplify the process, only H_2S is considered as an acid gas.

More free amine, no change to ionic strength

Fig. 4 shows the primary intended effect of neutralisation: Heat stable amine salts are converted to inorganic heat stable salts – even though total heat stable salt content is not changed. The simulation study was used to explore what changes are happening at the ionic level. As shown in Fig. 5, one clear and expected

Fig. 4: **Effect of neutralisation on HSS (5,000 ppmw)**



Source: ProMax® simulation courtesy of BR&E

Amine chemistry and corrosion (see Part 1)

$$H_2S_{(aq)} \leftrightarrow HS^- + H^+ \tag{1}$$

$$MDEA + H^+ \leftrightarrow MDEAH^+ \tag{2}$$

$$Fe_{(s)} \rightarrow Fe^{2+} + 2e^- \tag{3}$$

$$2H^+ + 2e^- \rightarrow H_{2(g)} \tag{4}$$

$$Fe_{(s)} + 2H^+ \rightarrow Fe^{2+} + H_{2(g)} \tag{5}$$

$$Fe_{(s)} + 2H^+ + 6H_2O \rightarrow [Fe(H_2O)_6]^{2+} + H_{2(g)} \tag{6}$$

$$2HS^-_{(aq)} + Fe_{(s)} + H_2O \rightarrow FeS_{(s)} + H_{2(g)} + HS^-_{(aq)} + OH^-_{(aq)} \tag{7}$$

$$FeS_{(s)} + 7H_2O \leftrightarrow [Fe(H_2O)_6]^{2+} + HS^-_{(aq)} + OH^-_{(aq)} \tag{8}$$

$$[Fe(H_2O)_6]^{2+} + HCOO^- \leftrightarrow [Fe(H_2O)_5(HCOO)]^+ + H_2O \tag{9}$$

$$[Fe(H_2O)_6]^{2+} + C_2O_4^{2-} \leftrightarrow [Fe(H_2O)_4(C_2O_4)] + 2H_2O \tag{10}$$

$$H_2O \leftrightarrow H^+ + OH^- \tag{11}$$

$$H_2S_{(aq)} \leftrightarrow H^+ + HS^- \tag{12}$$

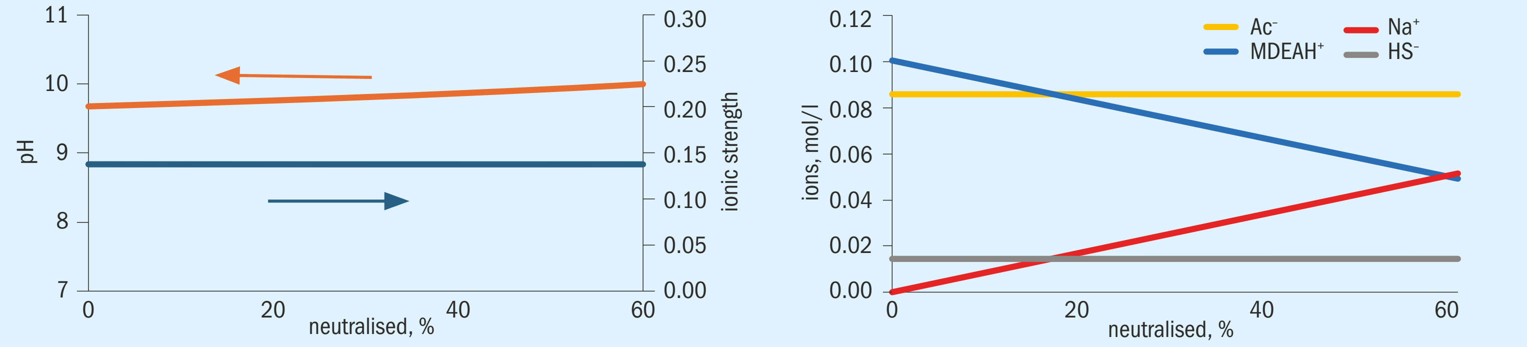
$$H_3C_2OOH \leftrightarrow H^+ + H_3C_2OO^- \tag{13}$$

$$MDEA + H^+ \leftrightarrow MDEAH^+ \tag{14}$$

$$NaOH \rightarrow Na^+ + OH^- \tag{15}$$

$$Na^+ + H_3C_2OO^- \leftrightarrow Na(H_3C_2OO) \tag{16}$$

Fig. 5: **Effect of neutralisation at low loading (0.005 mol H_2S/mol amine)**



Source: ProMax® simulation courtesy of BR&E

**See Part 1 for all References*

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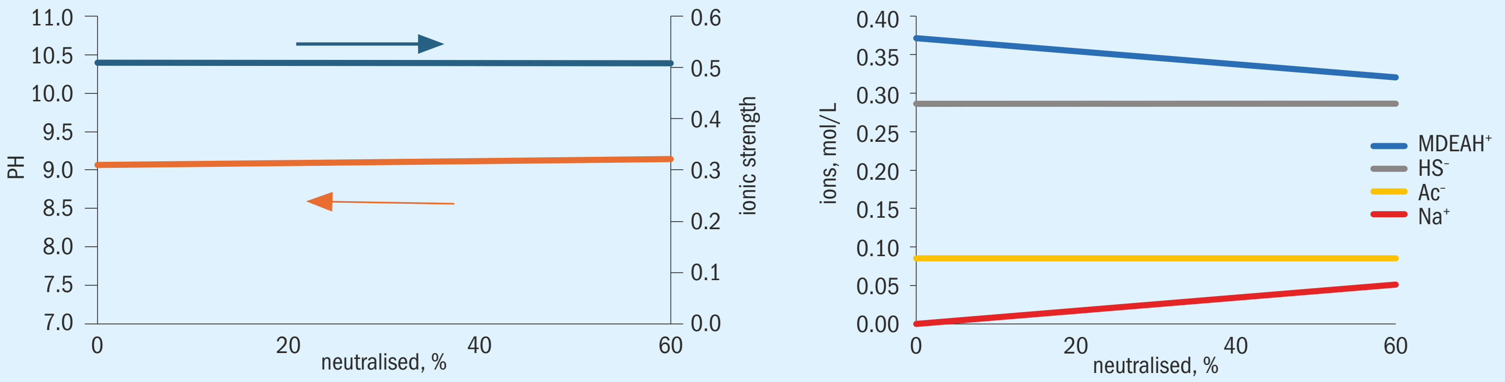
Fig. 6: **Effect of neutralisation at higher loading (0.1 mol H_2S/mol amine)**



Source: ProMax® simulation courtesy of BR&E

effect of adding NaOH is to raise the pH of the amine solution. The shift in pH is due to NaOH supplying OH^- anions to the solution, which consume H^+ through equation 11.

Due to the common ion effect, the increasing pH also frees protonated amine molecules by shifting equation 14 to the left.

This gives us one of the uncontroversial benefits of neutralisation: It converts protonated amine (also called bound amine) into free amine, which restores some incremental capacity to hold acid gas.

An unexpected finding from the ProMax® study is that ionic strength does not change appreciably due to neutralisation, and therefore other properties that depend on ionic strength (electrical conductivity, activity of ions, etc.) should not be expected to change very much either. This makes sense upon reflection: As shown in Fig. 5, the net effect of adding NaOH is to convert $MDEAH^+$ into Na^+, i.e., it changes one cation for another cation in a 1:1 swap without any net increase to the number of charged ions in solution. This simulation result is at odds with observations made in Reference 2 where adding NaOH to an HSS-laded amine solution resulted in higher conductivity in the lab. At this time, no explanation for this difference is offered – it could be an area for further investigation.

Fig. 6 shows the impact of neutralisation of a solution with the same HSS content, but higher loading (0.1 mol H_2S/mol amine). The behaviour of Fig. 5 would be unchanged. However, at higher loading, the H_2S dominates the ionic character of the solution, and the pH is essentially unaffected by neutralisation. Again, Na^+ ions replace the $MDEAH^+$ ions to provide an essentially unchanged ionic strength throughout the range of neutralisation.

Impact on corrosion rate

The effect of neutralisation on corrosion rate is not completely clear, with some evidence existing on both sides.

On one hand, lab work presented in Reference 7 shows that corrosion rate correlates with pH as shown in Fig. 1. This makes sense considering equation 6, which shows that iron corrosion requires a source of H^+ ions, which are generally less available as pH increases. Notably, the experimental work in Reference 7 was done in the absence of H_2S, so the protective influence of iron sulphide was not evaluated. Despite this fact, the data confirm that there is an acidic corrosion mechanism which would always be waiting to exert its influence any time fresh iron is exposed to the solution, e.g., when iron sulphide is removed by chemical solubility, flow-induced drag forces, or mechanical erosion.

Also, reactions between sodium and HSS anions, such as equation 16, are known to happen to some extent. For example, calculations done in Reference 9 suggest that caustic neutralisation might chemically bind approximately half of bicine anions. HSS anions which are partially bound to sodium cations will be less available to participate in the iron complexes which accelerate corrosion, i.e., such HSS anions will be less available to participate in reactions like equation 9 and equation 10.

Finally, there are numerous anecdotal stories of operating plants who report lower corrosion rates and longer amine filter life when they maintain controlled levels of neutralisation. Some of these plants have been following this practice for decades. Stories from the field are emphatically not the same as carefully collected data, but neither should they be rejected out of hand. There is a definite subset of our industry – professionals who operate real world process equipment year after year – which is convinced that neutralisation helps reduce corrosion.

On the other hand, the lab study in Reference 2 concludes that neutralising increases (not decreases) the overall corrosion rate in MDEA systems from 20 to 30 mpy before neutralising to 40 to 50 mpy after neutralising. Findings for DEA systems are less clear cut and may show reduced corrosion rate after neutralising. The authors of Reference 2 also emphasise that the best way to reduce HSS-related corrosion is to get rid of the HSS – a conclusion that bears repeating. Even at its best, neutralisation is a coping mechanism not a remedy. It can potentially extend the length of time between reclaiming or purging amine, but it does not remove HSS or other contaminants from the amine.

Higher lean loading

Another uncontroversial effect of adding NaOH is that it leads to higher lean loading. When HSS contaminants accumulate, they contribute additional H^+ ions to the solution, which drives Equation 12 to the left, converting more of the dissolved H_2S into its uncharged volatile molecular form, which has the net effect of making it easier to strip H_2S to very low levels. This effect was previously introduced in Part 1. Fig. 7 shows the impact on a typical TGU of neutralisation at three different levels of HSS contamination. As the neutralisation increases, the beneficial effect of the HSS on lean loading and treated gas H_2S is diminished. This represents a fixed reboiler duty. For the case of trying to hold lean loading constant, the reboiler duty would be increasing with increasing neutralisation.

Adding NaOH reverses this effect by supplying OH^- ions that tend to consume H^+ to make water by equation 11.

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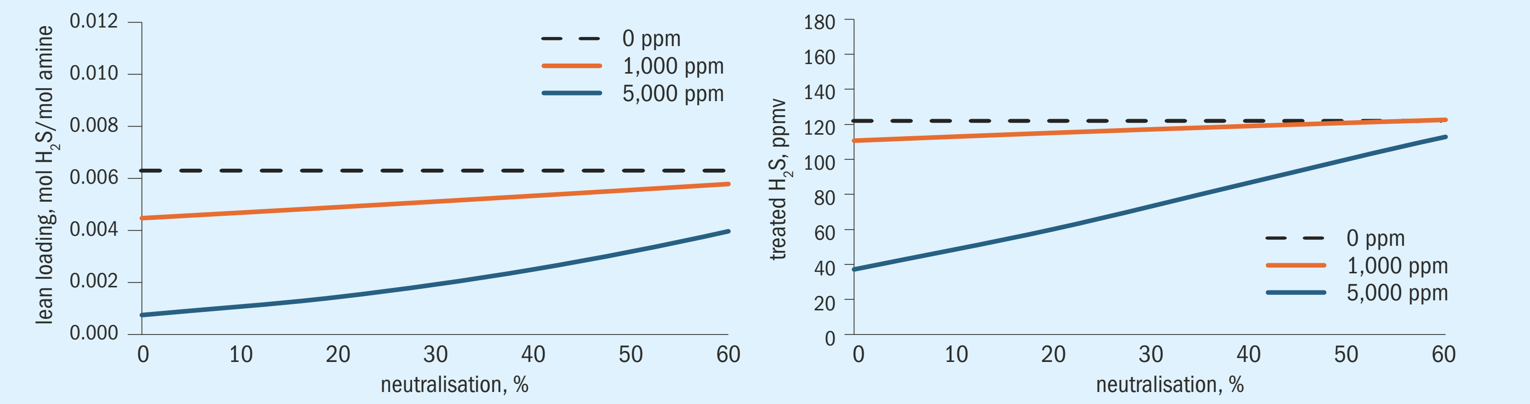
Fig. 7: **Effect of neutralisation on treating performance in a TGU with differing HSS levels**



Source: ProMax® simulation courtesy of BR&E

Numerous real world plant experiences with both intentional and accidental addition of NaOH to the amine have observed this increase in lean loading.

As long as the solution is not neutralised to 100% or higher, i.e. when the molar quantity of NaOH added is smaller than the quantity of acid equivalents from HSS anions, this effect will be limited to cancelling out the beneficial side-effect of HSS. We will soon see that the effect can become more severe if the solution is over-neutralised to approach or exceed 100%.

Lower soluble iron

In plant data, it is often observed that neutralising an amine solution leads to lower concentrations of soluble iron. The plant data sets below are examples.

Earlier we established two mechanisms whereby HSS anions increase the solubility of iron: i) by reducing the pH, which would affect the equilibrium of equation 3 through equation 8, and ii) by attaching to iron cations as ligands, which increase the solubility of iron through Equation 9 and Equation 10. Both of these HSS effects would be reversed by neutralising, thereby leading to a reduction in iron solubility.

For systems with CO_2, another proposed mechanism for this effect was given in Reference 2 which noted that neutralisation raises the solution pH. Higher pH shifts the equilibrium of dissolved CO_2, which primarily exists as bicarbonate HCO_3^-, to have a larger proportion in the form of carbonate CO_3^{-2}. The presence of carbonate and dissolved iron encourages the precipitation of iron carbonate.

Reduced volatility of acids in reboiler

Spooner and Costelow[10] described a regenerator at risk of failure by corrosion due to very high levels of formate at 15,000 to 20,000 ppmw, vs typical max limit of 2,000 to 5,000 ppmw. To extend the service life of the regenerator vessel, they employed a suite of changes to mitigate further damage, one of which was caustic neutralisation. Caustic neutralisation was used in this case to trap volatile formic acid in the bulk amine liquid where it is less corrosive due to the presence of amine. To investigate this claim, a ProMax® simulation was created to roughly match the vapour phase formic acid profiles shown in the paper. The study was not meant to exactly mimic Reference 10, nor to critique the conclusions or methods there, but rather to investigate the claim through detailed analysis of simulation results. The simulated dewpoint liquid for the reboiler vapor was found to have a pH of 7.76 for the base case and 8.15 for the neutralised case. The difference was that neutralisation reduced the volatility of formic acid, as expected. This result shows a directional benefit for neutralisation in cases with severe formate contamination. For more typical levels of HSS contamination, there will be much less volatility of HSS acids, and therefore this effect will not be significant in most amine units – though it is a great trick to keep in mind for extraordinary circumstances.

Plant data

Plant No.1 – Neutralisation leads to lower soluble iron

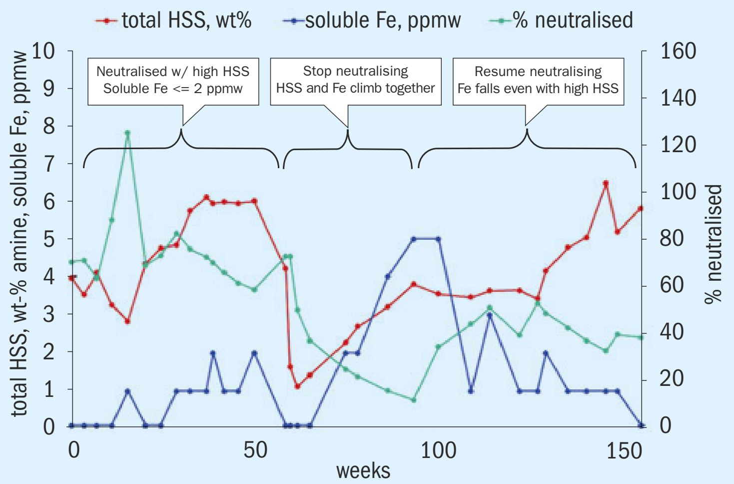
Data shown in Fig. 8 demonstrates a correlation between % neutralisation and soluble iron. Even when Total HSS are high, there is low soluble iron when neutralised. In this unit, HSS are predominantly formate and thiocyanate, which is typical for refinery service.

During the first time period, Total HSS are high at 3 to 6 wt-%, the amine is 60 to 80% neutralised, and soluble iron is low at ≤ 2 ppmw. At the end of this time period, the amine was reclaimed, which resulted in lower HSS and soluble iron.

In the second time period, HSS began to accumulate in the solvent, but the plant did not neutralise the salts. During this time, HSS climb to 3 to 4 wt-% and soluble iron climbs to 5 ppmw.

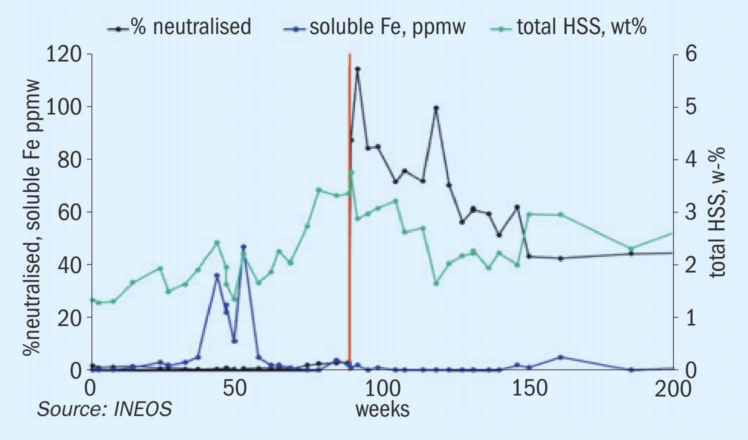
In the third and final time period, the plant resumes neutralising. As the plant comes up to 40 to 60% neutralised, the soluble iron again falls to ≤ 2 ppmw.

Fig. 8: **Plant No. 1 – Neutralisation leads to lower soluble iron**



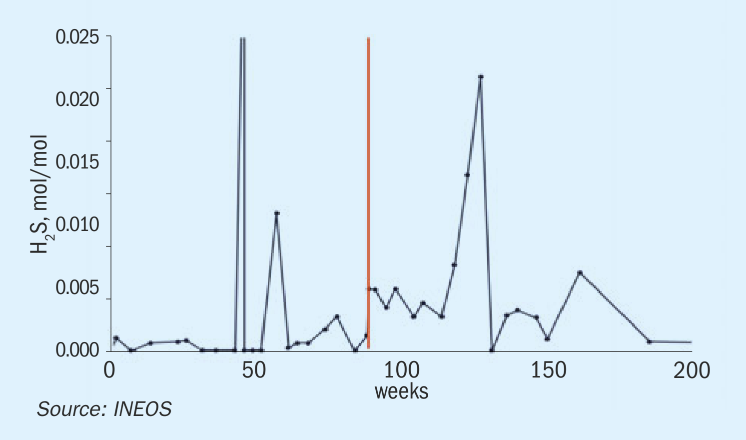
Source: INEOS

Fig. 9: **Plant No. 3, % neutralised, Soluble Fe, Total HSS trend**



Source: INEOS

Fig. 10: **Plant No. 3 lean loading trend**



Source: INEOS

Plant data

Plant No. 3 – Neutralisation leads to less corrosion and longer filter life (anecdotal)

In this H_2S and CO_2 system, the plant reported experiencing corrosion failures and frequent filter changes. They added NaOH to reach 7,000 ppmw Na+ and 100% neutralised (Fig. 9). The plant reported fewer corrosion issues and longer filter life. There was a noticeable increase in lean loading (Fig. 10), but soluble metals did not have a clear response (Fig. 9).

This rather inconclusive example was included in the paper to represent a typical real-world case: plant personnel report a benefit for neutralising, but supporting data are thin.

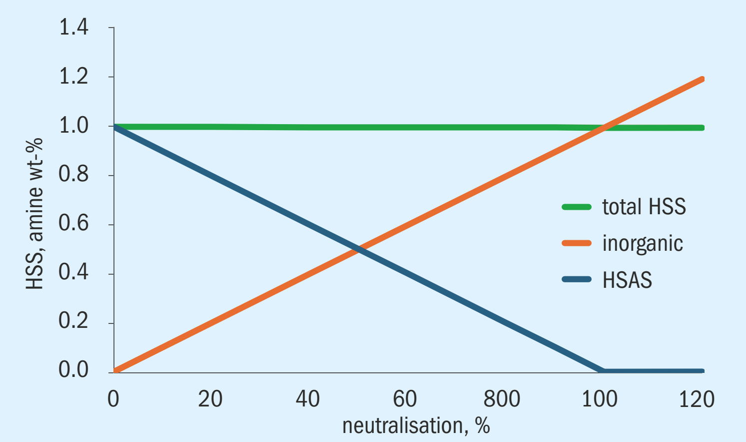
Effects of adding too much NaOH

Simulation study

If some neutralisation is good, is more better? Not usually. Fig. 11 shows a ProMax® simulation HSS chart for the 34% MDEA system with 5,000 ppmw acetate, extended to 120% of neutralisation. Eventually the HSAS drops to zero, meaning that no amine is 'bound' as HSAS.

Fig. 12 explores what is going on with the chemistry for a lower H_2S loading solution. As we continue to increase % neutralisation, the solution pH continues to rise and ultimately the ionic strength also begins to rise as more $[OH^-]$ ions are present. These effects would be expected to correlate with increasing conductivity and will directionally increase the risk of alkaline stress corrosion cracking. While the amine is technically 'unbound' from the HSS at 100% neutralised, the $MDEAH^+$ does not completely disappear, even at 120% neutralisation, due to the presence of the HS^- and OH^-.

Fig. 11: **Effect of over-neutralisation**



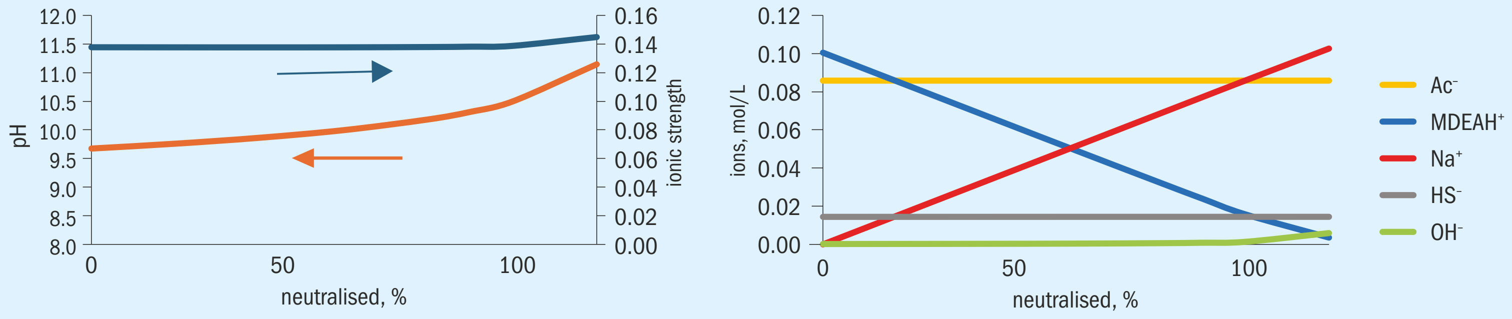
Source: ProMax® simulation courtesy of BR&E

In the case of a more highly loaded solution, over-neutralisation does not change the ionic character of the system substantially. The HS^- dominates relative to the acetate, so neutralisation only increases the pH by 0.1 and the ionic strength remains essentially unchanged.

Increased lean loading, potential for plugging

With respect to lean loading and potential for plugging, the trends which were explained above earlier are extended even further when too much NaOH is added. As the solvent approaches and exceeds 100% neutralised, the impact on lean loading becomes more pronounced. As the amount of excess NaOH increases, it begins to irreversibly trap H_2S in solution as NaHS, which – thanks to the common ion effect and equation 12 – also affects the ability

Fig. 12: **Over-neutralising simulation study**



Source: ProMax® simulation courtesy of BR&E

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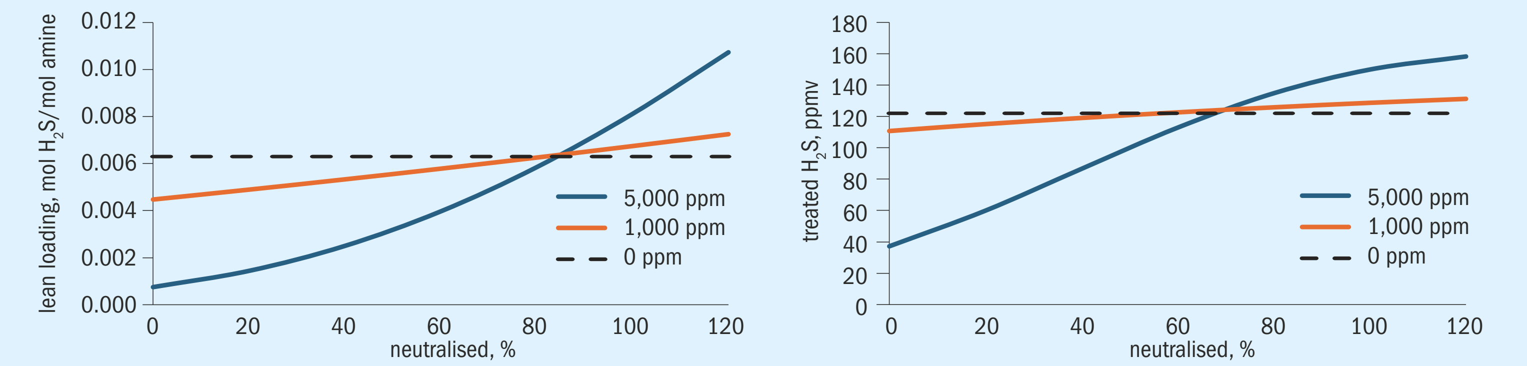
Fig. 13: **Effect of over-neutralisation on treating performance (fixed reboiler duty) in a TGU with varying HSS levels**



Source: ProMax® simulation courtesy of BR&E

of the solvent to pick up additional H_2S. Therefore, there is a further increased risk of more H_2S slip through the absorber and inability to reliably hit treating targets. Note that the impact on treated gas is not always observed, depending on the operating regime of each amine contactor. The effect on lean loading is shown in the following plant data example.

Fig. 13 shows the simulated impact of over-neutralisation on lean loading and treated gas H_2S in a typical TGU. At roughly 85% neutralisation, the lean loading has returned to the level for the case without HSS. Above this point, continued neutralisation leads to further increases in lean loading and H_2S in treated gas.

Potential risks of plugging also increase if a system is neutralised beyond 100%. Precipitates could include sodium salts (e.g., $NaHCO_3$, Na_2CO_3), iron salts (e.g., $FeCO_3$), or corrosion products like FeS which may tend to sluff off during neutralisation[2]. INEOS has direct experience with a refinery which over-neutralised to > 7000 ppmw Na and > 100% HSAS neutralised. This plant experienced severe plugging in their carbon bed which took considerable effort to clean out.

Plant data

Plant No. 4 – Over-neutralisation leads to higher lean loadings

This refinery ARU had unintentional Na^+ and K^+ incursion (Fig. 14) leading to > 100% neutralised solvent. The issue was eventually resolved. Soluble metals were low during the entire time. There was a clear correlation between over-neutralising and higher lean loadings (Fig. 15).

Conclusion

Neutralisation is not a panacea for all problems related to heat stable salts, but it continues to be practiced in industry with positive results. It would also be most advised for systems that are well-monitored with personnel who know their systems and the phenomenon of acid-base chemistry and its ramifications.

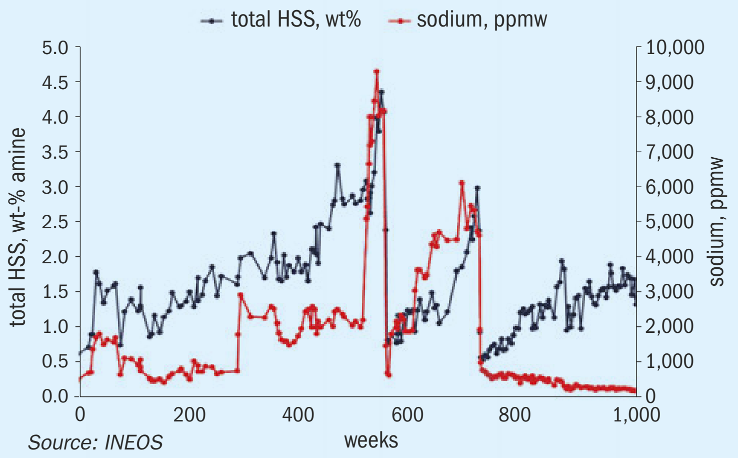
Benefits of neutralisation:

- restores amine's capacity for acid gas pickup;
- lowers corrosion rate (not unanimously agreed);
- can extend time until purge or reclaim is needed;
- low cost, quick to implement, uses materials that are often on-site already.

Potential drawbacks of neutralisation:

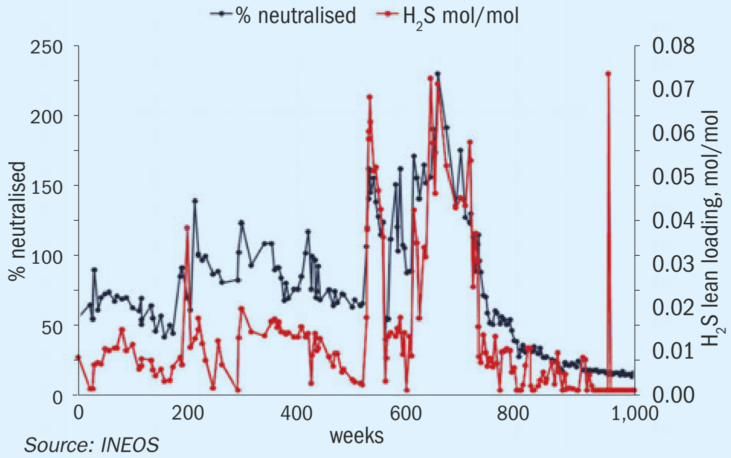
- total HSS level does not change, HSS anions are not removed;
- injecting too much or too quickly can lead to plugging and increased risk of alkaline stress corrosion cracking;
- system now has Inorganic HSS to deal with;
- can increase lean loading which can sometimes hurt acid gas pickup (this is not unique to neutralisation – it can happen with purge and reclaim too).

Fig. 14: **Plant No. 4 total HSS and sodium trend. HSS accumulated relatively steadily and were periodically reclaimed. Sodium incursion was unintentional and was eventually eliminated.**



Source: INEOS

Fig. 15: **Plant No. 4 HSAS % neutralised and H_2S lean loading trends. The correlation between % neutralised and H_2S Lean Loading is apparent.**



Source: INEOS

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Defined, designed, delivered, diagnosed

Mist eliminators in sulphuric acid plants are critical for maintaining production, protecting downstream equipment and minimising emissions, with each type having specific velocity ranges and turndown limits that determine particle-size capture performance. **Graeme Cousland** of Begg Cousland Envirotec reviews different mist eliminator types and some of the operational problems encountered which can be managed by correct installation, targeted cleaning or replacement, and selecting appropriate corrosion-resistant materials.

The duties of mist eliminators in a sulphuric acid plant are significantly important for maintaining production, for protecting downstream equipment and for minimising the environmental impact of its atmospheric emissions. Therefore, the design of the correct type of mist eliminator to meet the efficiency and pressure loss requirements is critical. Equally critical, however, is the understanding of the problems and challenges mist eliminators face during their operational lifetime, and the role played by troubleshooting.

Broadly speaking, sulphuric acid plant mist eliminators come under the following two groupings:

- Demister droplet separators:
    - ○ Knitted wire mesh demisters
    - ○ Co-knitted wire and fibre yarn mesh coalescer/demisters
    - ○ Structured mesh demisters
- Mist eliminator fibre beds:
    - ○ High velocity, impaction type
    - ○ High efficiency, low velocity Brownian diffusion type

The main issues that arise during operation and can affect all above mist eliminators are:

- Blockage by solids, insoluble or undissolved
- Process excursions (e.g. higher temperature, higher acid load) affecting efficiency
- Chemical attack (e.g. HF)
- Corrosion due to diluted acid (e.g. water leaks, humidity ingress)

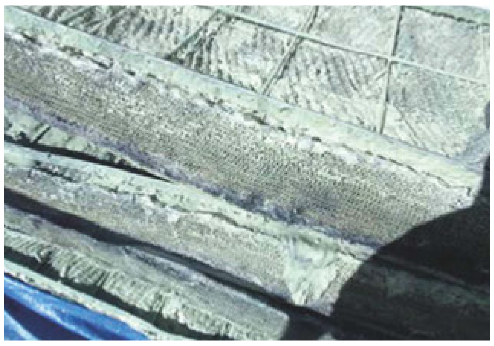

Photo 1: Sulphated demister sections.

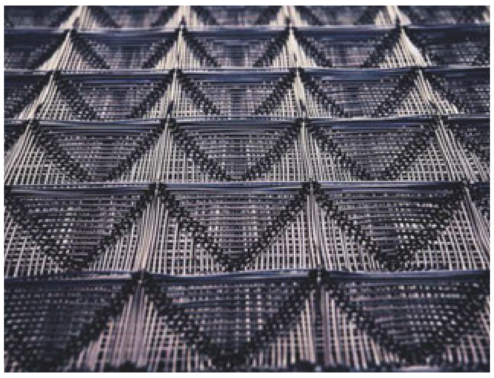

Photo 2: Structured mesh demister layer.

Demister droplet separators

Knitted wire demisters, which catch droplets larger than 5 microns, and coalescer/demisters or structured mesh pads, which catch particles of 2 microns and larger, are traditionally installed horizontally, or conically, in drying towers (some older plants may still have absorbing towers equipped with them still). The typical velocity range is between 2.0 and 3.5 m/s and they have a turndown to 30% before any loss of efficiency would take place.

Designed and sized to give guaranteed pressure loss and efficiency, problems happen when solids begin to block the mesh. The more dense and therefore the more efficient the mesh pad, the faster the blockage increases the pressure loss and causes flooding. The velocity through the remaining free volume of the mesh pad will entrain droplets from the flooded mesh pad. The solids can be ferrous sulphate (full surface or partial surface blockage), atmospheric dust or insoluble particles not removed by an upstream gas cleaning section, sublimed sulphur or nitrosyl crystals.

When inspecting the mesh pad in the tower from above you may be able to see evidence of sulphates (see Photo 1). However, it should already be expected if the recorded pressure loss trend showed a gradual or rapid rise of 30% or more. The demister would need to be cleaned or replaced.

Replacing the mesh pad with a less dense mesh style may slow the rate of blockage but the resultant reduction in efficiency is the trade-off. Installing a structured mesh style, however, is one way that pressure loss can be reduced while maintaining the overall collection efficiency (see Photo 2). Structured mesh pads are also generally easier to wash and re-use.

Corrosion of metal wire mesh (or even support grids) can be identified during an inspection and may be anticipated if acid drainage downstream increases. Corrosion may sometimes be localised, rather than general, and may point to a problem lower down in the tower.

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Photo 3: Shrunken ETFE mesh section.

Depending on operating conditions, required campaign length etc. the choice usually lies between 316L stainless steel, Alloy 20, high silicon alloys (e.g. Saramet 35 or SX) or ETFE fluoropolymer. The latter does not corrode but is heat sensitive and eventually shrinks above 80°C and does not usually last longer than three to four years (see Photo 3). Alternative arrangements, such as 'brickwork' ETFE mesh pad sections can help.

Ensuring that the mesh pads are correctly installed may sound obvious but sadly is often overlooked. If the mesh pad sections are not fitted and compressed in sequence as directed by the supplier's instructions, then you may not get the final section(s) in place. Worst case, unbelievably, is to find that the external contractor decides unilaterally to cut the mesh, thereby destroying the intentional oversize compression fit – resulting in gaps between adjacent sections and no mesh circumferential seal around the shell and therefore gas by-pass. Distances between the support grids on adjacent demister sections should be equal. Order a roll of extra, spare mesh which can be used to create a circumference seal against the shell where it is not truly round.

Photo 4: General solids in a standing filter.

Photo 5: Sulphur sublimation in a standing filter.

Additionally, ensuring correct installation also means that the demister is securely held in position against the upward gas flow. The fixing method should be strong enough to hold every section in place even when the mesh pad is being blocked. Only using tie wire is often insufficiently strong. Angle section hold-down bars on top or hook-bolt and clamp sets from below are recommended.

Troubleshooting such matters above is always good when a physical inspection can be made. During operation there are other tasks that need to be carried out regularly to monitor the demister's performance:

- Keep a record of the pressure loss to observe trends, up or down, and the rate of change.
- Do regular stick tests to check on changes of efficiency – sizes and quantities of acid burn marks on the stick, which can be photographed and kept for later comparison.
- Carry out sight glass observations, if possible.
- Record downstream acid drainage rates and changes.

Mist eliminator fibre beds

There are four 'collection mechanisms' applicable to mist elimination: impaction, interception, coalescence and Brownian diffusion. The impaction type of mist eliminator works purely mechanically, passing the acid particle-laden gas through, variously, coarse glass fibres and/or knitted wire mesh layers, often comprising multi-media materials. These materials are lighter density fibre beds, relying on the momentum of the acid particles to hit a fibre or wire and be collected, draining away from the gas flow. Used in drying towers and in final absorbing towers, they are generally between 1.0 and 1.6 m long, standing on a supporting tubesheet, so that the gas passes from inside to outside and the collected acid drains down the outer surface. Efficiencies vary according to the composition of the filtration media, but their efficiency reduces below 3 microns and they have little effect below 1 micron.

The typical velocity range is between 1.5 and 2.5 m/s and they have a turndown only to 50% before any loss of efficiency would take place. That means they must be carefully designed for duties with varying gas flow conditions, since at slower gas speeds through the filtration media acid particles can slip-stream past the fibres and wires. As an analogy, imagine riding a motorcycle through a forest – at high speed you would not be able to avoid hitting a tree, but at slower speeds you can weave your way between them. There is also a risk in a final absorbing tower of a visible stack plume if the regime in the tower changes due to a process upset or upstream equipment problem, generating more mist below 3 microns.

The Brownian diffusion type of mist eliminator uses all four mechanisms, but it is Brownian diffusion that gives the ability to collect sub-micron acid aerosols as well as larger particles and droplets. For optimum Brownian diffusion the gas would pass through the dense, saturated bed of small diameter glass fibres at a speed in the range of 0.05 to 0.25 m/s. Within that velocity range the sub-micron aerosols move randomly due to the random motion of the gas molecules and then contact a fibre where they are collected drop-wise or film-wise, before draining down the exit surface of the mist eliminator. The analogy here involves you walking carefully between trees in a dense wood, but gusts of wind push you onto trees. The slow gas velocities required mean that long mist eliminators can be used, hanging or standing, and many of them to keep the pressure loss within a reasonable range.

Typically, the emissions from absorbing tower Brownian diffusion mist eliminators will be below 30 mg/Nm^3 and mostly less than 20 mg/Nm^3 which means the stack will be optically clear. As the performance of Brownian diffusion mist eliminators can be guaranteed even with a turn-down to 30% it makes them invaluable for both intermediate and final absorbing towers.

When inspecting standing type mist eliminators in the tower, the inlet surface is the inside, which is visible from below. It is important to check the inside for signs of solids blockage (see photos 4 and 5) and, visible from above, for signs of sulphate deposits/formation. With a set of long, standing filters, it is difficult to see properly those in the middle as well as the

Photo 6: Nitrosyl crystals.

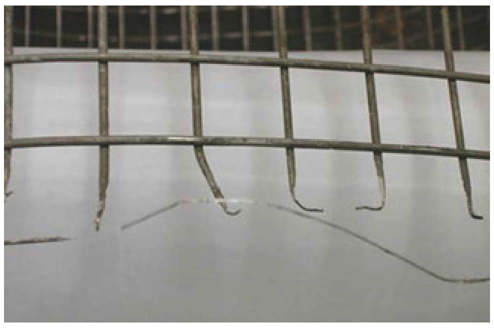

Photo 7: Corroded cage wires at the bottom.

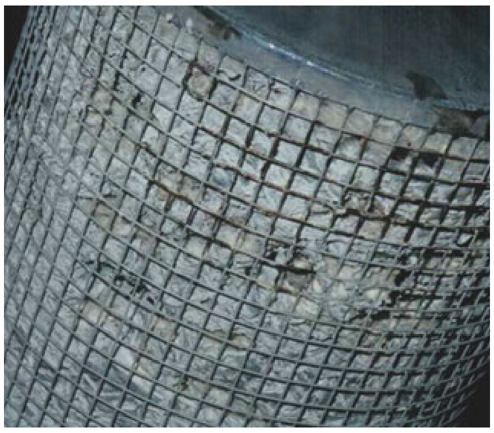

Photo 8: Glass fibre corrosion by HF at top of filter.

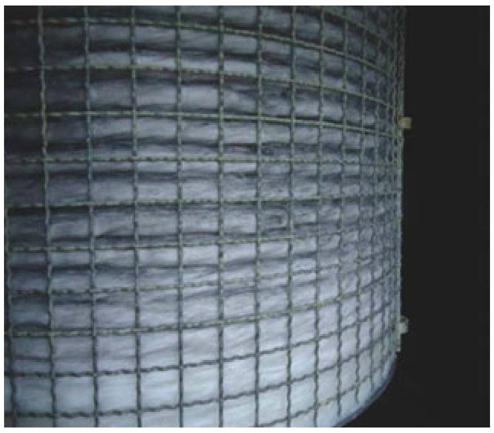

Photo 9: Glass fibre rope corrosion by HF.

central area of tubesheet and flange sealing. With hanging type mist eliminators, however, they can usually be inspected in the tower from below (looking for signs of solids on the fibre) and from above. In the case of fibre bed blockage by nitrosyl crystals, these are opaque and are not visible in and against the white glass fibre (see photo 6). In addition, from above the tubesheet it is possible to check bolting and flange/gasket seals of all the hanging type filters installed.

Corrosion of mist eliminator structures is initially found at the bottom of the structure, where a small amount of acid remains undrained from the fibre and which gets diluted by humidity, for example. The cage wires being the thinnest material involved are then corroded and, if they are welded to a flange or plate, the structure's integrity will begin to fail (see photo 7). When there is fluorine present in the gas, this will form HF which corrodes glass fibre, randomly and initially visible near the top of a mist eliminator (see photos 8 and 9). As the glass fibre bed thins and develops holes, there can be a noticeable decrease in pressure loss and a loss of efficiency seen on stick tests.

Good practice, when opening a tower during a shutdown, is to take general photos from the manway before any workers enter the tower. That way you can potentially see evidence of flange leakages (e.g. wet areas vs dry areas, traces of flange gas by-pass on tubesheet) before a team's boots disturb everything and cleaning begins. Simple, avoidable things happen like incorrectly torqued or missing bolts which mean that the flange/gasket seal is compromised and gas by-pass takes place.

Maintenance of demisters and mist eliminators

Cleaning a knitted mesh pad is not always easy. Using a hot water lance spray can be effective, but when there are solids in the middle layers of the mesh pad, it is a challenge. Even when there are only sulphates on the middle of the demister (fallen down from the carbon steel exit duct), failure to wash these away can lead to weak acid formation and wire mesh corrosion.

Care should be taken when the demister sections are removed from and re-installed into the tower. As previously mentioned in the comments on a demister's compression fit, the workers should expect a degree of resistance when removing the central sections. Damage done at this point can compromise the demister when the sections are re-installed. Bending of support grids and crushing of the mesh pad's sides can be hard to repair but would lead to gas by-pass if left untouched (see photo 10).

Photo 10: Demister sections damaged a lot.

It is also the case that repeated handling of mist eliminators involves risk of damage. However careful a crane operator tries to be, a 3.66 m long mist eliminator swinging out from, or back into, a tower manway or tubesheet hole can be damaged by hitting the circumference of the hole through which it is being lifted.

When cleaning the fibre beds of mist eliminators, care should be taken not to damage them by too high hose water pressure, or rapid lifting out of wash tanks causing excessive hydraulic stress on the fibre or by careless handling. After the final washing step (see Washing Guide on www.beggcousland.com) both demisters and mist eliminators should be dried as much as possible to avoid weak acid formation when back in operation. When deciding whether to wash or replace mist eliminators, it is unusual for an impaction type to be usable after a second washing. Brownian diffusion type can require washing due to general solids or sulphur sublimation, but in the case of the former reason it should be justified by a significant increase in pressure loss and not as a routine activity. It is not 100% effective in reducing the pressure loss to the original, clean state. Using an experienced, specialist company to do the washing is advisable, if available.

Taking care of your operating, maintenance and other procedures is a key target when getting the most life from your mist elimination equipment. Begg Cousland Envirotec understands how to customise mist eliminators for optimum performance, how to produce them reliably and how to assist customers with the troubleshooting assistance needed. Defined, designed, delivered and diagnosed.

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Catalyst unlocks new performance opportunities

In this real world case study, **Martin Ariel Alvarez** and **Mårten Nils Rickard Granroth** of Topsoe A/S demonstrate how cost effective catalyst changes can result in significant production increase without any equipment changes or revamps, all while maintaining compliance with emission limits.

Legislation on SO_2 emissions and shifting market dynamics have long been key drivers of innovation in the sulphuric acid industry. For acid producers, the challenge of increasing throughput without compromising emission levels remains a top priority. However, stricter SO_2 limits and the high costs of major revamps with lengthy payback periods make this goal increasingly difficult to achieve.

Traditional methods of boosting production eventually reach their limit. Further increase of gas flow is often not feasible due to blower constraints, and no more caesium catalyst can be added to avoid that stronger feed gas causing high emission. So, what options remain for plants that have already implemented all the usual upgrades but still need to push production further?

To address these challenges, Topsoe introduced the VK38+ catalyst in 2020 – a highly potassium-promoted solution designed to tip the scales and meet modern operational demands. Five years later, VK38+ has demonstrated its superior performance, with over a dozen successful references worldwide, some already entering their second campaigns with this catalyst.

This article shows a real-world case study from a sulphur burner unit associated with a large-scale fertilizer complex. The operator had through hard and diligent work succeeded in improving most performance metrics, but being ambitious, they wanted to increase productivity further. As is the case for many debottlenecked plants, the blower was already running at maximum capacity, and the pressure drop across the plant prohibited further flow increases. By working with Topsoe and implementing a solution including VK38+, the plant achieved a significant production increase without any equipment changes or revamps, all while maintaining compliance with emission limits. Best of all, the investment in the catalyst is estimated to be paid back in less than one campaign.

Table 1: **Overview of the three sulphuric acid trains**

Plant	Train A	Train B	Train C
Type of plant	Sulphur burning	Sulphur burning	Sulphur burning
SO_2 source	Elemental sulphur	Elemental sulphur	Elemental sulphur
Original capacity, t/d	4,500	4,500	4,500
De-bottlenecked capacity, t/d	5,000	5,000	5,000
Designer	Metso	Metso	Metso
Configuration	3+1 DCDA	3+1 DCDA	3+1 DCDA
Start-up	2011	2011	2011

Source: Topsoe

The sulphuric acid plants

In the production of any commodity, operational excellence is key to turning a profit. Sulphuric acid is no exception and across the globe producers are continually seeking to boost production capacity, implement better operational practices and comply with increasingly stringent SO_2 emission legislation. This case study reports on the successful implementation of a new Topsoe catalyst to boost acid production at a large-scale fertilizer complex.

Since its start-up in 2011, the complex – comprising of three world scale production trains (A, B, and C), each originally designed for 4,500 t/d of sulphuric acid – has consistently pushed the boundaries of performance, striving for record-breaking throughput while maintaining a strong focus on sustainability and emission compliance.

From the very beginning, the fertilizer company relied on Topsoe sulphuric acid catalysts in all three trains and has worked closely with Topsoe to continuously optimise and maximise production in a partnership of over 15 years. The initial catalyst loadings for the trains were specifically designed to achieve maximum capacity, incorporating not only standard products like VK38 and VK48, but also specialty solutions such as VK38 25 mm for dust protection, as well as VK59 and VK69 (see Fig. 1). These advanced catalysts help mitigate factors that could otherwise limit production, such as pressure drop accumulation in bed 1 or increased emission levels.

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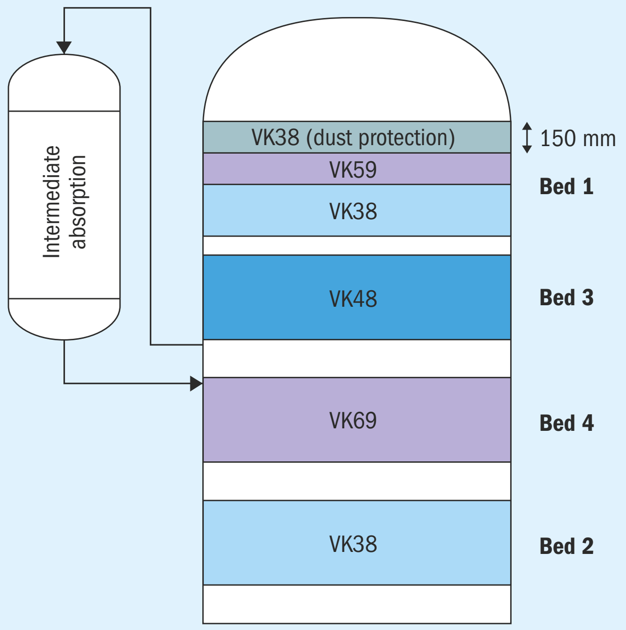
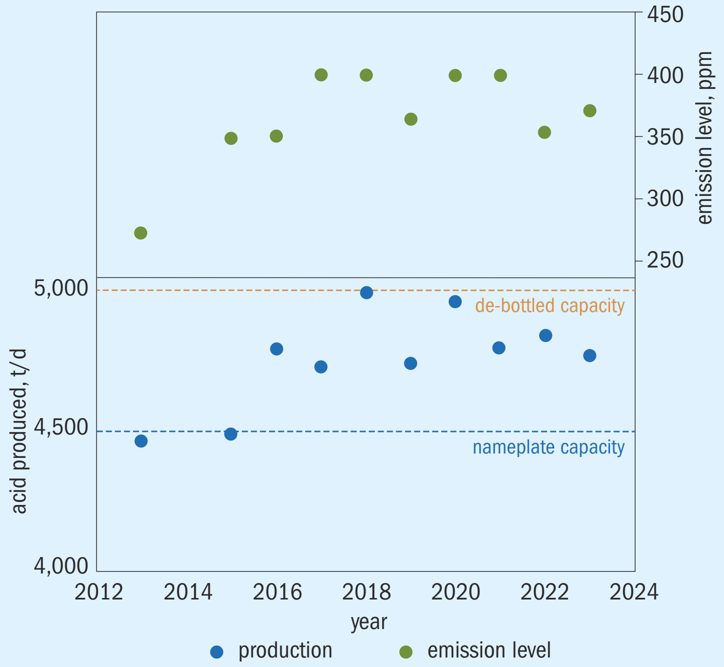
Fig. 1: **Schematic loading of the converters at Trains A, B, and C**



Source: Topsoe

Fig. 2: **Acid production and emission level for Train C**



Source: Topsoe

Over these many years, the plant has operated at the limit of emission levels and has been able to achieve production capacities above its nameplate capacity (Fig. 2). All three trains have operated at approximately 4,700 to 5,000 t/d of acid for campaigns lasting 36 months.

Having a highly active catalyst available is an important enabler for ensuring maximum capacity; however, it is not the only one. Many other factors have also been addressed by the company to achieve this goal.

Boosting acid production even further in Train C

Even though for more than ten years the plant has been able to operate above nameplate capacity, when the new highly active catalyst, VK38+, was introduced the fertilizer company requested Topsoe to conduct a study on the feasibility of utilising the extra activity of this new catalyst to increase production even further.

Topsoe worked together with the company to evaluate different alternatives and analysed the various bottlenecks that would need to be addressed in order to increase acid production for Train C, which was scheduled to be the next one to have its turnaround at that time.

The sulphuric acid trains are S-burning plants, which for a double absorption plant effectively means that production can only be increased by burning more sulphur:

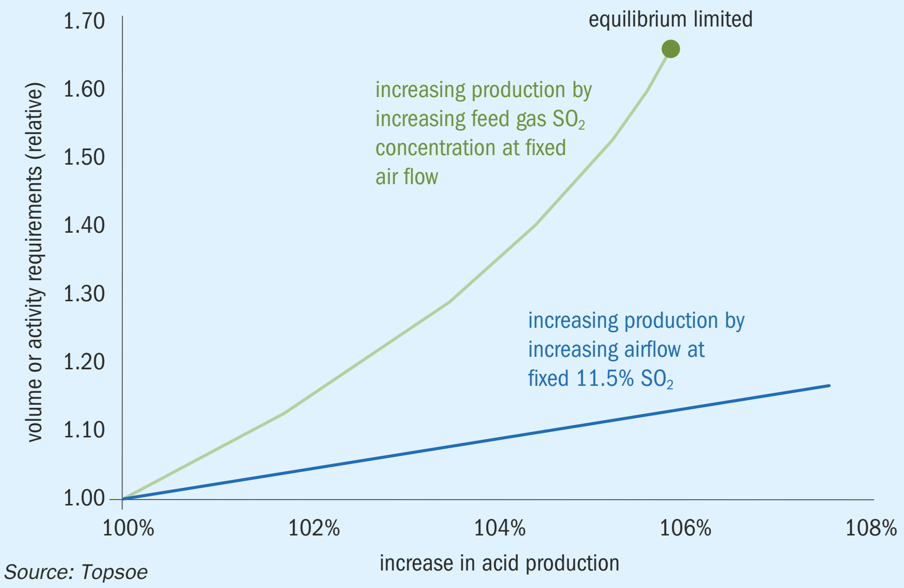
- If more sulphur is burned and the airflow is increased simultaneously, production will increase and the SO_2 concentration of the feed gas will remain at the same level.
- If more sulphur is burned but the airflow remains constant, production will increase, but the SO_2 concentration of the feed gas will also increase (and the O_2 level will decrease).

If the catalyst loading is not upgraded, SO_2 emissions will increase in both cases. However, the pros and cons of each option are different. Which option is best, depends on the specific case and plant.

In general, for S-burning plants operating above 11.5% SO_2, the first option (increasing production by increasing airflow) will require some catalyst upgrade (more catalyst volume or more active catalyst), but not as much as the second option (increasing production by increasing the feed gas SO_2 concentration). However, increasing the flow results in a higher pressure drop across the unit, which may not be possible for the blowers to accommodate.

The second option (increasing production by raising the feed gas SO_2 concentration)

Fig. 3: **Catalyst requirements needed to achieve increase in acid production at a fixed SO_2 emission in a S-burning plant at 11.5% SO_2**



Source: Topsoe

Table 2: **Summary of business case**

	Proposal	**Benefit**
Catalyst work	Bed 1 fresh catalyst filling, replacing VK38 with VK38+. Screening and topping up additional beds.	
Production capacity	+6%, comparing against 4,750 t/d (present conditions, EOR) +1.3% compared against 5,000 t/d (maximum capacity ever reached)	Additional sulphuric acid production.
Bed 1 volume reduction	-15%	Lower pressure drop in bed 1 (might increase campaign length)
Bed 1 dust protection layer	Increase from 150 mm to 200 mm	Potential for slower buildup of pressure drop in bed 1 (might increase campaign length)
Air flow increase	**+5.2%**	Blower can handle increased flow. No investment needed.
SO_2 concentration inlet converter	**11.70-11.80% to 11.95%-12.00%**	Marginal increase, manageable without new investment.
SO_2 emissions	Unchanged	No increase in emission level

Source: Topsoe

could, in principle, be attractive because it does not increase the pressure drop. S-burning plants do not experience the catalyst high-temperature limitation that some other types of plants have, as they operate with SO_2 concentrations around 10–12%. However, this does not mean the SO_2 concentration can be increased indefinitely, as there may be other equipment limitations (e.g., the furnace) that cannot operate at much higher SO_2 concentrations and temperatures than originally designed.

Another potential bottleneck for this second option, is the reduction in the O_2:SO_2 ratio, which can significantly increase the volume or activity required to keep the emissions below limit. This is especially true in plants already operating at or above 11.5%, since above this concentration the necessary increase in catalyst volume/activity to avoid an increase in the emission level is exponential (see Fig. 3).

Fig. 3 showcases in the X-axis the increase in production for a plant operating originally at 11.5% and a maximum emission level that cannot be exceeded.

If the increase in production is made by increasing the airflow (blue line) and keeping the feed gas at 11.5% SO_2, the catalyst volume/catalyst activity requirement increases linearly.

Table 3: **SOR Apr-2021 vs. SOR Apr-2024**

Date	**Acid production** (t/d)	**Date**	**Acid production** (t/d)	**Extra production** (t/d)
1 Apr 2021	4,982	1 Apr 2024	5,014	+32
2 Apr 2021	4,997	2 Apr 2024	5,039	+42
3 Apr 2021	5,004	3 Apr 2024	5,046	+42
4 Apr 2021	4,992	4 Apr 2024	5,056	+64
5 Apr 2021	4,994	5 Apr 2024	5,082	+88
6 Apr 2021	5,006	6 Apr 2024	5,087	+81
7 Apr 2021	4,999	7 Apr 2024	5,053	+54
8 Apr 2021	4,995	8 Apr 2024	5,042	+47
9 Apr 2021	5,000	9 Apr 2024	5,040	+40
10 Apr 2021	5,002	10 Apr 2024	5,040	+38
11 Apr 2021	4,980	11 Apr 2024	5,042	+62
12 Apr 2021	5,003	12 Apr 2024	5,065	+62
13 Apr 2021	4,999	13 Apr 2024	5,063	+64

Average emission level during this period: 400 ppm (SOR 2021) vs. 401 ppm (SOR 2024)
Source: Topsoe

However, If the increase in production is made by increasing the SO_2 concentration and keeping the airflow constant in its original value (green line), the increase in catalyst volume / catalyst activity turns quickly exponential. For S-burning plants, very high SO_2 concentrations could not be thermodynamically possible, due to the equilibrium not permitting high enough conversion in the temperature where the catalyst is active.

In many cases, one would utilise a high activity caesium catalyst in the last bed to counteract the less favourable gas composition. In this particular case, this solution had, however, already been employed during the original design of the plant to allow it to achieve the high name plate capacity with a somewhat smaller plant than otherwise would have been possible. Furthermore, the company had already taken advantage of the highly active caesium catalyst VK69 in bed 4 when pushing the production well over name plate capacity, resulting in plants operating close to the emission limit.

The plant in this case was therefore a case of a unit operating at the maximum capacity permitted by emissions, with the last bed fully loaded with caesium-promoted catalyst. Traditional approaches would have indicated that the limit had been reached. However, with the new highly active catalyst VK38+, there was an

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Table 4: **EOR Sep-2023 vs. SOR Apr-2024**

Date	Acid production (t/d)	Date	Acid production (t/d)	Extra production (t/d)
18 Sep 2023	4,684	1 Apr 2024	5,014	+330
19 Sep 2023	4,664	2 Apr 2024	5,039	+375
20 Sep 2023	4,690	3 Apr 2024	5,046	+356
21 Sep 2023	4,686	4 Apr 2024	5,056	+370
22 Sep 2023	4,496	5 Apr 2024	5,082	+586
23 Sep 2023	4,646	6 Apr 2024	5,087	+441
24 Sep 2023	4,694	7 Apr 2024	5,053	+359
25 Sep 2023	4,670	8 Apr 2024	5,042	+372
26 Sep 2023	4,684	9 Apr 2024	5,040	+356
27 Sep 2023	4,646	10 Apr 2024	5,040	+394
28 Sep 2023	4,711	11 Apr 2024	5,042	+331
29 Sep 2023	4,701	12 Apr 2024	5,065	+364
30 Sep 2023	4,662	13 Apr 2024	5,063	+401

Average emission level during this period: 383 ppm (EOR 2023) and 401 ppm (SOR 2024)
Source: Topsoe

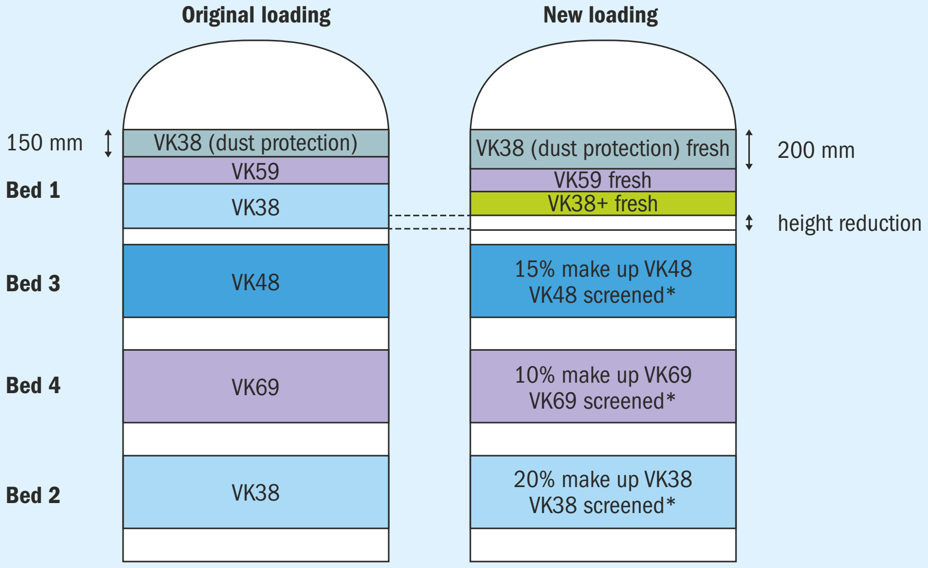
opportunity to boost the production further.

The Topsoe team used their proprietary simulation models and found that there was still room to further increase acid production by combining an increase in SO_2 concentration to around 11.9% to 12.0% (from 11.7 to 11.8%) with an increase in airflow to approximately 400,000 to 410,000 Nm^3/h (from 370,000 to 385,000 Nm^3/h). These new conditions would result in an acid production increase of around 6%, without raising emission levels if the catalyst loading was upgraded. The additional activity required for the new conditions of higher SO_2 and higher flow would be provided by using VK38+ in bed 1 and a top-up with fresh catalyst for bed 2 (20% make-up VK38), bed 3 (10% make-up VK48) and bed 4 (10% make-up VK69).

When this option was presented to the fertilizer company, they confirmed that there was some room to increase the SO_2 concentration to 11.9% to 12.0% (from 11.7 to 11.8%), but not beyond that due to plant and equipment constraints. On the other hand, the blower had adequate capacity for the new airflow, but there was a concern that under the new, higher flow conditions, the pressure drop across bed 1 could limit capacity for the latter half of the campaigns.

To address this concern, Topsoe showed that since VK38+ has higher activity than VK38, the bed 1 could be short loaded even for the new, more demanding, conditions, thereby reducing the pressure drop over bed 1. Additionally, although 150 mm of dust protection catalyst in the first pass has worked very well previously in these plants, it was proposed to capitalise on the extra available height and increase the dust protection layer to 200 mm to increase dust capacity further. The 150 mm layer used to this point had allowed the trains to achieve three-year campaigns on multiple occasions, however with the larger dust capacity the intention was to be able to increase this further. Extra dust capacity could also come in handy should the capacity boost lead to an increased dust load. The final proposal for increasing production is shown in Fig. 4.

Fig. 4: **Upgraded catalyst proposal for increased production capacity**



** Screened catalyst is from different ages: 2011/2014/2017/2020.*
The turnaround from Train C was scheduled for 2023. Source: Topsoe

Business case

The fertilizer company prepared a business case to evaluate the benefits and payback period of the new catalyst upgrade. In other words, they calculated how long it would take to recover the cost of the new catalyst through the additional earnings from increased acid production (see Table 2).

A very conservative return on investment, considering an increase of +64 t/d per day (compared to the maximum capacity ever reached for Train C, 5,000 t/d), was calculated by the company. They determined a payback period of 1.5 years.

This return on investment is conservative, as it does not account for savings from reduced pressure drop or extended campaign durations. Furthermore, it compares the new, higher production level to the previous maximum output. In reality, when compared to the plant's current operating level, the increase would be more than 300 t/d, not just 64 t/d. In any case, even under those conservative assumptions, the payback period was very attractive (the investment would be recovered in half a campaign).

The proposal was approved by the fertilizer company, and the catalyst loading was upgraded.

Results from real operation of Train C WITH VK38+

The fertilizer company started up Train C with the new loading at the beginning of 2024 and shared the production results.

The new production with the upgraded

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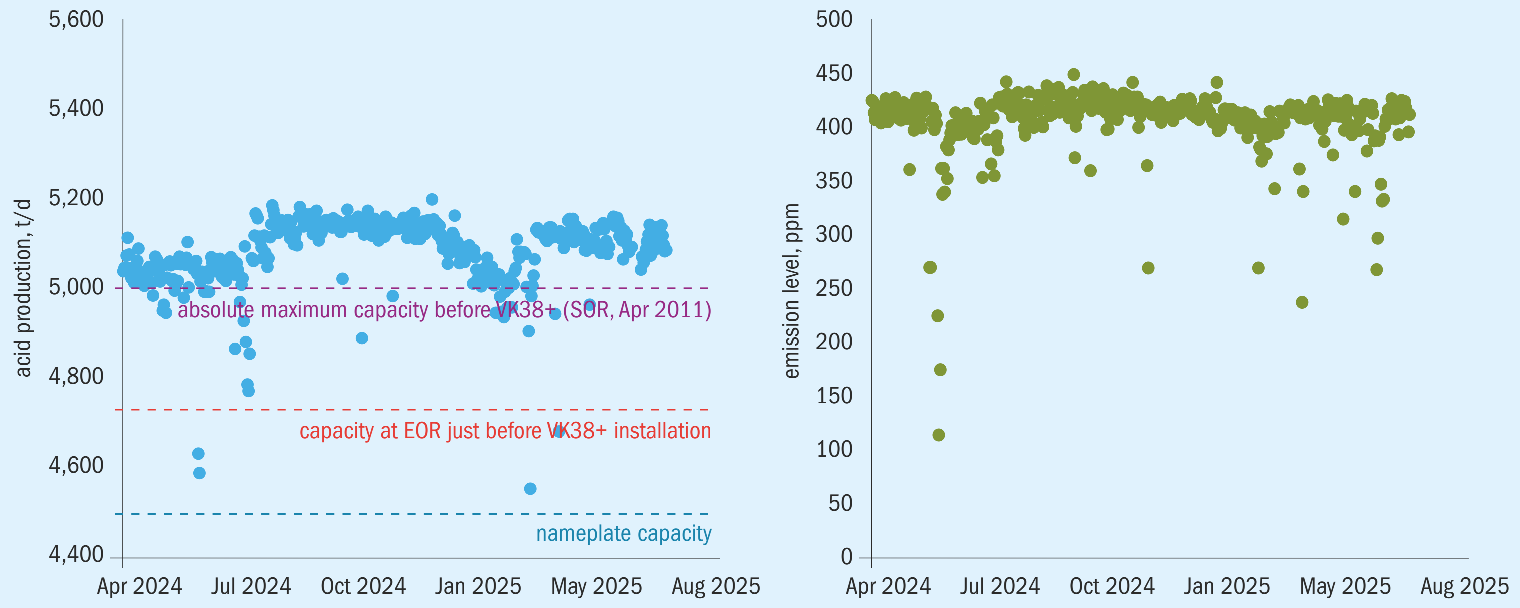
Fig. 5: **Capacity and emissions figures after VK38+ replacement**



Source:Topsoe

loading at start-of-run (SOR) in April 2024 is compared against the value at the same time during the last turnaround (last SOR, April 2021) in Table 3.

The new production with the upgraded loading at SOR (Apr 2024) is also compared against the production before the turnaround (September 2023) in Table 4:

As can be seen above, the upgraded VK38+ loading has significantly increased production after the turnaround (average: +387 t/d).

The improvement is also evident when compared to the maximum capacity period at SOR in April 2021 (average: +55 t/d).

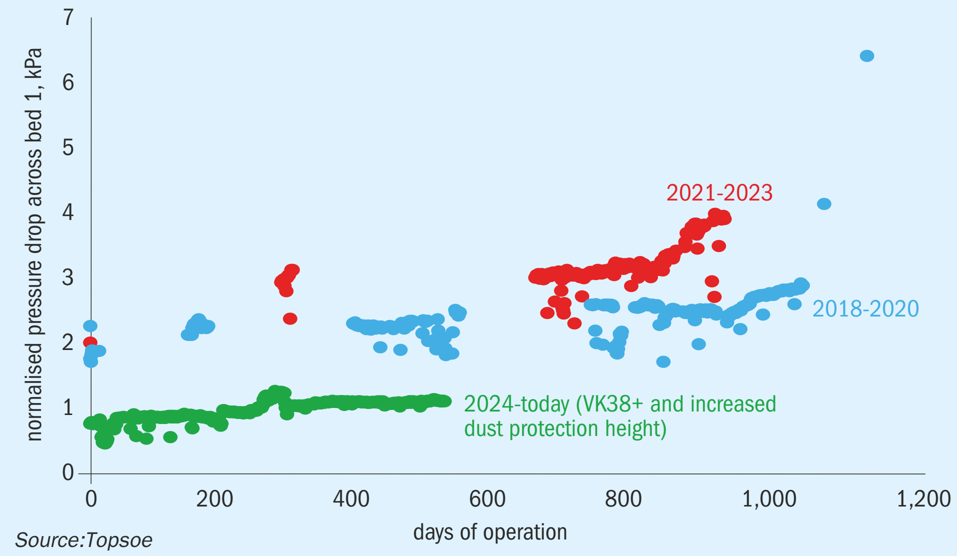
This increased acid production has been sustained to the present day. Fig. 5 shows how the new capacity has consistently remained above the previous maximum throughout the campaign, while emission levels have remained practically unchanged around 400 ppm, in compliance with the environmental legislation.

The pressure drop for the current campaign across the first pass with the new loading featuring a higher dust protection layer and a short-loaded VK38+ bed compared to the last two campaigns is shown in Fig. 6 (the values have been normalised using the design flow for comparison purposes):

After the full bed catalyst replacement and short-loading with VK38+, the pressure drop across bed 1 is considerably lower than the original values (1 kPa vs 1.9 kPa at SOR).

As a result, the operational team at the fertilizer company expect to be able to run Train C for approximately 3.5 to 4 years, taking advantage of the lower pressure drop.

Fig. 6: **Pressure drop trend across bed 1 for the last three campaigns in Train C**



Source:Topsoe

Conclusions and future plans

The catalyst upgrade using VK38+ has proven to be a significant success the fertilizer company, enabling higher production rates and lower pressure drops in a plant that was already operating at its maximum capacity. These improvements were achieved without the need for important modifications in the plant – only by changing the catalyst type.

This case demonstrates how VK38+ can unlock new performance opportunities, even for S-burning plants operating with high SO_2 strength and with full converters and Cs catalyst beds, where conventional approaches would suggest that further increase are not possible without major revamps.

The success of this project was rooted in strong collaboration and partnership between Topsoe and the fertilizer company. Open communication, thorough information sharing was essential to realising these benefits. The company's proactive approach to plant improvement and their commitment to achieving the best possible performance were also key factors.

The payback period for the catalyst upgrade was fast, further validating the business case for VK38+. Following this success, the same strategy has been applied to Trains A and B, achieving similarly positive results. ■

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Sulphur concrete sleepers: durable and reliable

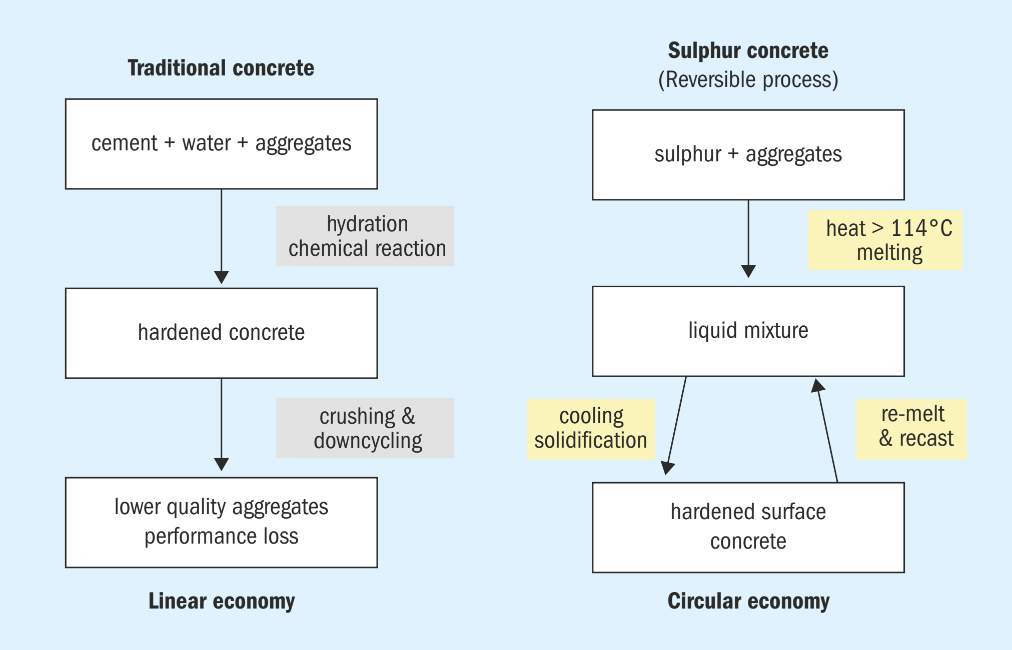
Thiotrack sulphur concrete sleepers combine high mechanical performance with true circularity, validated by over a decade of field experience and rigorous independent testing. **Denis Coppieters** of Thiotrack reports on the key features and successful performance of Thiotrack sulphur concrete sleepers, offering high fatigue endurance with a truly reversible circular binder.

Infrastructure managers are increasingly seeking materials that deliver high mechanical performance and authentic end-of-life circularity. Railway networks worldwide face mounting pressure to reduce carbon footprints while maintaining safety and reliability. Conventional cement-based sleepers have served for decades, but their environmental impact and limited recyclability pose challenges for a sustainable future. Thiotrack sulphur concrete sleepers offer a breakthrough: prestressed elements produced at industrial scale, delivering 60 to 80 MPa compressive strength and validated through extended fatigue testing to 5 million cycles – far beyond the 2 million cycles required by EN standards.

The key differentiator lies in the reversible binder: sulphur solidifies by cooling rather than hydration, enabling closed-loop recycling through melting, separation of steel components, and remoulding into new sleepers.

Thiotrack's journey began with its first sleepers produced in 2013, installed in track in 2014, and still performing successfully today – proof of durability and long-term reliability.

Fig. 1: **Mechanism diagram – hydration vs. sulphur phase change**



Source: Thiotrack

From hydration to phase change: Why sulphur enables circularity

Conventional concrete hardens through irreversible hydration of cement, making recycling complex and often limited to downcycling. Sulphur concrete, by contrast, is thermoplastic: sulphur melts at ~114°C and solidifies upon cooling, a purely physical phase change. This unique mechanism creates a dense, low-absorption matrix with excellent chemical resistance and allows end-of-life sleepers to be re-melted and re-formed without loss of performance (see Fig. 1).

Industrial manufacturing: Familiar geometry, faster process

Thiotrack sleepers are produced on prestressing lines similar to those used for cement concrete (Fig. 2).

Key process steps:

- Aggregates preheated to ~135–140°C
- Molten sulphur blended and cast into preheated moulds
- Demoulding in 2 to 3 hours (vs. 8 to 24 hours for cement curing)

This short cycle accelerates production and reduces energy for curing. The Baudour (Belgium) factory operates at 10 t/h, producing up to 120,000 sleepers/year (Fig. 4) plus sulphur concrete pipes, using standard prestressing reinforcement and fastening inserts.

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Mechanical performance: Strength and fatigue endurance

Compressive strength: Thiotrack sleepers consistently achieve 60–80 MPa, exceeding EN 13230 requirements and European network specifications.

Fatigue resistance: Independent testing (Fig. 3) by Technical University of Munich (TUM) on a B70 sleeper confirmed exceptional endurance:

- Normative requirement: 2 million cycles
- Thiotrack result: 5 million cycles, crack widths of 0.06 mm (loaded) and 0.03 mm (unloaded) (limits: ≤0.10 mm and ≤0.05 mm)
- Ultimate load measured after 5 million cycles: FrB > 394 kN, no fracture (requirement: >384 kN)

This performance demonstrates a service life comparable or superior to traditional concrete sleepers.

Durability and field experience

Thiotrack sleepers have been deployed across Europe (Fig. 5): Infrabel (Belgium), ProRail (Netherlands), SNCF Réseau (France). Feedback confirms compatibility with standard maintenance, including thermite welding, and highlights advantages in low water absorption, acid resistance, and abrasion resistance – ideal for harsh environments and coastal conditions.

Fig. 3: TUM fatigue setup

Fig. 4: Thiotrack – production line

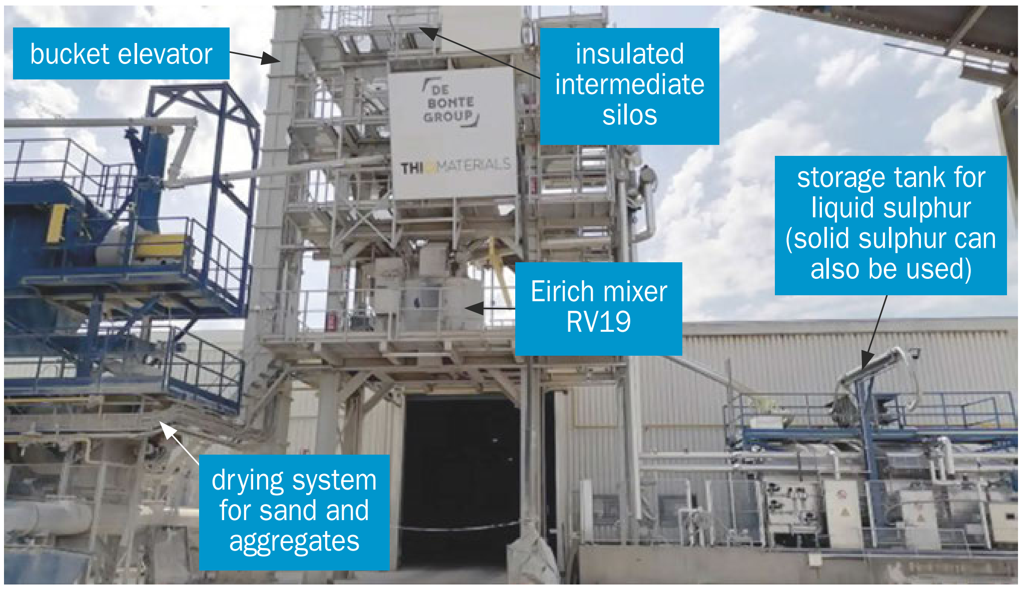

Fig. 2: Industrial plant – batching/mixing.

The reverse process: True closed-loop recycling

Sulphur’s thermoplastic nature enables a fully reversible lifecycle:

1. Heat the sleeper to liquefy sulphur
2. Separate prestressing wires and inserts
3. Recast new sleepers using recovered materials

Lab and field trials confirm equivalent performance for recycled sleepers. SNCF has operated recycled Thiotrack sleepers in track since 2020, validating circularity in real-world conditions.

Environmental perspective

Replacing cement with sulphur eliminates clinker-related CO_2 emissions and water use. While 85% of the mix (aggregates + sand) remains identical to cement concrete, the binder changes:

- Cement sleepers: ~15% cement
- Sulphur sleepers: ~10% sulphur

Sulphur’s carbon footprint (from refinery recovery via Claus process) is estimated at 232 to 276 kg CO_2 eq per tonne (Journal of Environmental Chemical Engineering, April 2024). In comparison, Portland cement averages ~748 kg CO_2 eq per tonne (Infociments, 2024).

Result

Replacing cement sleepers with sulphur sleepers reduces binder-level CO_2 emissions by ~70%, and overall sleeper footprint roughly half that of a CEM I cement sleeper, even accounting for heating energy during production.

Pipes: A complementary application

Thiotrack also manufactures sulphur concrete pipes (Fig. 5 last pic) for sewerage, leveraging the same binder technology for acid and abrasion resistance. This diversification reinforces the robustness of sulphur concrete for infrastructure.

Outlook: Partnerships for scale

Thiotrack invites rail operators, infrastructure managers, and industry partners to collaborate on pilot projects, regional production models, and joint testing programs – accelerating the transition to cement-free, circular sleepers. ■

Fig. 5: Field photo – Infrabel

Fig. 6: Pipes – Thiotubes installation

Prolonging campaign life with guard catalyst

M. Shanmuga Sundaram and **Sreekanth** of Süd-Chemie discuss the importance of pressure drop in a sulphuric acid plant and the many benefits that can be gained from using a guard bed, typically in the first bed of the converter to safeguard the catalyst bed and increase campaign life.

The pressure drop (differential pressure, DP) in a sulphuric acid plant is a measure of the pressure difference across components and equipment. Regular monitoring helps operators track performance and detect and troubleshoot problems early.

In an acid plant, each process step and piece of equipment has a designed pressure drop that typically increases over time for several reasons, including accumulation of foreign material, equipment damage, and scaling. The rate of increase in pressure drop indicates the condition of the equipment or process step. Pressure drop is monitored at two levels: the initial (baseline) pressure drop – measured under clean conditions and often compared with the design value – and its subsequent evolution. Although decreases in pressure drop from the original level can occur in specific cases, this article focuses on increases, which create many operational challenges and bottlenecks for the acid plant operator.

Pressure drop across each catalyst bed in the SO_2 converter reflects the performance of that bed. The rate at which pressure drop evolves in the catalyst beds is a critical factor when planning catalyst turnarounds for replacement or for screening and replenishment.

Low DP ribbed ring SulfoMax catalyst

Importance of pressure drop

An optimum pressure drop indicates efficient gas flow through the catalyst bed, ensuring proper contact between reactants and the catalyst surface. A high DP in the converter reduces conversion efficiency, increases energy consumption, increases mechanical stress on catalyst pellets, and lowers productivity. Many factors can cause an elevated DP in the converter; common causes include:

- accumulation of dust or other foreign material on the top of the catalyst bed;
- plugging of the catalyst bed bottom grids or support screens;
- unfavourable catalyst properties ;
- converter geometry;
- improper gas distribution;
- catalyst deterioration;
- catalyst poisoning;
- excessive catalyst loading;
- gas flow rates higher than the design rate;
- deterioration of bed-support inerts.

Similarly, a low differential DP in the converter also reduces conversion efficiency, which can increase stack emissions and lower productivity. Common causes of low DP include:

- gas channelling;
- insufficient catalyst volume;
- increased voidage in the catalyst bed due to foreign material;
- catalyst size and shape;
- poor gas distribution;
- oversized converter diameter (relative to flow);
- gas flow rates below design.

Converter design and DP

Converter design plays a critical role in achieving the optimal differential pressure. Key design considerations that affect DP include:

Material selection: Choose construction materials that resist deformation and maintain dimensional integrity under operating conditions.

Superficial gas velocity: Superficial velocity depends on the free cross-sectional area (converter dimensions). Velocity is a

PHOTO: SUD CHEMIE

Deformed catalyst

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primary factor in pressure drop across the catalyst bed.

Gas flow pattern: Careful design of gas flow paths and distribution systems helps ensure even flow through the bed and prevents channelling.

Bottom-grid design: A well-designed bottom grid optimises gas flow, minimizes unnecessary obstructions, reduces total pressure drop, and lowers the rate at which DP increases by preventing grid plugging.

Catalyst vs pressure drop

The size and shape of catalyst significantly affect both reaction performance and pressure drop in a reactor.

Catalyst size: Smaller catalyst particles generally show higher activity because of increased external surface area, but they also cause higher pressure drop due to reduced voidage and greater flow resistance.

Catalyst shape: Optimising catalyst shape requires balancing performance and pressure drop. For example, ribbed ring pellets can reduce pressure drop compared with cylindrical pellets of the same size.

Selecting the correct catalyst size and shape based on superficial gas velocity is critical because it determines residence time and the contact surface area available to reactants. Ribbed ring pellets of the same size as cylindrical pellets can offer up to 50% lower pressure drop.

Pressure drop increases with gas flow rate and decreases with greater catalyst surface area and higher void volume. While catalyst density and shape influence pressure drop, void fraction is a primary controlling factor.

Quantity: The optimum catalyst quantity ensures the required conversion and overall productivity.

Reliable pressure drop measurements

All analysis begins with reliable data; accurate pressure drop data is the foundation for sound decision-making, trend identification, and early detection of issues that could cause unplanned stoppages.

The pressure drop profile is a key health indicator for the acid plant; a stable, well-maintained profile indicates efficient operation and good process control. Close monitoring of pressure drop is essential: ensure the pressure points are well maintained with periodic cleaning, calibration of the sensors and cross-validation of the readings with a manometer or calibrated portable gauges. Perform thorough cleaning of pressure points during major shutdowns.

Why pressure drop evolves

The cause of DP evolution can be related to the catalyst, process and the equipment.

Catalyst-related factors

- Incorrect chemical composition can cause active pyrosulphate melt migration and deposition on bottom gratings/grids, blocking the gas path.
- Catalyst aging reduces physical integrity (sintering), increasing DP.
- Thermal stress and sintering compromise catalyst integrity and raise DP.
- Low crush strength causes particle breakage, generating dust and reducing void fraction.
- Catalyst shape and size affect surface area and void fraction, affecting pressure drop.
- Frictional losses during gas flow depend on internal pore dimensions.

Process-related factors

- Impurities originating from the sulphur feed or air stream can increase DP.
- Acid carryover into the catalyst bed degrades performance and raises DP.
- Moisture ingress (e.g., from boiler or economiser leaks) affects DP.
- Higher gas flow rates increase pressure drop.
- Inadequate cleaning, screening, or catalyst-handling practices accelerate DP evolution.
- Chemical poisoning (e.g., arsenic, fluoride) negatively affects catalyst behaviour.
- Operating conditions such as elevated temperature or higher inlet SO_2 concentrations influence DP.

Equipment-related factors

- Grid failure can cause gas channelling, resulting in reduced DP.
- Refractory breakdown can introduce refractory material into the beds, increasing DP.
- Mist eliminator failure can cause acid mist carryover into the converter bed.
- Steam/water equipment failures can cause moisture carryover into the converter bed.

Impact of catalyst physical properties on DP

Physical integrity: Physical integrity (mechanical strength) is a key property of catalyst pellets. Sharp edges or brittle pellets are more prone to breakage, lowering integrity. Prolonged exposure to acid mist or moisture accelerates deterioration and sintering.

Attrition: Low attrition rates reduce screening losses and extend catalyst life. Attrition depends on operating conditions, catalyst physical properties, and handling during screening.

Breakage: Pellet breakage increases pressure drop by reducing void fraction. Causes include improper handling, low crush strength, and exposure to high temperatures.

Sources of contaminants leading to DP evolution

Feed gas: Pressure drop across converter beds often results from contaminants carried in the feed gas. Clean feed gas extends catalyst life, slows DP evolution and extends catalyst screening intervals. Feed sources such as metallurgical smelting, spent-acid regeneration, and wet-gas sulphuric acid plants may contain heavy metals, organic matter, and particulate dust that should be removed upstream. In practice, gas-cleaning efficiency is sometimes suboptimal, allowing contaminants to reach the catalyst bed and cause mechanical and chemical deactivation in addition to increasing DP.

Active pyrosulphate melt migration and deposition on bottom gratings/grids, blocking the gas path.

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PHOTO: SUD CHEMIE

Foreign material carryover to inerts and catalyst

Sulphur feed: The form and purity of sulphur feed matter. Solid sulphur requires melting and filtration to reduce ash carryover. Molten sulphur from refineries is typically higher purity and contains fewer contaminants.

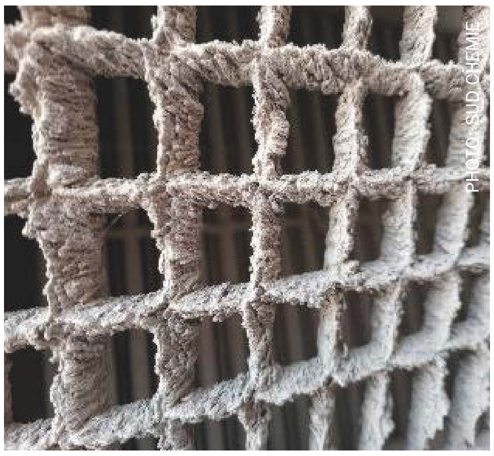
PHOTO: SUD CHEMIE

Air Filter Outer Mesh

Air: Airborne contaminants are common in fertilizer or bulk-material handling plants. Dust and particulates can deposit on catalyst surfaces, reducing active surface area and affecting DP. Drying tower (DT) position and performance play a significant role in preventing contaminant carryover.


PHOTO: SUD CHEMIE

Missing filter screens

Mitigation measures

Remove contaminants at source using appropriate filtration tailored to the expected inlet contaminants. Common filtration options include pressure leaf filters, cartridge filters, and ceramic cartridge filters; multi-stage filtration is often used. Regular maintenance is essential to keep filtration effective.

For air streams, install proper filtration at blower inlets, ensure the DT operates at its rated efficiency, and consider a mist eliminator at the DT outlet. Some plants use online automated back-flushing systems to remove accumulated dust and improve capture efficiency.

Ensure the proper drying procedure is followed during refractory work in the furnace. Maintain and dry refractory work and other equipment before start-up to avoid carryover. During cold startups, ensure no carbon carryover to the converter during heat-up.

Catalyst safeguards: Catalyst geometry that provides high surface area and higher voidage reduces pressure drop evolution while maintaining conversion efficiency.

Hot gas filters: Hot gas filtration is critical in sulphuric acid plants for removing particulates from high-temperature process gas and protecting downstream equipment. Innovative designs incorporate proprietary technologies to improve efficiency and safety. However, at critical temperatures particulates can become sticky and clog filter candles, increasing DP and may lead to costly shutdowns to clean the filter media. Modern solutions focus on preventing clogging and minimising downtime.

Dust guard catalyst: Installing a dust guard catalyst layer on top of the sulphuric acid catalyst reduces DP evolution. These guard pellets have larger sizes and pore volumes, which preferentially trap dust and impurities while allowing clean gas to pass to the sulphuric acid catalyst.

How SulfoMax GRR (guard catalyst) helps

SulfoMax GRR is a dust-guard catalyst designed to capture and retain contaminants while keeping the gas path unrestricted. Because the gas flow remains clear, DP buildup is controlled and the rate of DP evolution is reduced.

Chemically similar to functional V_2O_5 catalysts, SulfoMax GRR features enhanced geometry that improves dust capture and retention. Use of a guard layer reduces screening losses, improves gas distribution, lowers energy consumption, and extends catalyst life. Guard layers also reduce throughput loss and decrease the frequency of screening and related turnarounds.

Primary role: dust protection for the first bed (guard layer) to reduce DP evolution.

Secondary role: in some cases, GRR can replace ceramic inerts as a top support layer.

Other: SulfoMax GRR has a vanadium-based formulation which can initiate the conversion. Advantages over ceramic balls as top layer: greater surface area and a vanadia-containing melt on the catalyst surface that has higher affinity for dust, improving capture efficiency.

Operational note: as dust accumulates and the GRR pores become blocked, the guard layer typically needs replacement every campaign (about 12–18 months). When topping up the guard bed, place fresh GRR at the bottom of the guard layer and discard the exhausted top layer.

Way forward / recommendations

While preventing contaminants at the source is the best way to reduce DP evolution, an additional safeguard is to protect the converter's first bed with a guard catalyst layer. A modest addition of guard catalyst provides a fail-safe even when feed purification is well controlled, prolonging converter campaign life.

Benefits of a guard catalyst layer include:

- lower DP evolution, maintaining plant throughput;
- no additional power consumption;
- safeguards main catalyst activity by arresting carryover;
- unaffected catalyst conversion;
- longer catalyst life;
- longer campaign life, reducing screening frequency and related turnaround costs and stoppages;
- effective replacement for inert hold-down layers where headroom is limited;
- can be used after intermediate absorption stages to protect against mist carryover. ■

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