SCRUBBING UP NICELY

Ali Goudarzi, CECO Environmental, UAE, reveals how an ammonium nitrate producer maintained compliance with emissions regulations during a growth spurt.

It is common knowledge that there is an overwhelming global food shortage and, with the world's population growing exponentially, the demand for agricultural produce will continue to rise. Within CECO Environmental's line of work, fertilizer producers frequently have to adjust operations to align with market fluctuations and the evolving need to ramp up production output.

In the case of ageing manufacturing plants, operators and engineers often look to modify or debottleneck existing equipment to meet

increasing market demands. The challenges that come with increasing fertilizer production involve overcoming a variety of constraints, and identifying the best solutions is often confusing. When placed in this position, several initial conceptual questions may come to mind:

- Is it feasible to operate at larger volumes?
- What are the major impacts of running operations above 110% of design capacity?
- What are the consequential effects on the equipment?
- Is it going to be compliant with environmental regulations and is it going to be safe?
- How can OPEX and CAPEX be minimised with adaptations, along with the total cost of ownership of the equipment?

To answer these questions requires the right expertise to solve such tough engineering challenges, meet commercial market changes and help producers to adapt clean, safe and more efficient solutions. Achieving solutions that comply with regulations and increase capacities can provide an influx of revenue and, in turn, generate profits at higher market demands.

When ramping production rates up and pushing equipment beyond its original design limits, environmental emissions rise with increased contaminant loads. In many cases the most common methodology to adapt to these changes is to modify or debottleneck the existing equipment, preventing costly CAPEX in new larger capacity equipment.

Figure 1. Dual-stage wet scrubber.

Exhaust air streams from prill towers are heavily influenced by volume changes, which is important not only in terms of environmental compliance and opacity, but also with regards to operational concerns such as increased pressure drop and power consumption on existing systems. In the current market, the best applicable technology for lower limit emission requirements for high density and low density ammonium nitrate (AN) prill towers are dual-stage wet scrubbers equipped with candle filter (or fibre bed) mist eliminator technologies that remove sub-micron particulates.

The technology supersedes tight regulation limits set by the US Environmental Protection Agency (EPA)[1] and the European Environmental Agency (EEA)[2], and provides minimised OPEX for operators. As most prilling tower operations are regulated for AN dust content, nitric acid and ammonia emissions, a system like the dual-stage wet scrubber is thought of as best practice in industry.[3]

Case study

A large fertilizer production company in the US was experiencing difficulties with regulatory compliance while managing an upswing in market growth. Their existing production was unable to meet the volumes required to grow their business during peak market requirements. They had been experiencing bottlenecks in production and their plant started operating at higher capacities. The initial trail ran at 120% operation, showing non-compliance with environmental emissions. At this point production was forced to return to 110%. The customer approached the company for support and a concise study was done on how to increase production in a high density (99.8%+) AN prilling process from 550 to 600 tpd (or 110% to 120% capacity), without the need for a major overhaul or costly CAPEX which would render the investment uneconomical.

The client's existing system consisted of a dual-stage vertical scrubber, which used a heavily sprayed mesh pad and irrigated candle filter to remove ammonia gas and micro-prills of AN from the gas stream, as well as removing opacity given off from prill tower exhausts – a common problem throughout the world (Figure 1).

The first stage mesh pad packing arrangement was sprayed from top and bottom with nitric acid solution for two reasons: firstly, to absorb and react the ammonia gas to reproduce AN, and secondly to remove larger prills entrained into the gas stream (greater than 2 micron).

The second stage acted as a polishing stage to remove micro-prills or sub-micron particulates (less than 2 micron), which can often create highly visible opacity issues after passing through the sprayed mesh pad arrangement in the first stage. Candle filters in this case provide a denser packing media with higher removal efficiency than the mesh pads, and can trap the finer solid particulates within the fibre arrangement. The filtration system was then irrigated with process water to solubilise, which dissolved the trapped particulates,

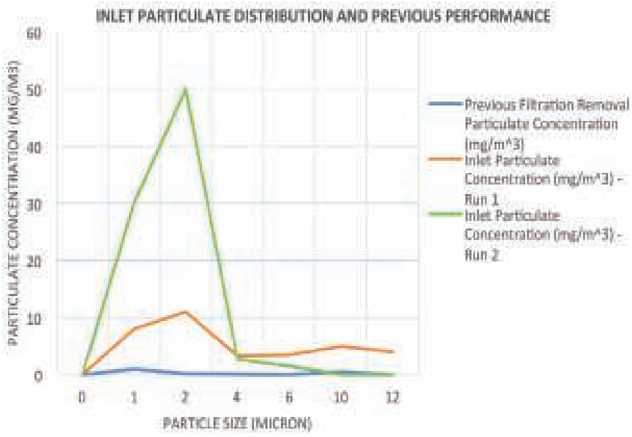

Figure 2. Inlet particulate distribution and previous performance.

Table 1. Particle distribution analysis for AN solids

Particle size (micron)	Percentage by mass (%)
‹0.1	3
0.1 – 0.3	9
0.3 – 0.5	13
0.5 – 1	30
1 – 3	30
›3	15

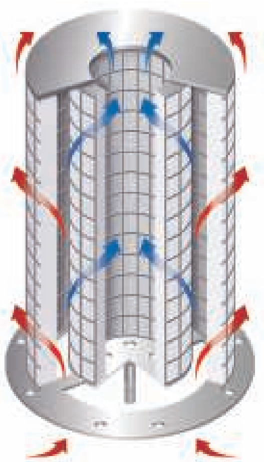

Figure 3. TWIN-PAK schematic.

thus preventing pressure build up and boosting removal efficiency of AN solids.

With the increase in capacity, the inlet contaminant conditions and operational process confinements were as follows for the vertical dual-stage scrubber:

- AN dust load – up to 300 mg/Nm^3 minimum (Table 1).
- Ammonia load – approximately 120 mg/Nm^3.
- Allowable pressure loss of 550 mm H_2O over the system. The pressure loss for the filters read as 350 mm H_2O.
- Gas flow rate of 316 000 Am^3/hr (emphasis on the high volume, due to capacity increase).
- Existing output performance of the conventional filters was 5 – 6 mg/m^3 of AN and ammonia content below 0.5 lb/hr at maximum capacity of 120%.
- Opacity had risen to 9%+.

The EPA's statutory regulations for high density AN prill tower exhaust emissions are:

- AN dust content: ‹2.5 mg/Nm^3.
- Ammonia content: 0.7 lb/hr or 0.3175 kg/hr.
- Opacity: ‹5%.

Figure 2 provides further details.

With the higher capacity generating emissions that exceeded the regulations outlined, a retrofit solution was designed to remove ammonia, AN prills and micro-prills and resolve opacity issues at 120% capacity operation by using TWIN-PAK® filters and a modified spray system arrangement to adapt to the increased gas flow rates.

The filters feature a double filtration design that uses the inner annular space within a conventional filter. This allows for more surface area for collection, reduces the gas velocity through the filters, and significantly reduces the pressure drop or the number of filters required (Figure 3).

With the changes to the filtration arrangement, a redesigned spray nozzle system was strategically positioned into the vessel arrangement to provide adequate wetting and absorption of AN dust.

The filters and the new spray system retrofits not only enabled the process unit's performance to exceed the environmental compliance requirements for the overall limits of AN dust content, but also enhanced OPEX and total cost of ownership through filter quantity and pressure drop reductions.

Table 2. Retrofitting changes (before and after)

Description of changes	Before retrofit	After retrofit
Candle filter (or fibre bed) mist eliminators	• Standard CECO conventional filter arrangement • 610 mm outer diameter x 3660 mm length • Polyester media with P3 Graded Bed™ arrangement • 62 filters installed into a 6.4 m diameter vessel	• CECO TWIN-PAK filter arrangement • 610 mm outer diameter x 3660 mm length • Polyester media with P2 Graded Bed™ (higher efficiency) arrangement • 50 filters installed into a 6.4 m diameter vessel
Atomising sprays	• Spray systems – hollow cone: 136 x ¼ in. ML1.5	• Spray systems – hollow cone: 136 x ¼ in. ML1.5 • Spray system – air atomised: 22 x ¼ in. XA-PR100

Tower internal changes combined with Graded Bed™ media technology and the adjustment to the media layer selections led to a number of results (Table 2).

Ammonia gas absorption and AN dust content

The output content was significantly reduced due to the TWIN-PAK filters increasing the filtration surface area and the Graded Bed (multi-layer) packed fibre media reducing the gas velocity. This enhanced the Brownian Diffusion method of collection to remove sub-micron particles and increased the overall efficiency. The modified spray system allowed more liquid contact area for collection and absorption through heterogeneous contact of liquids and solids at strategic location points.

Overall and final performance exceeded the EPA's standards and the client was again compliant with regulatory requirements.

- AN dust content: <2.5 mg/Nm^3.
- Ammonia content: 0.4 lb/hr or 0.1814 kg/hr.

Table 3 provides further details.

The alteration in media velocity allowed a higher efficiency Graded Bed to be custom designed to the new requirements and further improve the performance and output efficiency.

Table 3. Removal efficiency for Graded Bed (before and after)

Particle size (micron)	P3 Media (before retrofit – conventional filter)	P2 Media (after retrofit – TWIN-PAK filter)
<0.1	99.93%	99.96%
0.1 – 0.3	96.02%	97.78%
0.3 – 0.5	95.82%	97.92%
0.5 – 0.75	98.54%	99.37%
0.75 – 1	99.24%	99.68%
1 – 3	99.82%	99.93%

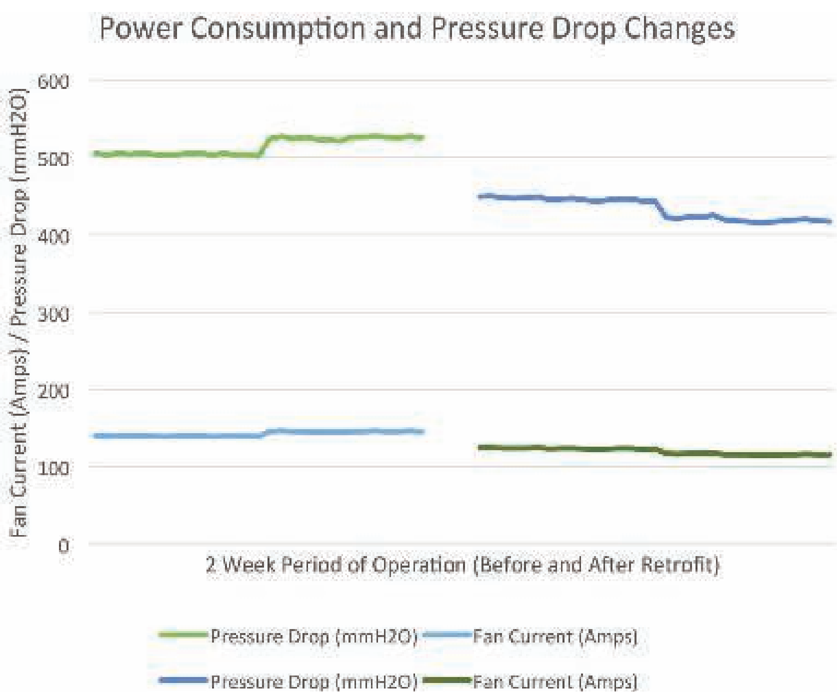

Figure 4. Pressure drop and fan energy consumption (before and after).

Opacity

The opacity was reduced to less than 5% and, as a result, no visible plume emissions were showing at the output of the vertical scrubber stack.

Pressure drop

With added filtration area and a reduced number of filters, a reduction in the wet pressure loss from the conventional filters was achieved, from 350 mm H_2O to 300 mm H_2O. Overall the wet pressure loss of the complete system was designed to give 450 mm H_2O at maximum conditions and further reduced to 420 mm H_2O at normal design conditions. This gave the client an overall pressure drop reduction on the system that reduced the power consumption of the fan extraction unit. In turn, the life span of the filters was also increased to allow older filters to be able to tolerate higher pressure differentials as time passed; two additional years of service life were achieved through this (Figure 4).

Extra washing filters

The extra spray locations enabled direct washing and liquid entrainment before the TWIN-PAK filters. This ended the need for an annual shutdown to remove long-term AN dust build-up from the filters. This reduced maintenance downtime OPEX and allowed for longer production runs.

Filter reductions

The client was able to further consider potential volume increases through unused filter openings due to the overall reduction in the quantity of filters. The company was now prepared for further production increases, with the potential for 12 more filters to be installed to handle further capacity spikes or further reduce the pressure drop of the overall system.

Combined and assembled, the retrofitting solution allowed the client to grow their production capacity and process above the designed norms while remaining in full compliance with environmental regulations. With a relatively low-cost expenditure the return on investment (ROI) was measurable after 12 months of high-volume operation – enabling cleaner, safer and more efficient processing to maximise the total return from the operation and meet growing market demands. WF

References

1. US Environmental Protection Agency; AP-42 SECTION 8.3 – Ammonium Nitrate.
2. European Environmental Agency; Directive 96/61/EC.
3. IFC; Environmental, Health, and Safety Guidelines for Nitrogenous Fertilizer Production.