# THE SULFUR SPECTRUM

**Bevan Houston and Mark Gilbreath, Matrix PDM Engineering, USA,** weigh up various cost-effective infrastructure options available to both sulfur producers and consumers.

With an over-abundant supply of sulfur expected to continue for the near term, the market dynamics along this vital supply chain present challenges for producers and consumers. Oil and gas producers, who typically sell the sulfur they remove from crude oil during the refining process, may decide to process it to solid form for longer-term storage. Sulfur consumers, like those who manufacture fertilizer, however, may be able to reduce feedstock costs by diversifying between the use of liquid and formed sulfur.

At either end of the spectrum, cost-effective and efficient options are available. This article presents technical and commercial decisions to be considered for sulfur forming, longer-term storage if commercial offtake is not available, and material handling, including dust and explosion control.

## Background

Sulfur is removed during the refining/processing for three primary reasons:

- Removal of hydrogen sulfide ($H_2S$) and sulfur dioxide ($SO_2$) from crude oil, typically referred to as sulfur recovery.
- It is mandated by regulations such as for ultra-low-sulfur diesel and MARPOL's pending IMO 2020 requirements for marine fuels. This is most commonly achieved through hydrotreating.

- Removal of sulfur from sulfur – a further reduction of $H_2S$ and other sulfur-based contaminants – is required by certain regulators based on specific circumstances. For example, transportation of molten sulfur, which must contain less than 5 or 10 ppm of $H_2S$ as required by European and Canadian regulators.

Elemental sulfur that has been recovered has unique characteristics that are a challenge all the way through the supply chain to the consumer. Molten sulfur has a very narrow temperature range for manageable flow and reasonable viscosities, becoming more viscous at temperatures above 300˚F. Solid sulfur in prill and dust is hydrophobic, repelling water. This make dust control by traditional surfactants very difficult.

**Figure 1.** Priller units showing space-efficient tower design.

**Figure 2.** Formed sulfur prill after screens.

## Formed sulfur processes

The objective in solidifying molten sulfur into a product that can be handled as dry bulk is to minimise the amount of fine sulfur particles during transport, transfer, storage, and reclamation. Solid formed sulfur prills can be handled much like any other dry bulk solid that is transported by ocean going bulk collier ships. This is important as many of the consumers of solid sulfur are located on different continents from where the sulfur is recovered. For example, there are large quantities of sulfur being recovered in the Middle East and the largest consumers of that sulfur are located in Northern Africa and China. Ocean transportation of solid formed sulfur prill is much more efficient that transportation of molten sulfur.

Solidifying molten sulfur is typically accomplished using one of three modern forming processes:

- Pastillation, whereby water is sprayed under a steel belt on which liquid sulfur drops are deposited to produce pastilles.
- Granulation, a process in which water is sprayed into a rotating drum to cool liquid sulfur that has been sprayed onto a seed curtain to form sulfur particles or 'seeds'.
- Wet prilling, whereby liquid sulfur is introduced at the top of a forming tank for direct counter-current heat exchange, with water, used to produce prills that are withdrawn from the bottom of the forming tank.

Pastillation has been a popular option given the fact that the equipment used in this process can also be used to create other products such as urea or sulfur bentonite. Pastillation is also used due to its ease of setup and lower environmental risks since the water and sulfur do not come into direct contact with one another during processing.

Granulation, a common method of sulfur solidification, is used in environments that require high total production capacity utilising multiple units. A single granulation unit can produce in excess of 700 tpd of solid formed sulfur granules.

Sulfur dust presents both a health hazard and potential for explosion if collected in a confined space with an ignition source, so it is important to have a process that minimises production of dust during material handling and transportation.

Wet prilling provides the benefits of pastillation and granulation, with significantly greater economic efficiency. For example, the Devco II system, a proprietary prilling technology which:

- Requires lower CAPEX, achieved through design, procurement and installation. Unlike pastillation or granulation units, prilling units lend themselves to modular construction. Major components include the forming tray, fume hood and scrubber (if required), forming tank, dewatering screen and dry product conveyors. Mechanical equipment includes the process water and cooling tower supply pumps and cooling tower with fan units. Additionally, no intermediate storage, pumping or pre-conditioning is required between the sulfur recovery unit (SRU) and prilling system.

- It achieves lower operational costs through minimal power consumption, single operation low mechanisation of process flow (gravity driven), minimal moving parts, no need for dust suppressants, and fast start-up/shutdown.
- Offers a single-unit capacity of 2000 – 2250 tpd with a footprint of just 10 x 8.5 m (compared to 38 x 22 m for a typical granulation unit and 28 x 26.5 m for a typical pastillation unit).

**Figure 3.** Molten sulfur at forming tray above the water column.

**Figure 4.** No airborne dust as sulfur prills are stockpiled.

**Figure 5.** Two large sulfur storage blocks with forms and pouring arms.

Wet prilling also offers modern process improvements for moisture control (2%), size uniformity and the ability to meet international commercial specifications. Except for very cold climates, process building enclosures are also not required.

Current environmental compliance and good practice for health and safety of employees is achieved by inclusion of basic vapour collection and a simple scrubbing unit.

## Material handling considerations

After the solid sulfur is formed by any of the described methods, the material is collected onto a standard conveyor belt for transportation to storage and reclaim, in some instances for loading to ship or rail car.

When considering material handling, windborne contamination (such as sand) as well as increases in free moisture due to rain must also be considered. Storage in buildings can protect dry sulfur from the elements, but – given the explosive nature of sulfur – it also requires greater dust management. As mentioned, elemental sulfur in small particles and dust is hydrophobic. Because of this, dust control and conveying transfer points (especially in ship holds) is a major challenge.

A number of commercially-available dust suppression products are also available that, if properly distributed at transfer points along the material handling conveyor system, can be effective. However, simply increasing the amount of traditional dust control surfactant is not the best solution and can result in moisture levels in the shipment that are outside of the required commercial standards.

Wet prilled sulfur is less dusty from the time it is produced. The inherent 2% moisture content remains with the prill through the loading process and minimises the need to add water-based surfactant solutions. There are many locations around the globe that have successful outdoor storage of wet prilled sulfur with minimal dust control issues and no buildings.

Acidity control is also important for protecting material handling equipment and facilities. Stainless steel construction is ideal, however, experienced providers of sulfur material handling systems are generally able to offer more cost-effective solutions.

## Longer-term storage

For longer-term storage, when prices for offtake are unfavourable or when the infrastructure needed to move sulfur to market is either disrupted or non-existent, sulfur block storage is the lowest cost solution possible. Sulfur blocking can be accomplished by relatively straightforward distribution systems that deliver molten sulfur to very large rectangular formed areas.

Molten sulfur is transported by pipe to multiple vertical columns. This sulfur is radially distributed within a rectangular area defined by movable forms. These forms can provide for 1 m thick layers of sulfur to be formed as sulfur solidifies at ambient temperatures. After the 1 m layer has formed and solidified, the segmented side panels that form the perimeter are lifted up and moved inward to form a step sided wall of solid block formed sulfur.

Step form technique provides a stable and safe block of solid sulfur. These individual blocks of sulfur can be as large as 100 x 100 $m^2$ with heights up to 15 m. Rates of solid block forming can be as high as 5000 tpd.

An alternative to sulfur block storage is storage of molten sulfur in an aboveground storage tank. However, because such a tank is the most capital-intensive infrastructure along the sulfur value chain, a key driver is how much molten sulfur storage can be economically justified, whether in a small aboveground surge vessel, a sulfur pit/vat, or an aboveground storage tank. A common guideline for tank storage needs when developing a new facility is two weeks of supply.

Molten sulfur tanks require special design considerations for heating coils in the bottoms and control of temperature in the vapour space at the top of the tank, as well as controlled venting. Corrosion is a given in molten sulfur tanks and additional allowance for wall thickness during design can be very cost-effective over the lifecycle of a given facility.

## Conclusion

Regardless of which end of the spectrum an owner/operator may find themselves, there are cost-effective and efficient infrastructure solutions for sulfur to help them achieve their business objectives.

By considering and understanding the various options for solid block disposition, sulfur forming, stock yarding and transportation, companies who produce sulfur as a byproduct can achieve very successful results. Multiple solutions are available for sulfur handling and each situation and location will need its own combination of systems and infrastructure to move the sulfur product to its most commercially desirable destination.