MOVING WITH THE TIMES

Patricia Wories, Enersul Ltd Partnership, Canada, considers the evolution of the sulfur recovery industry.

The evolution of sulfur handling in Western Canada has provided much of the driving force for the development of many sulfur forming processes. Prior to the development of sulfur forming plants, molten sulfur was poured into large blocks, which were then broken up, crushed, loaded into railcars and transported to the Canadian West Coast. Here, the sulfur was unloaded and stockpiled, awaiting export to offshore markets. The operation was time-consuming and dusty due to the brittle nature of elemental sulfur. Despite the dust and safety problems associated with the handling of bulk sulfur, large scale commercialisation of sulfur forming did not occur until the early 1970s. This was precipitated by an explosive event at the Vancouver Terminals and, on 1 July 1972, the Vancouver Port Authority became the first major sulfur-exporting port in the world to ban the handling of conventional dry bulk crushed sulfur on the grounds of environmental impact. It was this ban that prompted further development of alternative sulfur forming processes.

Early sulfur forming processes, such as slating, were an improvement over bulk sulfur but it then became clear that slating by no means eliminated the dust issue. Problems emerging as well as ageing and deterioration of product prompted research and development groups to explore the basic science of sulfur forming and develop new technologies.

Increasing export volumes, environmental pressures and occasional dust explosions forced the industry to seek ‘second generation’ forming technology. In 1973, the Sulfur Development Institute of Canada (SUDIC) was inaugurated to investigate new uses for sulfur in North America. As part of the group’s focus, SUDIC was asked by the Canadian Industry Sulfur Forming Committee to examine the forming processes that were available and choose one process

Table 1. SUDIC specifications

Property	Premium product specification
Shape and size	Generally spherical, between 2 – 6 mm
Size distribution	• Less than 5% to be retained on a No. ¼ US screen (6.3 mm) • A minimum of 75% to pass through a No. 3.5 US screen (5.6 mm) • A minimum of 75% to be retained on a No. 7 US screen (2.8 mm) • Less than 2% to pass through a No. 16 US screen (1 mm) • Less than 0.5% to pass through a No. 50 US screen (0.3 mm)
Moisture content	Less than 0.5% by weight of moisture (bulk average) as produced
Friability performance	Less than 1% of fines (-50 mesh material) generated under standard stress level I friability test
Bulk density	No less than 1040 kg/m agitated (vibrated)
Compaction	• Fines generated after direct shear test under static loading of 165 kPa (approximately 15 m stockpile) not to exceed 0.2% fines by weight • Fines generated after direct shear test under dynamic loading at 165 kPa not to exceed 0.5% fines by weight
Angle of repose	Not less than 25°
Other	Chemical composition must not be altered from the feedstock chemical composition except for moisture and entrained gases

Table 2. Product quality comparison

	Slates	Air prill	Wet prill	Pastilles	GX
Friability (percentage of fines)	7 – 10	<2	3.2 – 4.1	<2	<2
Loose bulk density (kg/m)	1040	1170	1220	1080	1220
Packed bulk density (kg/m)	1200	1290	1370	1290	1360
Angle of repose (in degrees)	32 – 40	23.5 – 27	27 – 30	27 – 30	26.4 – 28.2
Flowability	Low	Good	Average	Good	Good
Moisture content (percentage of weight)	<1.5	<0.05	<2	<0.05	<0.5

(acceptable to both shippers and terminal operators) that the industry could adopt. With the aid of Alberta Sulphur Research Ltd (ASRL), a number of criteria to evaluate the product originated and, although no single process was selected, the SUDIC's premium product specification emerged.

SUDIC was disbanded in the mid 1980s, but its criteria gained substantial worldwide acceptance. It continues to define what most industry experts call 'premium product' today. Its specifications are shown in Table 1.

Advantages of premium product

The primary advantage of a premium sulfur process is that the product is less friable than a non-premium product. Friability is a measurement of how easily the product crumbles and produces dust when tumbled in a drum. The shape, size and some specific potential contaminants in the formed sulfur product are among the factors that affect friability.

Spherically formed sulfur is the ideal shape for handling and transportation. The spherical shape eliminates protruding areas of sulfur that can easily break off and turn to dust during handling and transportation.

Particle size is the next critical factor in creating a premium product. Formed sulfur is inherently brittle with large particles tending to break down a lot easier than small particles due to their larger inertia during movement caused by handling and transportation. However, small particles are more prone to wind and leakage loss. This forces a tradeoff for sulfur producers to choose an optimal size. Research has shown the optimal size range for premium sulfur particles is 2 – 6 mm.

Moisture content is also critical in producing a premium product. Moisture has historically been added to non pre-premium product to reduce dust generation. However, as well as increased transportation costs, the addition of moisture can produce two serious problems – firstly, acidity, which results in corrosion, and secondly an increase in the amount of energy needed for melting by one-fifth for every additional 1% of moisture present.

The ideal criteria

Companies responsible for the storage, handling and transportation of sulfur recognise that there are certain highly valued properties of solid formed sulfur. The following attributes are generally considered for a premium product:

- Minimal friability: the objective is to reduce the likelihood of product breakdown and fugitive dust release during storage, handling and transportation.
- Maximum loose and compacted bulk density: the objective is to manipulate product shapes such that minimal storage is required to achieve maximum packing of the granules and to minimise any breakage that can occur due to compressive forces in high stockpiles.
- Maximum angle of repose: the objective is to raise the angle of stockpile to reduce the stockpile's footprint.
- Flowability: the objective is to ensure that no plugging occurs in product flow through conveyor/chute transfers.
- Minimum moisture content: the objective is to reduce the moisture content of newly-formed product, reduce the ability of the final product to retain moisture, and minimise freight costs.
- Optimise remelting characteristics: the object is to create a product that is quick to remelt with low energy costs.

There are a number of forming processes currently in use worldwide that have been successfully commercialised. Table 2 provides a general summary of how each process compares to SUDIC's ideal criteria.

As the sulfur industry moves forward through the 21st Century, non-premium formed sulfur products, while continuing to operate as a cost-effective choice for

Figure 1. Kaybob Alberta GX granules.

Figure 2. Enersul's GXm3.

Figure 3. Enersul's GXm1.

forming, are becoming more location-specific and market-specific due to higher friability levels and higher moisture content. The latter factor leads to increased energy requirements during melting, increased transportation costs, and the potential of increased acidity. The demand for premium sulfur product continues to be pushed by increasingly higher industry standards and tighter environmental regulations, particularly in new emerging sulfur production markets.

Granulation evolution

Granule strength, and therefore dust generation tendencies, during handling and transportation is sensitive to a number of different factors, including: FEED liquid sulfur purity, liquid sulfur temperature, cooling rates of water and air, seed generation quantity and size, and product size.

In the late 1970s, Enersul developed its GX sulfur granulation process to meet industry demand for a safer, higher production, premium product process. The granulation process is a size enlargement process, whereby liquid sulfur is sprayed through nozzles inside a rotating granulation drum onto a curtain of sulfur seed particles. Lifted by flights inside the drum, the seeds fall in curtains and are then lifted again to be sprayed with a successive layer of liquid sulfur. The layers of sulfur are solidified onto the seed, which causes a progressive buildup of layers of sulfur on the core particle. With repeated application of liquid sulfur, the seed increases in volume and weight. As the granule is enlarged, each coating of liquid sulfur is fully and structurally bonded to the layer beneath. This creates a spherical granule that is entirely dry and completely free of voids.

There have been three major milestones for the company's process. The first was removing the baghouse and replacing it with a safer wet scrubber system; the crusher that was located at the head end of the recycle conveyor belt as the source of sulfur seed was removed. The second was to increase production to 50 tph, and the third was to develop a gantry-less process while incorporating several other design changes. The current sulfur granulation process is the GXm1 design, which has improved product quality, reliability and environmental friendliness, as well as reduced downtime and maintenance costs. This process continues to be the company's flagship model, operating at 1200 tpd.

Gantry design

The original gantry design was installed inside the drum, running lengthways from end to end. This allowed the gantry to receive falling granules that were picked up by the drum flights to form a granule curtain in front of the sulfur header nozzles at a predetermined distance to allow for seed generation and efficient cooling.

The motivation behind the gantry removal was to create a cleaner operation, improve product quality and reduce downtime and housekeeping requirements. This resulted in the removal of three components from the gantry design: the gantry, seed generation nozzle and resistance temperature detectors (RTDs). This resulted in a cleaner operation that consistently produces high quality granules with very little oversize and build-up of sulfur inside the drum.

The value of the operator

A forming machine that runs itself and produces high quality product has not yet been invented. Proper operating practices and procedures are a must for any sulfur forming and handling facility. Operators are a valuable resource that must be properly trained for operation, safety, maintenance and housekeeping to ensure premium sulfur product is produced.

Conclusion

The recovered sulfur industry has come a long way in a just a few generations along the road to safer, more environmentally friendly and economically justifiable methods of storage, handling and transportation to the end-user over long distances and challenging routes. Having installed over 140 GX sulfur forming units globally, Enersul continues to welcome new developments and refine forming processes at all product levels in order to provide clients with the forming and handling equipment that suits their needs.