Sulphur solidification and handling systems

The complete package – from melt and solidification to handling and storage
Sulphur solidification and handling systems

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1. Introduction

1.1 Sulphur solidification and handling systems

As a result of environmental concerns, the processing of crude oil into fuel, be it gasoline, diesel or kerosene, now requires the extraction of as much sulphur as possible.

The most advanced process is the Claus process, which converts $\text{H}_2\text{S}$ into elemental sulphur, with the resultant properties:

- **Temperature:** 125 - 145°C
- **Purity:** > 99,9%
- **$\text{H}_2\text{S}$ content:** < 10 ppm

As further processing very often requires liquid sulphur (e.g. for the production of sulphuric acid and fertilizer), it is advantageous to transport and store sulphur in liquid form. However, temperatures of between 124 - 145°C mean that handling, transportation and storage could pose a problem from the point of view of safety and economics, so liquid sulphur is handled only if one or more of the following factors apply:

- Short distances.
- Short storage cycles.
- Availability of adequate storage system.
- Availability of adequate infrastructure for transport, be it road, ship or railway transport.
1.2 Formed sulphur

More often, for easier handling, storage and transportation, sulphur is formed into pastilles/semispherical granules. The pastilles, as produced by the Sandvik Rotoform® principle, are globally accepted as a premium quality product, delivering the following significant benefits:

- High purity (bright yellow colour).
- Low friability and high impact abrasion resistance (low visual dust generation).
- Good flow characteristics, but high angle of repose.
- Easy remelt (no agglomeration).
- Low moisture content.
- Stable properties over time.
- Consistent quality.

Considering the fact that formed sulphur is moved on average 15 times between production and re-use (various steps of handling, transport, storage, etc.), much attention needs to be given to low friability and subsequently low dust generation. In this respect the Rotoform pastille shows very low dust at stress levels I and II of the SUDIC test (a method accepted worldwide for the simulation of sulphur handling and subsequent generation of dust).
Sulphur Handling

CLAUS PROCESS

LIQUID SULPHUR

STORAGE  SOLIDIFICATION

indirect HEAT EXCHANGE  direct HEAT EXCHANGE

ROTOFORM® PROCESS  FLAKING PROCESS

STORAGE  STORAGE

END USER
2. The Sandvik Rotoform process

Based on steel belt technology, Sandvik has developed an efficient and environmentally friendly process for the cooling and solidification of molten sulphur.

The basic principle consists of a continuously running steel belt, which is cooled from the underside by spraying water through nozzles. A specially developed feeding system – the Rotoformer – deposits liquid sulphur in form of droplets onto the steel belt. These are cooled as they run with the steel belt and discharged in form of solid pastilles/semispherical granules at the end of the system.

2.1 Liquid sulphur characteristics

The characteristics of liquid sulphur as it arrives at the Rotoform unit from the desulphurisation and associated degassing plant are as follows:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur content:</td>
<td>not less than 99.5 %</td>
</tr>
<tr>
<td>Temperature for premium quality:</td>
<td>max. 135°C</td>
</tr>
<tr>
<td>Pressure:</td>
<td>1.5 – 2 bar</td>
</tr>
<tr>
<td>Viscosity:</td>
<td>4 cP at 125°C</td>
</tr>
<tr>
<td>H₂S content:</td>
<td>less than 10 ppm</td>
</tr>
</tbody>
</table>
2.2 Process description – pastillation with the Rotoformer

The Rotoform® process consists of several different operations. The process starts with heatable sulphur pumps nearby the sulphur tank or pit. The flow of the liquid product into the tank is controlled by a valve, which guarantees a constant level of product. Steam or oil heating facilities eliminate the possibility of the sulphur freezing in the tank and all pipework used to convey the product is similarly heated. The pumps supply the liquid sulphur, at a constant pressure, to the Rotoform system.

The Rotoformer consists of a heated, cylindrical stator, which is supplied with liquid sulphur, and a perforated rotating shell that turns concentrically around the stator, depositing sulphur drops across the whole operating width of the steel belt.

The circumferential speed of the Rotoformer is synchronized with the speed of the belt: drops are therefore deposited without deformation. Heat released during solidification and cooling is transferred by the stainless steel belt to the cooling water. This is sprayed against the belt underside, collected in tanks and returned to the recooling plant. At no stage does the cooling water come into contact with the sulphur.

At the cooler end, pastilles are taken off with a discharge knife and pass, via a chute, to a collecting belt for further processing. To eliminate the possibility of damage to the pastilles when being discharged, a silicon-based release agent is applied to the steel belt as a thin film. An automatic filling system ensures that a sufficient quantity of the release agent is always held in the tank.

The Rotoformer is equipped with an effective exhaust system, with a tight exhaust hood; an air exhaust and throttle flap is positioned above each Rotoformer. A fan ventilates each plant. The pastilles are transferred to the storage silo via a bucket elevator.
2.2.1 Different types of Rotoformer

The Sandvik Rotoform process was developed in the early 1980s, for the pastillation of various products in the chemical, food and plastic industries. Since then, more than 1400 units have been installed around the world.

Two different types are available for the pastillation of sulphur, both of which supply pastilles of premium quality and the same semi-hemispherical shape:

a) **Rotoform 3000:**
   This is the standard Rotoform for this application and provides a granulation capacity of up to approx. 6000 kg/h

b) **Rotoform HS:**
   In 2005, Sandvik Process Systems made a significant breakthrough with the development of its Rotoform HS system, a high capacity version of the standard Rotoform offering double the throughput - plus a range of additional benefits including easier, more economical servicing.
   The Rotoform HS provides improved safety – if anything is caught between dropformer and belt, the dropformer automatically raises to minimise the risk of damage or injury. Furthermore servicing is easier because of fewer components to check and replace.
   The main difference between the Rotoform HS and the base model is the diameter of the rotating outer shell that deposits the molten product onto the steel belt. Using a 250 mm diameter shell rather than the usual 80 mm means the influence of centrifugal force on the droplet shape is reduced; as a result, the system can be operated at a higher speed while maintaining control of end product quality - in other words, still delivering a consistent pastille with a regular, hemispherical shape.
Sandvik steel belt coolers with Rotoform system

Feeding (liquid sulphur)  Discharge (solid sulphur pastilles/ semispherical granules)
2.2.2 Advantages of pastillation

Both Rotoform types (Rotoform 3000 and HS) provide a number of significant advantages.

**High quality end product**

The Rotoform system delivers free-flowing pastilles of uniform size and quality – ideal for subsequent handling, storage, transportation and remelting or reprocessing.

- 100% premium product quality as determined by SUDIC procedures
- Uniform pastilles, diameter between 2 to 4 mm (without screening)
- Excellent crushing strength
- Low abrasion during handling and, as a result, low visible dust generation
- High angle of repose
- Discharge temperature from steel belt cooler below 70°C for smooth downstream handling of solid product

**Proven plant design for efficient processing**

This is a highly flexible system, its modular design enabling rapid and economical changeover to partial operation as required.

- From liquid to solid in one step
- Indirect heat transfer - no contact between product and cooling media
- Well-defined cooling times for controlled crystallisation
- Quick start-up and shut-down of plant
- Environmentally friendly production – low sound emissions, low dust emissions, minimal air extraction required, closed cooling water system ensures no contamination of water
Designed for long term economy

Sandvik Rotoform systems have been employed in a wide range of applications throughout the world and have proved themselves to be one of the most economical solidification processes available.

– Well proven technology
– Low energy consumption
– Low water consumption – only make-up water for the recooling system
– Easy maintenance and operation
– High availability – up to 8600 hours/year.
2.2.3 Use of the preconditioner

Sulphur can be formed at temperatures ranging from 122 to 145°C but the best results are achieved in the range below 135°C. Therefore, when the sulphur temperature is above 135°C, the use of a preconditioner to reduce the temperature to the optimum level will result in benefits in terms of both capacity and quality. The preconditioner also eliminates temperature fluctuations in the liquid sulphur feed ensuring that it reaches the Rotoformer at a predetermined, uniform temperature within very narrow tolerances.

Cooling is effected by a sulphur cooler (tubular heat exchanger). The sulphur is cooled by a mixture of water and glycol - known as thermal fluid (TF) – which circulates by means of pumps with a delivery head that compensates the pressure loss of the TF-System. The system pressure itself is set by blanketing of nitrogen, allowing temperatures of above 100°C without evaporation of TF.
2.2.4 Environmental aspects

Of all the processes available on the market, the Rotoform® process is one of the most environmentally friendly. By means of the continuously operating steel belt cooler, the heat is transferred in an indirect way and neither the product (sulphur) nor the cooling water can be contaminated. Due to very short retention time (less than 10 sec. on the steel belt), only a limited amount of H₂S, SO₂ and sulphur vapour can be released. Cooling water is normally recycled and the extracted fumes do not require any treatment such as scrubbing or incineration.

Emissions and other environmental data are within the following limits, which are valid as a standard across virtually the entire sulphur producing industry:

SO₂: max. 0,5 g/m³ at flow > 5 kg/h.

H₂S*: max. 5 mg/m³ at flow > 50 g/h

Dust**: max. 50 mg/m³ at flow > 0,5 kg/h

Noise: < 85 dB (A) at 1 m

* valid for degassed sulphur below 10 ppm

** particles < 0,6 mm diameter
3. **Handling of solid sulphur**

Rotoform pastilles have been shown to provide the ideal shape and form for solid handling, with a number of key properties.

1. **Uniform pastille size**
   As well as being the ideal form for stockpiling, uniformly sized granules are also important when remelting solid sulphur or blending with granules of other chemicals.

2. **Free flowing product**
   Pastilles are the ideal form for storage, transportation, weighing & bagging and subsequent handling of sulphur.

3. **Low friability and low dust content**
   Pastilles provide a number of environmental advantages, of which these two are among the most important.

4. **Low water content and low acidity**
   Pastilles clearly offer a range of inherent advantages, but an effective granulation system - particularly one used for the pastillation of sulphur – also needs to satisfy a number of key technical issues. Sandvik has the know-how and experience to design, manufacture and commission complete handling installations, tailor-made to the requirements of each client. This includes:
   - Systems for the transportation of sulphur, i.e. conveyor belts, inclined conveyors and bucket elevators
   - Silos including charging and discharging devices
   - Weighing and bagging systems for different types of bags, big bags or bulk material
   - Truck and railcar loading systems
   - Complete control systems

This level of experience extends to systems where expertise in problem-solving is required, such as installations where potential threats such as earthquakes or explosions need to be taken into account; where the specific weather conditions of the plant location are a factor; or in the selection of appropriate materials to resist the effects of abrasive and corrosive sulphur.
Examples of solid sulphur handling

Sulphur conveying

Bucket elevator with pastilles

Stacking and reclaiming

Stacking

Ship loading

Truck loading
4. Typical plant examples

Sulphur solidification and handling plant at Suez Oil Processing (capacity 150 t/day)
Sandvik Rotoform system for sulphur solidification at Motor Oil Hellas (capacity 450 t/day)
Sulphur solidification and handling plant at Bapco (Bahrain Petroleum Company), Bahrain (capacity 1200 t/day)
5. **Global service**

As a result of the growing number of sulphur installations in which we are involved (now in excess of 350 worldwide), we have extended our service network and are now in a position to provide local service for all existing and planned installations.

This, together with the clear technical advantages of our systems, has been a deciding factor in many customers' decision to choose Sandvik sulphur solidification and handling systems.

6. **Quality assurance**

Sandvik Process Systems has a quality program in place (DIN EN ISO 9001). A group of engineers ensures compliance of equipment with the relevant specifications. Quality control plans are established for individual components of the plant.

Sandvik Process Systems is approved to
- DIN EN ISO 14001 – environmental management system
- OHSAS 18001 – organizational health and safety

7. **Conclusion**

This process is the ideal solution for oil refineries, something that is clearly demonstrated by the fact that all major oil refineries in the world, where sulphur production has increased substantially over the last years, are equipped with this system. In short, this versatile process – which is supported by an efficient and global service network – provides a reliable and environmentally friendly solution to the issue of handling sulphur in the most efficient way possible.
8. Update on recent Sandvik sulphur pastillation plants (2000-2008)

Caltex, South Africa
Omsk Refinery, Russia
Ameriven, Venezuela
Coogee Chemical, Australia
Ferrostaal, Germany for Chile
Petrofac International for CPCL, India
Econova, Italy
SK Engineering, Korea for Oman Refinery Corp., Oman
LG Engineering, Korea for Izmir Refinery, Turkey
Snamprogetti, Italy for AGIP, Libya
JGC, Japan for Atyrau Refinery, Kazakhstan
Technip Germany for Turkmenbashi Refinery, Turkmenistan
Technip, Italy for Motor Oil Hellas, Greece
JGC, Japan for Sohar Refinery, Oman
Rosneft Refinery, Russia
Biprokwas Poland, for NIIOC, Iran
Petrofac International for Crescent Petroleum/Sharjah
Universal Aquarius/Philippines
Repsol/Spain
Lukoil/Bulgaria
Promtech/Austria for Ufa/Russia
ABB/Netherlands for Kirishi/Russia
Coromandel Fertilizer/India
Petrochina Sichuan/China
OIEC/Iran for South Pars (Phase 9+10)
Essar Oil/India
BAPCO/Bahrain
ODCC/Iran, Ilam/Iran
Techint/Argentina for Aramco/
Saudi Arabia
Foster Wheeler/UK for ENOC, Dubai
Bechtel/UK for Reliance/India
Archinsk Refinery/Russia
Produquimica/Brazil
TOYO/Japan for Petrobras/Brazil
Statoil/Norway
Mangalore Refinery/India
Nizhnekamsk/Russia
Larson & Toubro for Indian Oil/Gujarat, India
Key Group for Beltransoil/Belarus
IDP for Cepsa/Spain
Lukoil/Russia
Technicas Reunidas for Khabarovsk Refinery/Russia
Intecsa Ind. for Repsol/Spain
9. The world’s favourite sulphur solidification process

More sulphur granulation units around the world carry the Sandvik badge than any other. Of these, more than 350 are Rotoform pastillation units. Want to know why?

- High quality end product: free flowing pastilles of uniform size and premium quality
- From liquid to solid in one step
- Environmentally-friendly production
- Highly flexible modular design
- Turnkey plant capability
- Worldwide service network

**Now with power pastillation**

Our latest success, the Rotoform HS (high speed) system, is specially designed for high capacity sulphur pastillation and offers up to 2x the standard throughput rate.

No other system can deliver this combination of benefits – no wonder Rotoform is the most popular solution on the market.

Sandvik Rotoform®

The world’s favourite sulphur solidification process

Sandvik Rotoform
sulphur pastilles
10. Total capability in granulation for the oil and gas industry

Complete solutions available to handle a full range of extracted materials:

- Sulphur + Sulphur Bentonite
- Paraffin-wax
- Pitch
- Asphaltene

Complete installations based on the proven Sandvik steel belt technology:

- Patented Rotoform® system
- Automatic process
- High availability (up to 8600 h/year)
- Clean production – no cross contamination of product or cooling water; all emissions below legal limits
- Global service network

Proven capability
Our expertise in granulation solutions based on the environmentally-friendly pastillation on the Rotoform® system, the most popular and efficient of its kind in the world with more than 1400 units delivered.

Twice the capacity
With our latest development – the Rotoform HS – capable of delivering twice the production capacity of standard systems with products like sulphur, urea, caprolactam, Bisphenol A and naphthalene – we can now offer you our fastest granulation solution ever!