To handle and move molten sulphur and sulphuric acid, special pump designs—together with special materials of construction—are necessary to achieve the best reliable solution. Here is an overview of available pump designs and materials for these harsh services.

**Pumps for Molten Sulphur**

In recent years, the total world-wide production of sulphur has grown steadily. Sulphur production (Table 1) has been increasingly influenced by involuntary production of elemental sulphur at gas plants, oil refineries and other hydrocarbon processing operations (recovered sulphur).¹

When transporting sulphur in liquid form, it is important that the liquid properties are taken into consideration. Abnormal variations in viscosity, with changes in temperature, only allow sulphur to be pumped satisfactorily in the range of 135-deg C to 155-deg C.

For this reason, most pumps used for molten sulphur applications have a heating jacket used to keep the temperature constant in all wetted parts. Also, the content of hydrogen sulphide (H₂S) directly influences the temperature range, when sulphur can be pumped with an acceptable viscosity (Figure 1).

There are several alternatives for shaft sealing. For vertical pumps, stuffing box packing would be adequate, while for horizontal pumps hydrodynamic shaft sealing, mechanical seals or magnetic drive arrangements are recommended.

Although vertical pumps are widely used on sulphur melting plants, it is not uncommon to use various designs of horizontal pumps.

Horizontal pumps for molten sulphur can have a heavy-duty design with hydrodynamic shaft sealing (e.g. for molten sulphur containing solids), or modern heavy-duty magnetic drive design (e.g. for clean sulphur). Magnetic drive pumps have the advantage of safe operation without any leakage of hazardous hydrogen sulphide.

The design of vertical pumps depends not only on the purity of sulphur, but also on the size of the sulphur tank or vessel. For example, cantilever pumps are limited in their submergence depth. For clean sulphur, single or multistage pumps with foot and intermediate bearings can be used for submergence depths of up to 17-m.

For applications with impure sulphur, the solid size, hardness and concentration influence pump design. Sleeve bearings...
in hardened material, with internal product lubrication or with external grease lubrication or cantilever pumps, offer a suitable solution for such applications.

**Heatable Magnetic Drive Pumps**

A modern pumping solution for molten sulphur applications are heatable magnetic driven pumps, which have zero leakage and easy maintenance.

Zero leakage is especially important for recovered sulphur, which contains mostly H₂S gas that should not come into contact with the atmosphere. Pumps with a mechanical seal always have some sulphur leakage, since it is required to lubricate the seal faces. Often this leakage can be seen in the mechanical seal area as solid sulphur.

Heatable magnetic driven pumps have been used for molten sulphur applications for ten years with very good results. Due to the nature of sulphur, these pumps use a special design.

In the magnetic coupling / isolation area, a good heat exchange is required in order to dissipate the heat caused by magnetic losses. The sleeve bearing is manufactured with erosion-resistant silicon carbide and it has intensive lubrication that also allows operation at lower capacities.

However, the pump has a definite minimum allowable flow rate in order to avoid heat generation inside. The intensive heating area around the pump casing and around the isolation area ensures a constant temperature during operation and a safe start-up. With the jacketed volute casing drain, the pump can be safely emptied without the risk of sulphur crystallization after pump shut-off.

**Heavy Duty Horizontal Heatable Pumps with Hydrodynamic Shaft Seal**

Hydrodynamic shaft seals have been used for over 75 years as a means of creating a seal without contact or wear during operation.

During operation, the main impeller back vanes work in conjunction with one or more auxiliary impellers to hydrodynamically relieve the pump stuffing box completely from pump suction and differential pressure. In addition, solids are kept away from the shaft sealing area. This pump design works best under permanent operation at a fixed speed with steady suction pressure.

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**Table 1**

<table>
<thead>
<tr>
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<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
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<td>Total Production</td>
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<td>64.9</td>
<td>66.9</td>
<td>69.8</td>
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<tr>
<td>Recovered Elemental</td>
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<td>41.8</td>
<td>43.4</td>
<td>45.6</td>
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<td>Sulphur (in other forms)</td>
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<td>16.7</td>
<td>16.9</td>
<td>17.7</td>
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<tr>
<td>Total Involuntary</td>
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<td>58.5</td>
<td>61.3</td>
<td>63.3</td>
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<tr>
<td>Mined Elemental</td>
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<td>1.1</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Pyrites</td>
<td>5.5</td>
<td>5.3</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Total Voluntary</td>
<td>6.8</td>
<td>6.4</td>
<td>6.6</td>
<td>6.5</td>
</tr>
</tbody>
</table>

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**Figure 1.** Viscosity of sulphur and influence of H₂S on the viscosity.

**Figure 2.** Heatable magnetic drive pump.
Vertical Sulphur Pumps

Horizontal pumps cannot be installed in sulphur tanks / pits below ground level. Suitable vertical pumps must be considered. Different designs of vertical pumps are available.

For recovered sulphur, pumps with shaft support bearings are suitable. Submergence depths longer than 2000-mm require additional intermediate bearings. The vertical shaft is supported by anti-friction bearings on the top, outside the tank and by sleeve bearings below the mounting flange. The sleeve bearings are lubricated by the sulphur.

It is recommended that the maximum pump speed of vertical sulphur pumps is limited to 1500-rpm at 50-Hz or 1800-rpm at 60-Hz, to reduce the risk of temperature rise in the sleeve bearings. Radial forces and pump vibration can be limited. The special design feature of vertical molten sulphur pumps is the heating jacket on the discharge bend, shaft and discharge pipe.

Certain vertical pumps (Figure 4) have some additional design features. Some can have up to three stages, which allow a high differential head at low speed. The discharge and the shaft column are built as a complete unit to give optimum stability, especially for pumps longer than 2000-mm. This complete unit also requires only a very small opening in the tank/pit. In addition, all pumps have a double volute casing, which reduces radial forces to a minimum. This results in low wear of sleeve bearings, which increases the MTBF for these pumps.

Materials for molten sulphur pumps vary from cast iron, cast steel and stainless steel depending on the application.
Pumps for Sulphuric Acid

*Spiritus Vitrioli* is the ancient name alchemists used when referring to the type of etching liquid now known as sulphuric acid. Initially they produced this acid from alum, but later by burning sulphur with saltpeter.

Today, sulphuric acid is produced from pyrites, from other metal sulphides, or from gases containing sulphur, the principal source however being pure sulphur. Sulphuric acid is reckoned among the most important basic substances of chemical technology and is used in large quantities especially by the industrial nations of the world.

It is not without reason that the magnitude of sulphuric acid production is taken as a measure of a country's state of development. The world's annual production of sulphuric acid is more than 185 million tons (Table 2).

Although the technology used in sulphuric acid production may be viewed as fully developed, one is still, as before, trying to improve the methods by increasing the yield and by increased use of the heat produced in the process.

As a result of strict environment laws new ways of producing sulphuric acid were invented, e.g. by thermal dissociation of waste acids, by suitable reconditioning of sulphur containing waste gases, or by the use of sulphur containing minerals.

The concentration and partial pressure of the reaction components are decisive factors for the conversion. Based on the principle of mass action, the company Bayer Leverkusen invented the so-called double catalysis process (DP 1136988 German Patent) at the start of the 1960s.

In this process, 90 percent of the SO₂ is converted into SO₃ initially before primary absorption. The remaining gas is again converted in the catalysis, thus increasing the conversion rate from 90 percent to 99.5 percent, or even higher, before final absorption takes place.

In a heat recovery system, developed by a large company, the heat released by the exothermic reaction in sulphuric acid plants can be utilized for the generation of steam at 10 bar pressure. For the design of circulation pumps at the front end of the tower, materials that have to withstand concentrated sulphuric acid (99 percent) at temperatures of up to 240-deg C are required.

For these applications, suitable alloys are required which offer the highest corrosion resistance, even against erosion corrosion. The same, of course, applies to any other sulphuric acid plants equipped with energy saving heat recovery systems.

Sulphuric acid is used as an important auxiliary and decomposition agent in many branches of industry. It is used in the production of fertilizers, synthetic washing agents and explosives, and is also used in large quantities in the paper, fiber, plastics and the metals industry.

Sulphuric acid does not always remain as a true reaction agent in the final product, but as a result of contamination turns into a residuary acid. Today, after suitable treatment, this acid is increasingly recycled into the process.

Up to medium concentration, sulphuric acid is almost dissociated into ions. The aggressivity of the acid is therefore increased at concentrations between 20 percent to 80 percent. At higher concentrations, the dissociation is reduced and the acid therefore becomes less aggressive.

The speed of corrosion of metallic materials in sulphuric acid is a function of temperature, concentration and flow velocity. The presence of salts, gases or solids can affect the aggressiveness of the acid immensely.

Figure 5 below shows to what extent the concentration, temperature and velocity of sulphuric acid alter the erosion/corrosion rate of an austenitic chromium-nickel steel.

In a sulphuric acid plant, vertical and horizontal centrifugal and decomposition agent in many branches of industry. It is used in the production of fertilizers, synthetic washing agents and explosives, and is also used in large quantities in the paper, fiber, plastics and the metals industry.

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In a sulphuric acid plant, vertical and horizontal centrifugal
gal pumps are used to transport diluted and concentrated acids that, apart from SO$_2$ and SO$_3$, can also contain solids. By selecting suitable resistant materials and pump designs that match the particular process conditions, the high demands made on the pump can certainly be met.

Standard materials can only withstand the enormous corrosion and erosion corrosion to a limited extent. Erosion corrosion, which occurs frequently, particularly in centrifugal pumps is caused by the interaction of liquid flow and powerful turbulence, as well as chemical effects.

If a material of sufficient resistance is not used, or worse, if the pump is operated too far from its best efficiency point, the effect of this intensive type of erosion corrosion can very quickly lead to the destruction of the pump. The life-time of a centrifugal pump is therefore not only dependent on the material used, but also on the way the pump is operated.

**Horizontal Pumps for Sulphuric Acid Service**

For sulphuric acid, horizontal pumps with different sealing systems are available. The appropriate system depends on the duty point, the acid properties and the temperature of the application. Sometimes the available and suitable material of construction for a pump component limits the use of a certain

design (e.g. spacer can for magnetic drive pump).

A highly corrosion-resistant chromium alloy silicon cast iron, called Siguss, has been developed. It has good resistance to wear and increased chemical resistance. This material is chemically resistant to H$_2$SO$_4$ at all concentrations up to boiling point, therefore suitable for all sulphuric acid applications including the evaporation of waste acid.

Due to the brittleness of the material, a special armored
pump design is required (Figure 6). This material can only be used for horizontal pumps.

**Vertical Pumps for Sulphuric Acid Service**

Typical sulphuric acid plants are equipped with vertical pumps throughout the various stages of the process (drying tower, primary and secondary absorption tower and oleum tower).

Depending on the actual location of the pump in the process, different materials will be required to withstand acid concentrations and temperatures. Each pump manufacturer has their own materials developed for these special requirements. Figure 7 shows a typical vertical acid circulation pump.

Slight changes in acid concentration and/or temperature can result in serious equipment damage. Figure 8 shows a damaged pump impeller.

Pumps for these type of applications require a high level of engineering. Pump manufacturers should be consulted to find the most reliable solution regarding design, materials of construction, sealing systems and pump operation.

**Footnotes:**

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**Figure 7. Vertical acid circulation pump.**

**Figure 8. Damaged pump impeller.**