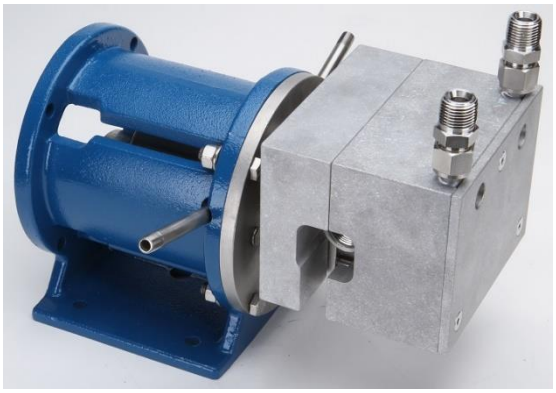
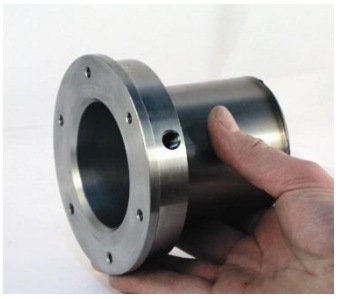
Application Note to the Field	Pumping Molten Sulfur with Liquiflo Gear Pumps
Application Note Number: 2507-1	**Date:** July 1, 2025

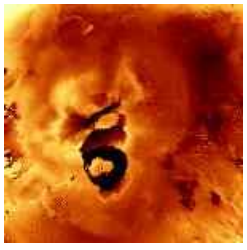
Sulfur (atomic symbol "S") is an abundant nonmetal chemical element which exists as a bright yellow crystalline solid at normal room conditions. Sulfur is used to produce sulfuric acid and a variety of other important sulfur-based compounds and products. These include vulcanized rubber, sulfites, sulfates, sulfa drugs, Epsom salt, sulfonic acids, dimethyl sulfoxide, thionyl chloride, pulp and paper, photographic film, batteries, pharmaceuticals, explosives, gunpowder, fireworks, matches, insecticides, fungicides, fertilizers, plasticizers, preservatives and more.

Molten sulfur is one of the most difficult chemicals to pump. First, high operating temperatures are needed to keep a normally solid element in a liquid state. Then, precise temperature levels must be maintained – small variations lead to wide changes in viscosity. If the sulfur gets too cold, it solidifies in the pump and piping, requiring intensive, expensive downtime; too hot, and it polymerizes, turning into a near solid.



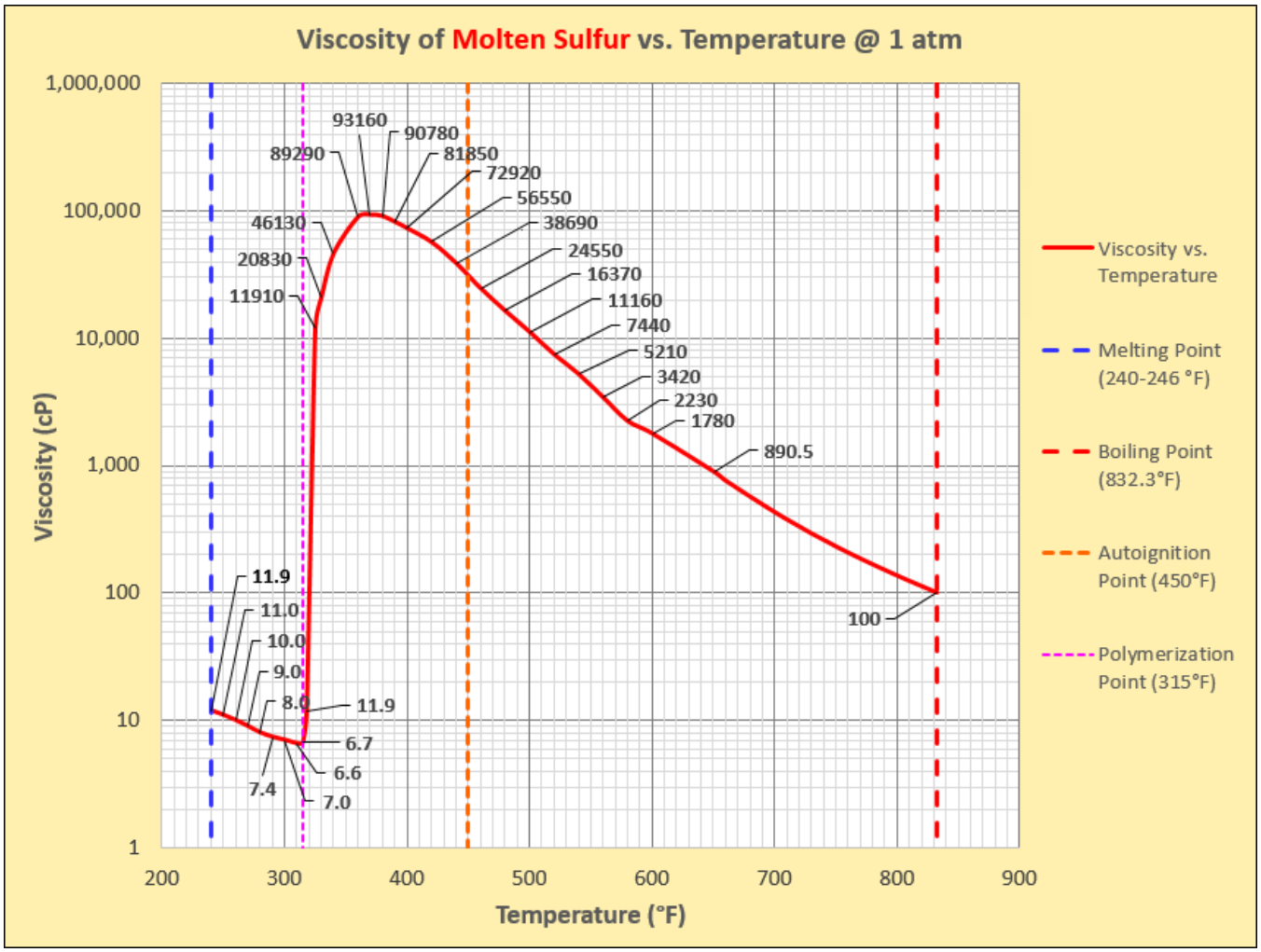
Therefore, it takes and extraordinary pump to transfer and meter sulfur – and this is precisely what Liquiflo can supply to our customers for this difficult application. Liquiflo's highly specialized gear pump design uses a **magnetic drive**, a **temperature control (heating) jacket** on the pump end to maintain temperature, and a patented **Dual Kan® enclosure**, which is a double wall containment can designed to circulate a heat transfer fluid between the walls of the can. The Dual Kan is fitted over the driven magnetic area, so sulfur can be melted before the pump is started. These features allow the sulfur to stay within a very tight temperature band. As a result, the pump is able to deliver accurate, pulse-free flows; and, liquid temperatures are kept within the optimum range, allowing trouble-free operation.





At 246°F (119°C), sulfur is completely molten and changes to an orange color and then to a dark red color as the temperature is increased. Molten sulfur is typically pumped at 250 to 300 °F (121 to 149 °C) where its viscosity is low (11 to 7 cP). **The temperature must be maintained within this relatively narrow range to keep the sulfur in a free-flowing liquid state.** Below 315°F (157°C), liquid sulfur consists mainly of cyclo-S_8 molecules. Above 318°F (159°C), the viscosity will start to increase rapidly due to polymerization and will reach approximately 93,000 cP at 370°F (188°C). Above 380°F (193°C), the viscosity will consistently decrease until it reaches 100 cP at the

normal boiling point of 832.3°F (444.6°C). This behavior of the **absolute viscosity of molten sulfur as a function of temperature** can be seen in the following logarithmic graph:



Suggested Gear Pump Constructions for Pumping Molten Sulfur:

Liquiflo's standard gear pump construction for molten sulfur is: **Mag-drive** with the **Dual Kan** option, **316 SS Housings**, **Alloy-C drive & idler gears**, **Carbon wear plates & bearings**, **Tungsten Carbide coated 316 SS drive & idler shafts**, **Teflon O-rings** and **316 SS bearing pins**. In addition, a **Temperature Control Jacket** ancillary device is required for the pump end to precisely control the temperature. Examples for the pump model code and heating jacket part number are given below:

Example Model Code for H9F 316 SS Pump: H9FS**11**EE102006B**D**-8(280) (**Alloy-C** Gears)
Part Number for Temperature Control (Heating) Jacket: H9F-HJ

For the above pump construction, Alloy-C gears are used in lieu of 316 SS gears because the latter material is highly susceptible to galling wear. This is a form of adhesive wear that causes the material of one gear to be removed by the other gear when the gears contact each other. Galling wear is exacerbated when the fluid viscosity is low and there is insufficient lubrication between the gears. Such

is the case with molten sulfur, where the viscosity at the required pumping temperature is typically less than 10 cP. Galling can also cause the gears to bind (usually when the pump is idle), which can result in a seizure failure of the pump.

Liquiflo suggests using double metal gears only when the fluid viscosity is 100 cP or greater. This is to prevent an excessively high wear rate of the metal gear teeth due to continuous contact during operation when the viscosity is too low. For viscosities under 100 cP, a nonmetal idler gear is the standard choice. However, since plastic gears are not acceptable for use with molten sulfur, this leaves only Carbon as a possible idler gear choice. **Although Carbon is chemically compatible with molten sulfur, it is not ideal for the idler gear material because it is brittle.** Impact with the metal drive gear can cause the gear teeth to break or chip which will reduce the performance and possibly cause other problems with the pump.

Since the wear rate is proportional to the square of the speed, **the wear rate of the Alloy-C gears can be significantly reduced by limiting the pump speed to 600 RPM.** This also has the benefit of reducing the PV load on the bearings, which will reduce the wear rate of these critical components. The moderate viscosity of molten sulfur (8 cP @ 280°F) will help to maintain a fluid film between the bearings and shafts as the speed is reduced, further mitigating the wear rate. The disadvantage of running the pump at a lower speed is that a larger pump size will be required, which may be more expensive, but the result will be a reliable application.

In recent years, Liquiflo has gained experience with utilizing **double Nitronic 60 gears** for difficult applications where other double metal gear materials would wear at an unacceptably high rate. Nitronic 60 is a grade of nitrogen-strengthened austenitic stainless steel that has nearly twice the strength of 316 Stainless Steel and is highly resistant to high-temperature oxidation and wear from impact and galling. **Nitronic 60 is a superior material to other metal alloys for resisting physical wear at the more extreme conditions of high temperature, high pressure and low viscosity.**

Nitronic 60 is comparable to 316 Stainless Steel in chemical resistance to molten sulfur, but is superior in resisting pitting, stress corrosion cracking and crevice corrosion. Double Nitronic 60 gears can last longer than Alloy-C gears at more extreme conditions and should be considered for this service. Nitronic 60 gears are currently available for H-Series gear pump models **H7N thru H14F in 316 Stainless Steel construction**. An example for the pump model code with Nitronic 60 gears is given below, where the "**11**" code in **Positions 4 & 5** of the previous pump model code example, has been replaced by the "**NN**" code:

Example Model Code for H9F 316 SS Pump: H9FS**NN**E**E**102006B**D-8(280)** (**Nitronic 60** Gears)

The "**D**" in **Position 15** of the above model code denotes the **Dual Kan** option and the "**-8(280)**" suffix indicates a **Temperature Trim @ 280°F** for the Carbon bearings in **Position 7** (Code "**E**"), where the inner diameter of the bearings is increased to accommodate the thermal expansion of the metal shafts.

For any questions about selecting Liquiflo gear pumps for molten sulfur applications, please consult the Liquiflo Applications Group.