# Specific Gravity & Viscosity – Part 2

Joe Evans, Ph.D http://www.PumpEd101.com

Last month we learned that the power required by a centrifugal pump is directly proportional to the specific gravity (SG) of the pumped liquid. We also learned that, as long as the liquid has a viscosity similar to that of water, the weight of the liquid has no effect upon the flow and head (in feet) produced. This month we will take a look at the effect of viscosity. Viscosity is a liquid property that is independent of SG and, unlike SG, it can be very complex. Viscosity can affect all of the operational characteristics of a pump. What follows is but a brief introduction - - if you work with liquids of varying viscosity, I encourage you to look further into this subject.

If you are familiar with the term resistivity, you will find that it shares a similar trait with viscosity. Resistivity is the "internal" resistance of a particular substance and is due to the interactions among the atoms or molecules that make up that substance. It is an indication of how well a substance will conduct an electrical current. Viscosity is the "internal" friction of a liquid and is due to the cohesive forces of the molecules that make up the liquid. It is an indication of how well that liquid will flow. Although viscosity is often defined as a resistance to flow or shear, most of us tend to think of it as a liquid's thickness or stickiness. Water and gasoline are thin liquids while motor oil is thicker. Corn syrup and molasses are even thicker and the thickness of a liquid is related to its viscosity. Still, resistance to flow is a key measurement in determining the actual viscosity of a liquid. In the USA an instrument, known as the Saybolt Universal Viscometer was widely used in the petroleum industry to measure low to medium viscosities. It measures the time it takes for a certain amount of liquid to flow through a glass tube and the result is viscosity stated in Seconds Saybolt Universal (SSU). The larger the SSU number, the greater the viscosity. The Saybolt Furol Viscometer measures higher viscosities in units of SSF. There are also a number of other measurement methods and two of the more popular units of measure are centipoises (cP) and centistokes (cSt). Conversion tables and calculators are available to relate these various units. I will use the SSU unit of measure in this column.

The viscosity of many liquids is related to their temperature. Viscosity can decrease with an increase in temperature or increase when the liquid is cooled. For example, at 60°F Texas crude oil has a viscosity of 400 SSU. Increase that temperature by just 40° and its viscosity drops to 120. The Viscosity Index (VI) is used in the petroleum industry to relate the effect of a change in temperature on viscosity. A low VI indicates a rather large change while a high VI is characteristic of oils with relatively stable viscosities.

It is not difficult to accept the fact that a liquid's viscosity might decrease as temperature increases but, there is another effect that is a bit more difficult to visualize. Physical agitation can also influence the viscosity of certain liquids. Some, including paints, ketchup and mayonnaise fall into a category known as thixotropic liquids. When agitated, these liquids will exhibit a lower viscosity. Others such as cream and clay slurries are called dilatant liquids and these exhibit an increase in viscosity during agitation.

Centrifugal pumps are often used to pump liquids with viscosities up to 2000 SSU and sometimes higher (as a point of reference, water has a viscosity of 32 SSU). As viscosity increases the operational characteristics of a centrifugal pump will change per the following general rules - - 1) flow, head and efficiency are reduced and 2) the brake horsepower required is increased. These changes are largely due to an increase in the fluid friction and the "disk" losses that occur due to viscous drag on the impeller. The increased fluid friction reduces head and flow while viscous drag increases the horsepower required. Both take a toll on hydraulic efficiency. Table 1 illustrates these general rules.

**Effect of Viscosity on BEP Performance**

| Viscosity | GPM | Head | Efficiency | BHP |
|---|---|---|---|---|
| 32 | 170 | 125 | 0.75 | 7.2 |
| 200 | 160 | 122 | 0.64 | 7.7 |
| 500 | 150 | 117 | 0.53 | 8.4 |
| 1000 | 140 | 111 | 0.42 | 9.3 |
| 2000 | 120 | 105 | 0.31 | 10.3 |

Here we see the BEP performance of a small centrifugal pump when pumping liquids of varying viscosity (corrected for variations in SG). The top row shows the results for water while the lower rows represent liquids of increasing viscosity. As predicted, flow, head and efficiency are reduced while BHP increases.

Determining the effect of viscosity on centrifugal pump performance is not as straight forward as our SG example. Testing a specific pump with the actual liquid at the required temperature will always provide the most accurate results. Unfortunately, most pump manufacturers do not have this capability and doing it on your own can be both time consuming and expensive - - especially if you do not already own the pump.

In the early sixties, the Hydraulic Institute (HI) developed a graphical system that used a collection of viscous test data to predict centrifugal pump performance when pumping liquids of varying viscosity. The graph provided correction factors that adjusted the water based values for head, flow, and hydraulic efficiency. Although the results were reasonably reliable, the system was limited to true Newtonian liquids pumped by radial flow impellers. Another limitation of the system was that the test data used to provide the correction factors was based on petroleum oils and often understated pump performance when pumping other types of viscous liquids. In January of 2006 HI introduced ANSI/HI 9.6.7 ("American National Standard for Effects of Liquid Viscosity on Rotodynamic Pump Performance"). This revised procedure overcomes some of the shortcomings of the original system and also provides equations that can be used by computer based viscosity calculators to predict pump performance. Go to this link ( http://www.lightmypump.com/viscosity/Viscosity.html ) to access an online viscosity correction calculator.

*Joe Evans is the western regional manager for Hydromatic Engineered Waste Water Systems, a division of Pentair Water, 740 East 9th Street Ashland, OH 44805. He can be reached at joe.evans@pentairwater.com, or via his website at www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.*