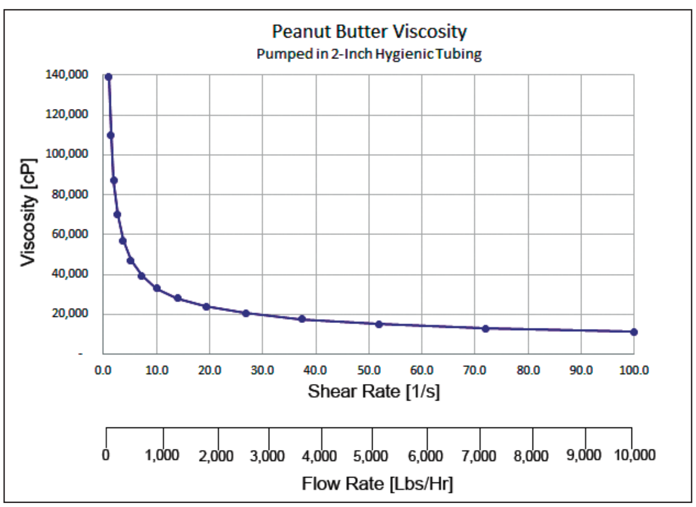
from experience

Go With the Flow for Successful Viscous Fluid Design

The June 2013 issue of From Experience examined the influence of temperature on fluid viscosity, and the practical design considerations to accommodate the pressure drop changes that can occur. Fluid viscosity changes due to flow rate are a second consideration for many food products that are mixed or pumped. The original concept of viscosity developed by Sir Isaac Newton theorized that the force required to move a fluid changed in constant proportion to the speed at which the fluid moved. Sir Newton called that ratio of force to velocity, measured as the ratio of shear stress to shear rate, viscosity. However, many food products do not behave in a "Newtonian" manner. A very common form of this non-ideal behavior are the pseudoplastic or "shear thinning" fluids, where increasing the shear (pumping rate) actually reduces the apparent viscosity. Examples of shear thinning are observed with many formulated food products, spreads and pastes, peanut butter, and some cultured dairy products. A variation of shear thinning fluids are plastic fluids, such as tomato ketchup, where force is first required to initiate flow, after which the fluid "yields" and begins to flow as a shear-thinned fluid. A less common occurrence are "shear thickening" fluids, where the apparent viscosity increases with flow.



Practical experience with your fluids is one guide for a new design or modification to a mixing or pumping system. However, test data is recommended for many instances, and is readily obtained from a variety of sources. A very common instrument used to test fluid is a Brookfield rheometer. The reported results should be provided over a range of shear rate values and temperatures, as illustrated for a peanut butter sample. Note the characteristic curve of this pseudoplastic fluid, which will eventually flatten out to a near constant viscosity at high shear rates. Your fluid test report should be returned with the viscosity reported against the rheometer's shear rate. To translate the test shear rate into a flow rate for pipe sizing, the following equations may be applied:

$$\text{gamma} = \frac{39 \times q}{d^3} = \frac{0.08 \times Q}{d^3 \times \text{rho}}$$

gamma = shear rate (1/s)
q = GPM
Q = Lbs / Hour
d = Internal pipe diameter, inches
rho = Specific Gravity

Knowing viscosity at a corresponding flow rate, and for a given pipe size and length, the pressure drop in the piping system can be calculated, and pump requirements determined. If the resulting pressure drop is too high, then the flow or line size must be adjusted for a given operating temperature.

experience in brief

While peanut butter is an extreme case, it is important to account for the difference in apparent viscosity at low and high shear for many shear thinning food products for a successful design. Several good practices include:

- Installing a VFD motor on pumps and agitators to initiate fluid movement, then gradually ramping up the motor speed (pumping rate or agitator RPM) as the fluid thins out and pressure drop decreases.
- Providing larger diameter inlet piping to viscous pumps to promote flow into the pump and thereby avoid high pressure drop and low Net Positive Suction Head Available (NPSHA).
- Controlling tank and piping temperatures with jacketing or heat tracing.

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Direct Comments/Questions to:
Warren Green, Manager
Process Engineering
wgreen@hixson-inc.com

Phone: 513.241.1230
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