

Fomtec Technical Advices

FTA No. 60

Viscosity

General

The viscosity of a fluid is a measure of its resistance to move at a certain force put onto it. In daily language we talk about thickness, e.g. syrup has higher thickness or viscosity than water. Hence, it is easier to pour water through a small opening than syrup. The same goes for firefighting foam liquids.

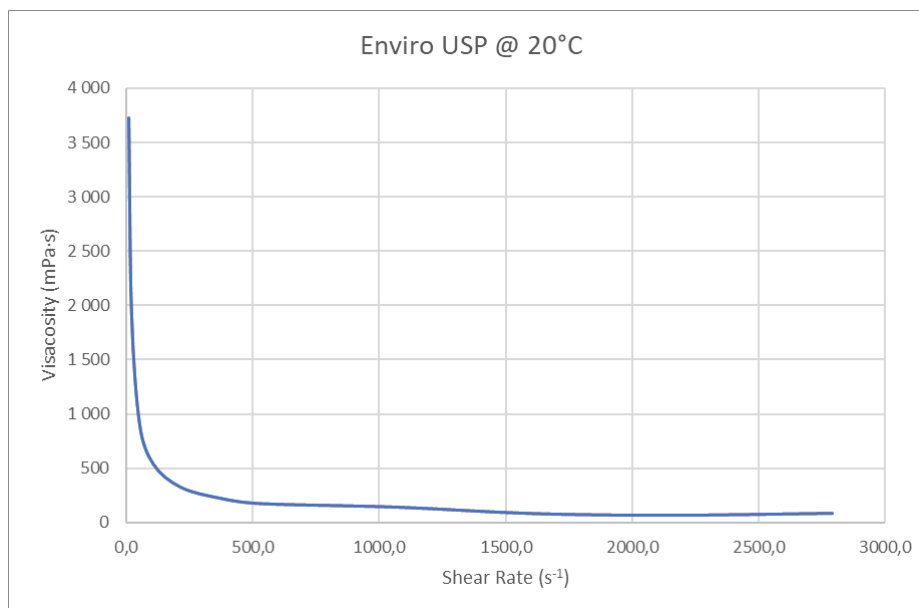
Some foam liquids are formulated with thickening agents in order to manage the expected performance. Hence, they have higher viscosity than other foam liquids. This needs to be considered when designing system to get correct dimensions of piping and a suitable proportioning device to get right induction.

Typical foam liquids with high viscosity are the so called alcohol resistant types especially designed to be used at fires involving water soluble fuels (e.g. methanol, ethanol, acetone, isopropyl alcohol etc.). Lately, there has been introduced fluorine free foam liquids (FFF:s) on the market with high fire performance in the range of AFFF:s. Most of these are also high in viscosity in order to meet the performance. In some cases these are marketed as drop-in replacement for traditional AFFF:s, but obviously that is not the case. In order to use high viscous FFF-types the system needs to be assessed and adjusted to handle the higher viscosity in order to obtain correct induction.

Viscosity Measurement and Units

Viscosity is measured by various types of viscometers (measurement at one given shear rate) or rheometers (measurement at different and defined shear rates). The first types are frequently used as quality control instrument and gives an idea on the "thickness" of the liquid in the can as is. The latter method is used to measure viscosity more detailed at different shear rates (see below) and shows the behaviour of the liquid in motion and can be used for system design.

For example, foam concentrates with high viscosity are very shear thinning. This means that viscosity decreases rapidly when applying a force to it to move, like pumping. This behaviour is crucial for the concentrate to be fully functional and give a correct induction at the injector. This shear thinning behaviour is not seen in a viscometer, but has to be studied in a rheometer. The result from a rheometer is a table or graph showing how the viscosity is decreasing with increasing shear rate (which is equal to the force put on the liquid).



The graph above is showing the viscosity decrease by shear rate. The shear rate is not an easy parameter to understand, but think of it as rubbing the palm of your hands against each other. The more intense you rub, the more energy you put in resulting in warmer hands. The range of the shear rate illustrated above corresponds to a spindle of about 3 cm diameter immersed in the liquid and rotated at different number of revolutions (rpm). The lowest shear rate is generated by a spindle spinning from 5 rpm to the highest by 1300 rpm.

By using this curve, engineers can design systems with the correct proportions of piping systems, flow rates etc. This cannot be achieved by a single measurement point done with a viscometer.

Since viscosity can be measured in many different ways, the units of the viscosity are also varying and depending on the method used. There is also a distinction between viscosities, depending on the method; one is called dynamic viscosity and the other kinematic viscosity.

The SI unit is Pascal second (Pa·s). Normally the unit mPa·s is used ($=1000 \cdot \text{Pa} \cdot \text{s}$), since viscosity values in this unit are quite small. A low viscous foam concentrate has a viscosity about 10 mPa·s up to high viscosity AR-type concentrates to 4000 mPa·s. Another unit that frequently appears is centipoise (or cP) that is the unit in the CGS-system. To translate mPa·s to cP is very easy:

$$1 \text{ cP} = 1 \text{ mPa} \cdot \text{s}$$

Both mPa·s and cP are called dynamic viscosity and are preferably measured by a rotating spindle dipped into the liquid.

Another measurement is with a glass capillary viscometer, where the viscosity is determined by the time it takes for the liquid to pass between two defined lines in a glass capillary. This viscosity is called kinematic viscosity and is given in the units m^2/s (sometimes as mm^2/s) or Stokes (St). $1 \text{ m}^2/\text{s}$ is equal to 1 000 000 mm^2/s and $1 \text{ mm}^2/\text{s}$ is equal to 1 cSt.

It is quite easy convert mPa·s to cSt (or mm²/s), the conversion factor is the density (or specific gravity as it also called) of the liquid.

$$\text{Kinematic Viscosity (cSt or mm}^2\text{/s)} = \frac{\text{Dynamic Viscosity (mPa} \cdot \text{s)}}{\text{Density (g/ml)}}$$

Examples:

The dynamic viscosity of a foam liquid is 2700 mPa·s and the specific gravity (or density) is 1,045 g/ml. Then the kinematic viscosity is calculated as 2700/1,045 = 2584 cSt (or mm²/s).

The kinematic viscosity of a foam liquid is 1800 cSt and the specific gravity is 1,025 g/ml. Then the dynamic viscosity is calculated as 1800 · 1,025 = 1845 mPa·s.

Dependence on Temperature

Viscosity of a liquid is normally depending on the temperature at which it is measured. Higher temperature decrease viscosity and lower temperature increase viscosity. Some foam liquids increase quite heavily when temperature goes well below 0°C. These are in some cases marketed as freeze protected foam liquids suitable for use at temperatures well below -10°C. Measuring viscosity on these type close to their freezing point shows that the viscosity is so high that it is not possible to pump or move the liquid. It is more acting as a soft rubber ball. Still, there are no sign of ice crystals in the sample.

Viscosity at Different Shear Rates

The viscosity is in some cases depending on how much force we put into the liquid. These type of liquids are referred to as non-Newtonian and are normally high in viscosity – like syrup. Liquids where the viscosity is independent of the force put into it are called Newtonian – like water.

The word used for the amount of force put into a liquid is called shear rate. It can be illustrated by rub your hand against each other. The more force you put into it the faster the hand are rubbed and the more friction and heat is created. The more speed you have when rubbing hands the higher shear rate you have between them, the warmer it gets. In a liquid, the more shear rate that is applied the easier it flows.

Data for viscosity at different shear rates can be found in the TDS for most of Fomtec's high viscous products.

Recommendation

To know the viscosity of a foam liquid is an important parameter in order to make correct design and have a fully working system when needed. The size of pipes, type of pumps and selection of suitable proportioning devices are examples of equipment needed to be adjusted for the viscosity. Make sure you get the viscosity data needed for the product from your supplier. Fomtec are providing viscosity curves for the most common products on their TDS.