

Viscosity of Foam Concentrates

- Definition of viscosity
- The ways of measuring it and the units of measure
- Explanation of what it means for firefighting systems



Viscosity is simply the resistance of a fluid to flow. Some fluids such as water are very runny and have low viscosity, others such as oil can be much thicker. You can think of it as the internal friction opposing flow within a liquid.

Measuring Viscosity

There are two ways to measure viscosity – either move an object through a static fluid, or move the fluid through a static object.

A viscometer generally uses the first method – a spindle or disc is rotated in the fluid and the resistance to movement measured – this gives the dynamic viscosity. The standard unit of dynamic viscosity is Poise, P. Since this is too large a unit, centipoise cP (one-hundredth of a Poise) is generally used. An alternative unit is the Pascal second Pa.s. This is also a large unit and milliPascal seconds mPa.s are more convenient. One centipoise is the same as one milliPascal second.

A capillary tube uses the second method – the time taken for a volume of fluid to pass through a capillary tube is measured - this gives kinematic viscosity. The standard unit of kinematic viscosity is the Stoke, St. This is divided by one hundred to give centiStokes or cSt, which is also expressed as mm² per second. The relationship between dynamic and kinematic viscosity is:

kinematic viscosity = dynamic viscosity divided by density of the fluid

Since most foam concentrates have a density close to 1, they can be treated as the same, therefore:

$$\begin{aligned} 1 \text{ cP} &= \\ 1 \text{ mPa.s} &= \\ 1 \text{ cSt} &= \\ 1 \text{ mm}^2\text{second}^{-1} &= \\ 1 \text{ mm}^2/\text{second} &. \end{aligned}$$

Newtonian fluids

A simple definition of viscosity is the amount of movement in the liquid when a force is applied. In most liquids the movement is proportional to the force applied,

i.e. – if you double the force you get double the movement.

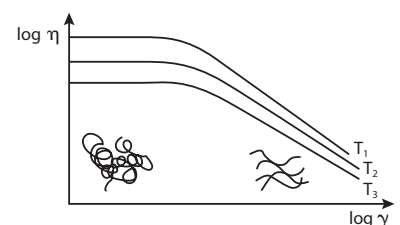
The viscosity is the same whatever force is applied – these are known as Newtonian liquids. Most simple liquids and solutions, including AFFF foam concentrates are Newtonian, such as JetFoam or Tridol^{CS}. Some alcohol resistant products such as Niagara^{CS} are also Newtonian products, even though this is an “AR” products.

Non-Newtonian fluids

Suppose we have a solution of a polymer, and the polymer chains are all entangled with each other like spaghetti. If we apply a small force to the solution, the tangled polymers give a great resistance to movement and the viscosity is very high. As the force increases, the polymers start to untangle and the resistance to movement is reduced. A greater force results in a lower viscosity.

Fluids that behave like this are described as non-Newtonian, shear thinning or pseudoplastic. AR foam concentrates like Alcoseal^{CS} and Tridol^{CS} ATF Ultra contain xanthan gums which behave in this way.

Graph 1 below shows the effect of increasing shear on the polymers and the viscosity.



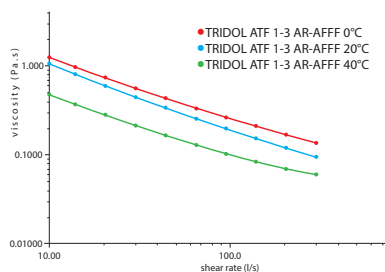
Graph 1 - The effect of increasing shear on the polymers and the viscosity.

The viscosity of non-Newtonian AR foam concentrates is measured with a Brookfield viscometer and a rotating spindle. There are different spindles and rotation speeds available, but the convention for foam concentrates is usually spindle 4 and 60 rpm. Most foam concentrates give viscosities in the range 1000 – 2000 mPa.s using this method.

An alternative way to measure viscosity is a cone and plate viscometer. A thin film of fluid is trapped between a smooth plate and a conical rotating disc that rotates at different speeds. The advantage is that the shear rate at each speed can be calculated to generate a plot of viscosity vs shear rate.

Viscosity of Foam Concentrates

Graph 2 shows the viscosity of Tridol⁶⁶ ATF Ultra 1/3 measured using a cone and plate viscometer at different temperatures. From this graph it is possible to see how a liquid become less viscous as the temperature increases. Conversely, as the temperature drops, viscosity will increase.



Graph 2 - The viscosity of Tridol⁶⁶ ATF Ultra 1/3 measured using a cone and plate viscometer at different temperatures.

Gels

Tangled polymers give thick solutions, but if there is any attraction between the polymer chains, then a three-dimensional structure, or a gel can form. Gums can contain negatively charged groups, and cations such as metals can cross-link the chains making suitable tank construction vital.

Polymer-free alcohol resistant products

Angus Fire's Niagara AR-FFFP was the first product to make it possible to overcome these viscosity problems and simplify induction systems. As Niagara⁶⁶ is Newtonian it overcomes viscosity problems.

The difference Between "Low Viscosity" and "Newtonian"

Some products have been described as being "low viscosity" whilst others are "Newtonian". As we have seen, Newtonian has a specific definition whereas "low viscosity" means a product has a lower viscosity than another but will still be viscous.

Key Considerations

Induction & proportioning

Variations in viscosity can affect an induction system's accuracy as a proportioning rate is calibrated to a specific viscosity. Changes in viscosity, or foam concentrate, can mean an installed system needs modification.

Low temperature

As the temperature drops, on-board a ship or in a cold climate, the viscosity of a product will increase. Be sure to select a concentrate suitable for the temperature range.

Phase separation & Product testing

The polymer in some inferior products may separate during storage, rendering the product unusable. Angus Fire conducts storage and stability testing to ensure high product quality.

The need for regular inspection and testing of foam stocks is recognised in international standards such as NFPA 11 (2010 edition), section 12.6.

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