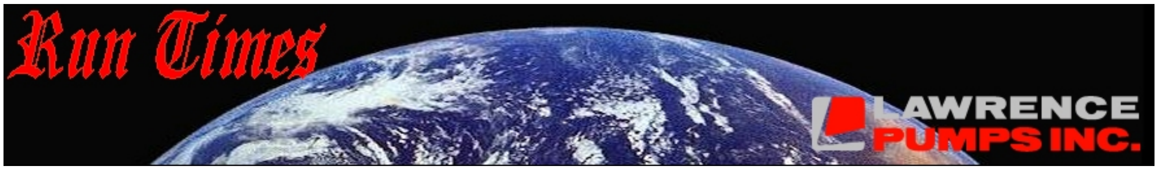

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Many processes involve the pumping of viscous fluids. Although centrifugal pumps generally serve as an efficient means of fluid handling, performance can be dramatically impacted by viscosity. In this issue we'll discuss some of the factors that affect pump performance loss when handling viscous fluids.

A solid exhibits elasticity when exposed to a shearing force. Provided that the solid's yield strength is not exceeded, the material will return to its original position once the shearing force is removed. This is a characteristic that separates solids from liquids. Gases and liquids are inelastic. When a shearing force of any magnitude is applied to a gas or a liquid, it will shear. The amount of shear for any given force is dependent on viscosity. Viscosity is a measure of a liquid's resistance to a shearing stress from an applied shearing force. This internal fluid resistance to shear may be thought of as fluid friction.

Fig 1 shows two parallel plates with fluid between them, that are separated by distance Y. If one plate moves relative to the other, there will be a shearing force exerted on the fluid. The velocity gradient of the fluid between the plates is linear, with the fluid adjacent to the moving plate traveling at the same velocity as the moving plates, and the fluid next to the stationary plate being stationary. Sir Isaac Newton postulated that the amount of shear stress in a fluid is directly proportional to the velocity of the fluid at any point between the two plates. Liquids that exhibit this characteristic are said to be Newtonian fluids. The vast majority of liquids are Newtonian. There are some liquids that are non-Newtonian, that exhibit more complex behavior when subjected to a shearing force, but they will not be discussed here.

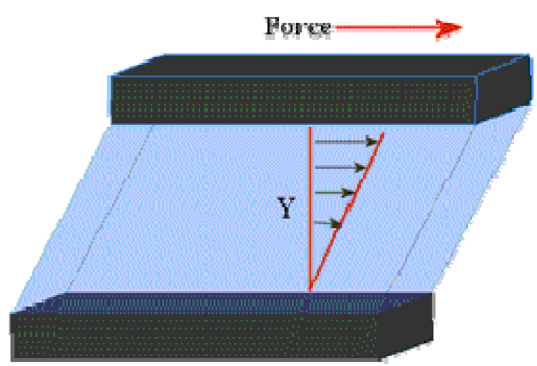


Fig 1

As stated earlier, viscosity is a measure of a liquid's resistance to a shearing force. Dynamic viscosity (η) is a constant that relates shear force to shear stress for a given liquid. The unit of measure for dynamic viscosity (η) is the poise which is equal to $1\ Kg{\cdot}m^{-1}{\cdot}s^{-1}$. Dynamic viscosity ($\eta$) is most commonly expressed in terms of the centipoise. One poise = 100 centipoise and one centipoise = $1\ g{\cdot}cm^{-1}{\cdot}s^{-1}$. Conveniently, water has a viscosity of almost 1 (1.0020) centipoise at 20^oC. All fluids have inertia characterized by their mass. Kinematic viscosity (υ) takes a fluid's inertia into account. Kinematic viscosity is equal to the dynamic viscosity divided by the fluid density. The unit of measure for kinematic viscosity is the stoke. It is usually expressed in terms of the centistoke where 1 stoke = 100 centistoke. The unit for the centistoke is $cm^2 \cdot s^{-1}$.

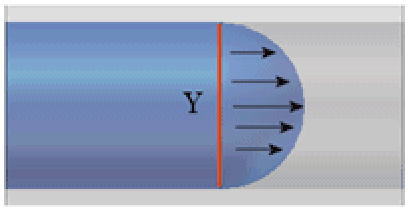
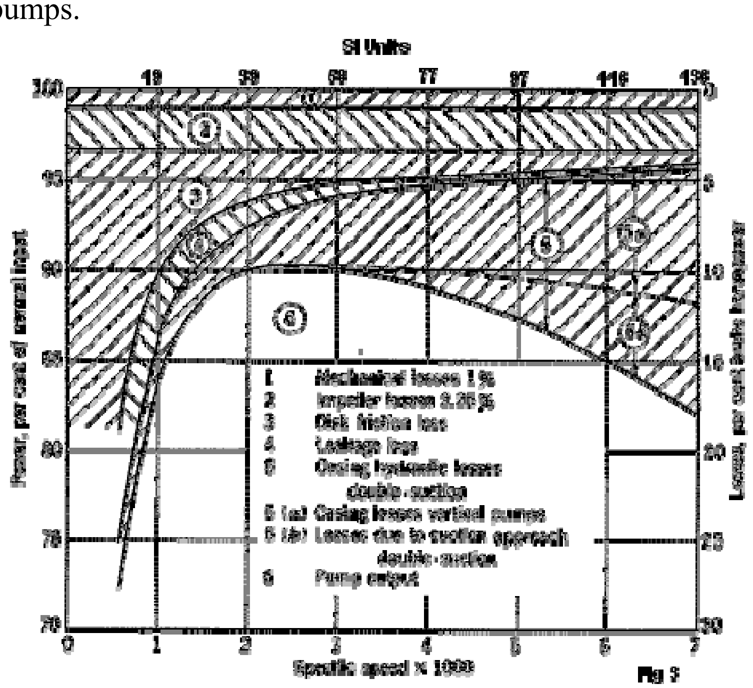


Fig 2

In a pipe of diameter Y (Fig 2), fluid friction will decrease in proportion to the distance from the pipe wall. For a given fluid velocity, friction losses are higher for smaller diameter pipes. For instance, water moving at 10 ft/sec through a ¾" pipe has a head loss due to friction of about 60' for every 100' of pipe. That same 10 ft/sec velocity in a 6" pipe loses only 5' of head for every 100' of pipe.

It might be helpful to think of a centrifugal pump in terms of a rotating disc (the impeller) that is parallel to two stationary plates (the casing side walls). The viscous forces, or fluid friction, acting on the impeller are directly related to the surface area of the impeller, the rotational velocity of the impeller, and the clearance between the impeller and sidewall. The passages between the shrouds of an enclosed impeller, and the pump's volute are similar in behavior to fluid flow in piping. The frictional losses will be directly related to the fluid velocity and the cross sectional and surface areas of the fluid passages.

Low flow (small passage), high head (large diameter impeller) pumps have greater frictional losses than high flow (large passage), low head (small diameter impeller) pumps. At a constant rotational speed, the pump specific speed is related to the ratio of flow to head. Fig 3[1] depicts the relative impact of various pump internal losses at various specific speeds. Note the high percentage of disk friction losses associated with low specific speed pumps.



The greatest impact that viscosity has on a centrifugal pump is increased power draw. The increased power draw comes from the frictional forces required to turn the impeller within the viscous fluid. Head and flow are also affected by the friction losses of fluid flow through the impeller and volute passages. The amount of viscosity that can be practically accommodated by a centrifugal pump is related to pump size and specific speed(Fig 4)[2]. There is no specific limitation. Increased viscosity will result in decreased performance and increased power consumption. For any given style and size of pump, use of a centrifugal pump will, at some point, become impractical.

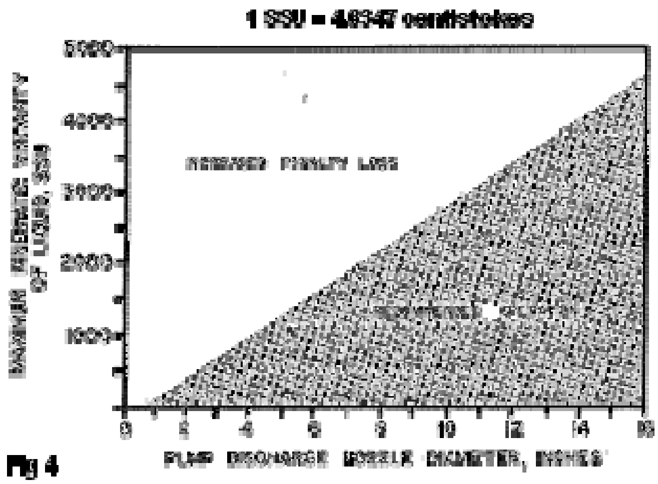


Fig 4

Tools for the prediction of performance loss due to viscosity in a centrifugal pump are based upon empirical analysis. Performance data from tests of a broad range of centrifugal pumps have been analyzed, and guidelines published, establishing viscosity correction factors. Perhaps the most well known are those published by the Hydraulic Institute. Other international standards exist as well, and they do differ somewhat from one another, most likely due to differences in the pumps used for the testing. In recent years, a good deal of work has been done to advance computational fluid dynamics (CFD) to where it can accurately predict viscous effects through numeric calculations. However, at this time, CFD still requires performance tests to form the basis for accurate computational models.

In summary, the effect of viscosity in a centrifugal pump is dependent on the surface area, distance, and relative velocity of fluid contact surfaces. Large capacity pumps operating at high specific speeds will be subjected to lesser power and performance penalties than smaller pumps operating at lower specific speeds. Pump design may be modified somewhat to improve viscous performance, but because the pump geometry is largely constrained by operating conditions, the ability to manipulate viscous effects is limited.

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[1] Centrifugal and Axial Flow Pumps – A.J. Stepanoff, Ph.D. – 1957, John Wiley and Sons
[2] Centrifugal Pumps Design & Application – Lobanoff and Ross – 1992, Gulf Publishing Company