MicroFab Technote 99-02
Fluid Properties Effects on Ink-Jet Device Performance

Introduction

The general fluid property requirements for a fluid to be used in a piezoelectric demand-mode ink-jet device are as follows:

Viscosity: **0.5-40cp (Newtonian)**
Surface Tension: **20-70 dy/cm**

Some fluids with properties outside these ranges may be dispensed using ink-jet devices, but with increased difficulty / decreased performance. Combinations of the extreme values may also have poorer performance. If the fluid is heated or cooled, the above properties are required *at the orifice.*

The values above are appropriate for fluids with a specific gravity near 1. For high density fluids, such as molten metals, the values above should be converted to kinematic values using the density of water.

Newtonian behavior is not strictly required, but the fluid properties at the orifice flow conditions must be in the above range. Thus as shear thinning fluid could have a low shear rate viscosity much higher than the 40cp. Viscoelastic behavior causes significant performance problems.

Particle suspensions, such as inks, are acceptable as long as the particle / agglomerate size and density do not cause the suspension to depart from the fluid properties range given above. Particles that are >5% of the orifice diameter will cause at least some instability in drop generation behavior, but still may be acceptable in low concentrations.

Viscosity Effects

Increasing fluid viscosity acts to dampen the acoustic waves used to create a drop. Increasing viscosity also causes an increase in drive voltage required to create a drop of fixed velocity and a decrease the effect orifice diameter, thus decreasing the drop size at fixed drop velocity.

Although surface tension and density a weak function of temperature, viscosity is a strong function of temperature. Thus the effect of viscosity variation can be shown most clearly by the operation of a fluid of a range of temperature. As an example, two devices were operated in demand mode at 2kHz over approximately 0-25°C. Isopropanol was operated in a 71µm diameter device and an aqueous mixture (10% isopropanol) was operated with a 65µm diameter device. The effects on drive voltage and weight are shown in Figure 1. These quantities are plotted versus viscosity (shown in Figure 2) in Figure 3.

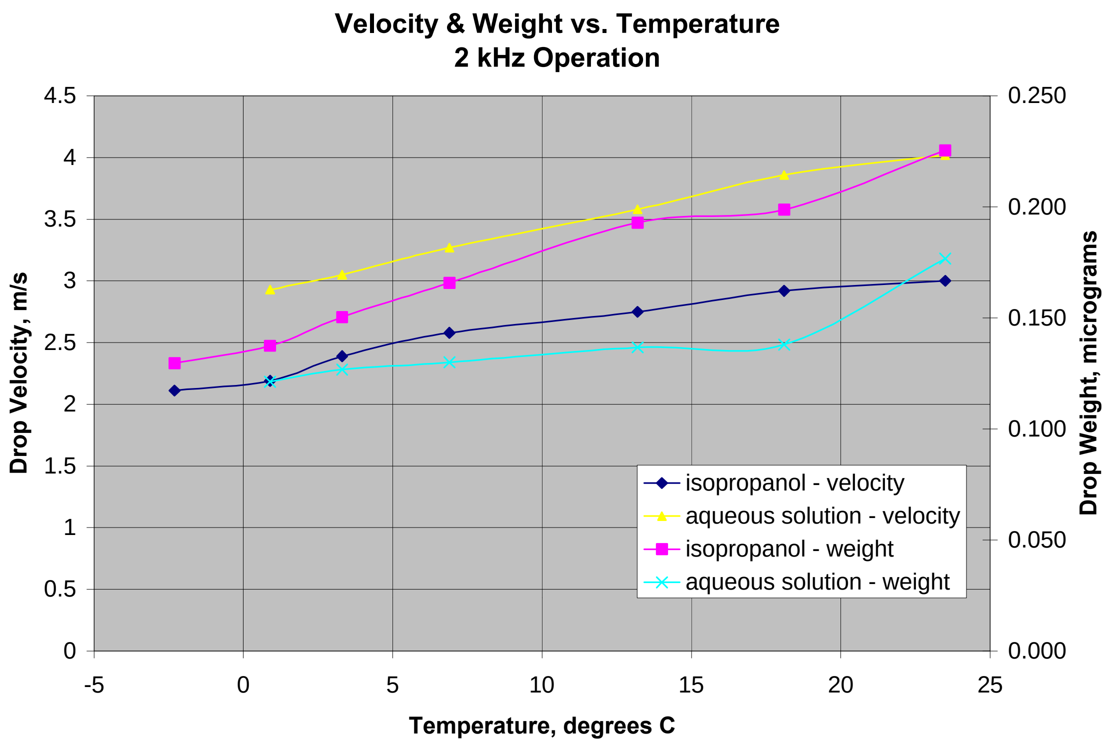

Figure 1

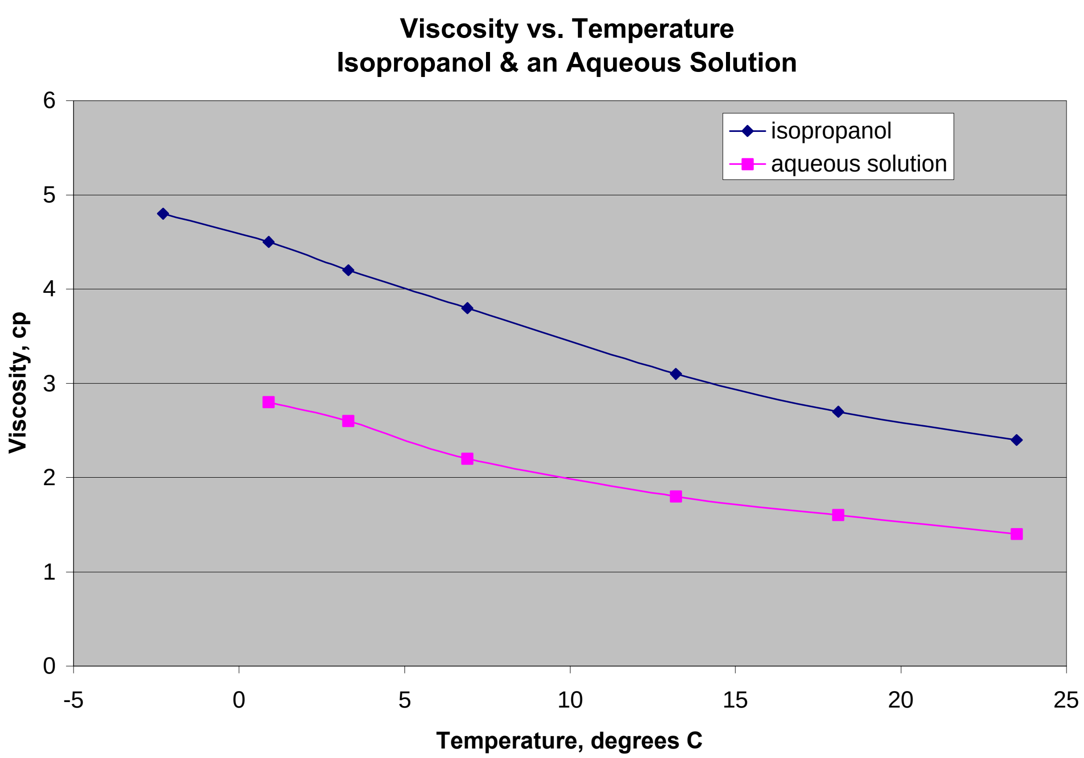

Figure 2

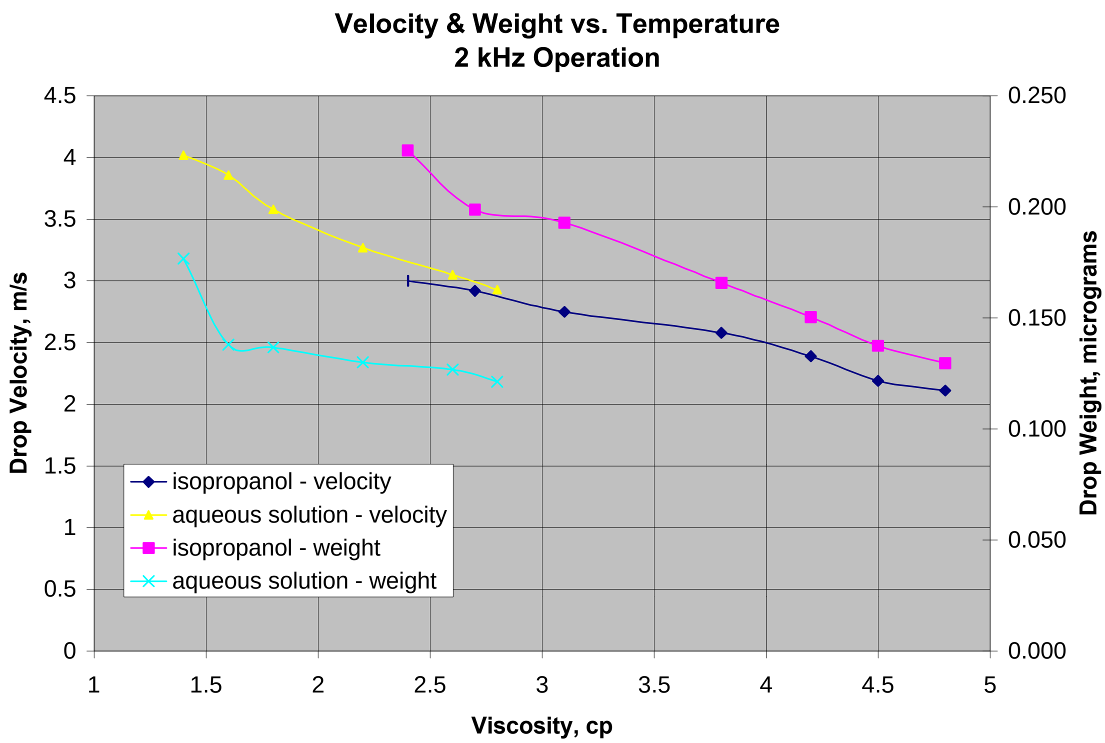

Figure 3

Finally, viscosity acts to dampen the instabilities that lead to satellite formation. Figure 4 shows satellite-free drop formation with ethylene glycol (18cp, 47 dy/cm). Figure 5 shows drop formation for isopropanol (2cp, 22 dy/cm), with a satellite forming after each drop is ejected.

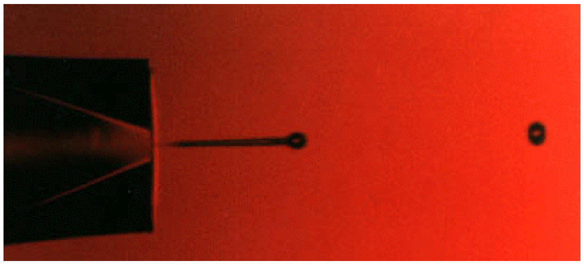

Figure 4

Figure 5

Density Effects

Variation of density does not directly effect the performance of a fluid in a demand mode ink-jet device, but usually indicates a variation of acoustic speed and/or bulk modulus of the fluid, both of which effect the optimum waveform timing (see Technote 99-03) and amplitude requirements. In practice, density, acoustic speed, and bulk modulus effects are minor, and even liquid metals have waveform requirements similar to water and low density solvents.

Surface Tension Effects

Surface tension has a small effect on the drive voltage requirements for a device. As surface tension increases, the drive voltage required to achieve a constant drop velocity will increase. Very low surface tension can result in an increased likelihood of air ingestion, particularly at high drop velocities. Very high surface tension materials require special consideration in the selection of orifice materials and coatings.