Ink Viscosity Effects on Drop Generation

E. Mariano Freire
Xerox Corporation, Webster, New York

The drop volume and drop velocity in a thermal ink jet transducer generally increase with the ambient temperature. This well known effect can cause print defects due to excessive inking in long print jobs since the printhead would normally heat up with use. It is therefore of practical interest to understand the origin of this effect so that ways of controlling it can be found.

Several causes can be identified for this temperature dependence. The inks normally used have a negative dependence of viscosity on temperature. The viscous losses during the drop ejection are therefore smaller at higher ink temperatures resulting in a more efficient process and thus faster and larger drops. Another quantity that changes with temperature and that can affect the jetting performance is the thermal energy stored in the ink at the time of nucleation. At higher ambient temperatures more thermal energy is stored in the ink and this can result in a larger and more explosive bubble which in turn would produce a larger and faster drop. There is yet another effect that can be playing a role in the drop generation dependence on temperature. During the bubble collapse the bubble pressure drops below atmospheric. This tends to pull the ink back into the channel and therefore slows down and limits the amount of ink ejected with the drop. The minimum pressure reached during the collapse depends on the ambient temperature, with the higher ambient temperatures corresponding to higher pressures. It follows that at higher temperatures the contribution from this effect should be smaller and therefore more ink should be ejected with a faster drop.

The experiments reported were intended to explore the importance of the first of the effects mentioned above, namely, the effect of the ink viscosity dependence on temperature. In order to do this, the viscosity and temperature had to be separated somehow. This was achieved by varying the concentration of an ink additive used as viscosity builder. The substance used for this purpose was poly (ethylene glycol) (PEG 600). The drop volume and velocity measurements were made using a sideshooter type printhead.

A set of three inks containing variable concentrations of PEG 600 was used for these experiments. In the first phase, viscosity versus temperature was determined for the three inks and then a multilinear regression analysis run on the data to obtain a mathematical expression of viscosity as a function of temperature and PEG 600 concentration,

$$\mu = f(c,T). \quad (1)$$

Here μ is the ink viscosity, c the PEG 600 concentration, and T the temperature. The results are plotted in figure 1.

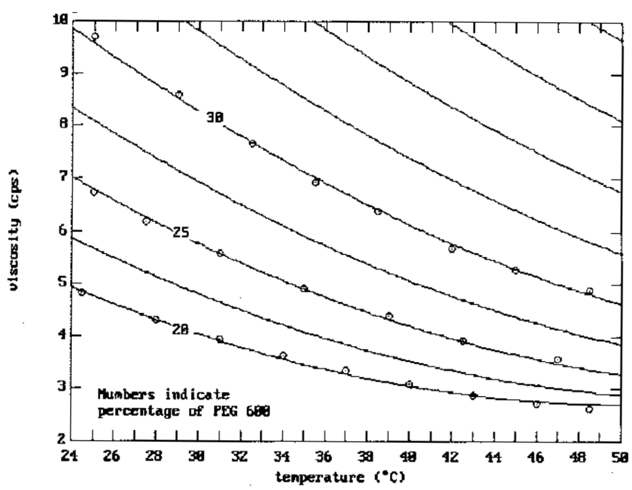

Figure 1. Vicosity versus temperature for various PEG concentration.

In a second part of the experiment, drop velocities and drop volumes were determined as a function of temperature for the three inks considered. A multilinear regression analysis was run for this data to obtain the dependence of drop volume and velocity on temperature and PEG 600 concentration, i.e., expressions of the form,

$$V = g(c,T), \quad (2)$$

$$v = h(c,T), \quad (3)$$

were found, where V is drop volume and v is drop velocity. The results are plotted in figures 2 and 3, respectively.

Equation (1) can now be inverted to obtain the PEG 600 concentration as a function of viscosity and temperature. In turn, that can be replaced in (2) and (3) to obtain:

$$V = G(\mu,T), \quad (4)$$

and,

$$v = H(\mu,T). \quad (5)$$

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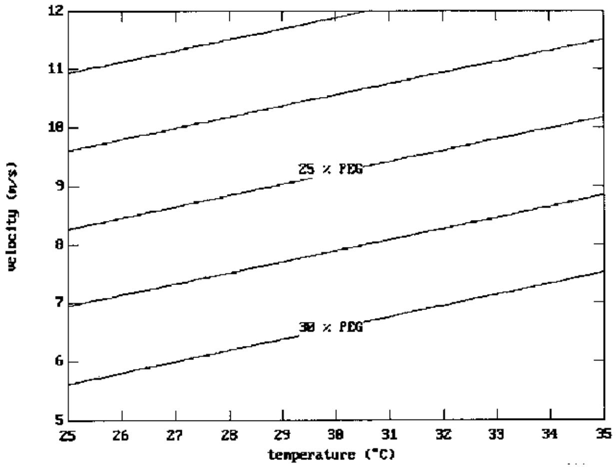

Figure 2. Drop volume versus temperature for various PEG concentrations.

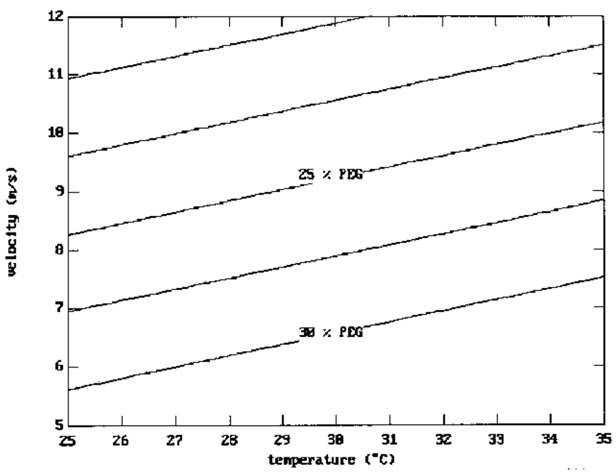

Figure 3. Velocity versus temperature for various PEG concentrations.

One can now draw plots similar to the ones shown in figures 2 and 3 but now instead of the curves being at constant PEG 600 concentration, these curves will now be at constant viscosity. The results are shown in figures 4 and 5. The mathematical manipulation done implies that when one moves from a point in one of these curves to another along the same curve, the temperature changes but so does the ink in such a way that the viscosity remains constant.

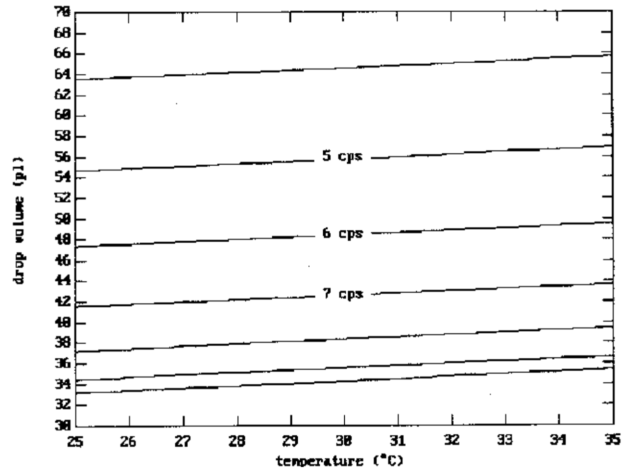

Figure 4. Drop volume versus temperature for various ink viscosities.

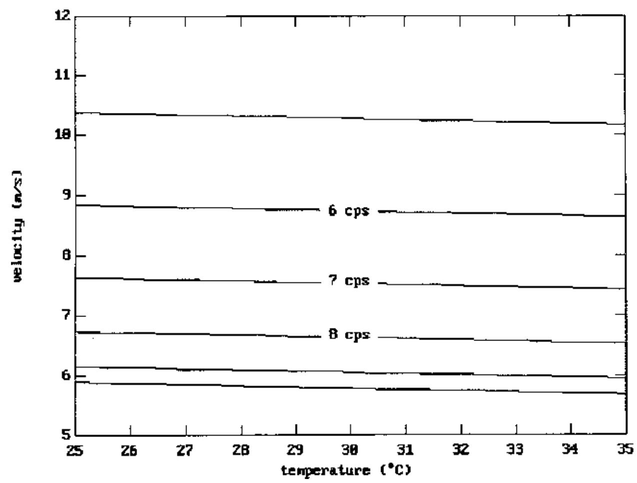

Figure 5. Drop velocity versus temperature for various ink viscosities.

As can be seen in these figures, once the dependence of viscosity on temperature is “factored out,” the net dependence of both drop volume and velocity are quite small. (In fact, the slope obtained for the drop velocity case is slightly negative.) These results indicate that, at least for the ink system used, the most important effect in the drop volume and velocity dependence on temperature is the one associated with the ink viscosity.