

would correspond to a Bond number $B_{\text{deform}} = 0.053$. However, we note that because of the smectic's apparent yield stress, the surface tension does not play the same crucial role as it does for the isotropic and nematic liquids. Thus, the Bond number at the onset of deformation is given only for completeness, and does not play an important role in the physics. Because of the extremely high viscosity at small flow rates, the smectic A bridge took several hours before its sagging shape equilibrated. More D_2O was then added to the bath and the shape of the bridge deformed further, but did not collapse. Finally, at $\Delta\rho_{\text{collapse}} = 0.065 \text{ g cm}^{-3}$, the bridge pinched off and collapsed into pieces at each of the two rods.

To understand the behaviour of a bulk smectic A under stress, we examined the creep flow for 8CB using a cone and plate rheometer [24]. A constant stress in the range of 1 to 50 dyn cm^{-2} was applied for 2 min, and then another 2 min was permitted for elastic recovery. (Nearly identical results were obtained for much shorter duration measurements of 10 s.) This was done for several different stress values, at each of the three temperatures 25.5, 28.5, and 31.5°C. Note that the nematic-smectic A transition temperature is 33.5°C. Figure 5 shows the strain versus shear stress at the end of the shear cycle. At low stress the strain was very small and completely elastic. Above some critical yield stress Y we observed the onset of inelastic flow, where it is clear from figure 5 that Y is a strong function of temperature T . At the nematic-smectic A phase transition temperature the yield stress vanished. The yield stress versus temperature in degrees Celsius is shown in the inset of figure 5.

The maximum value τ_{max} of the shear stress in a vertical cylinder of isotropic material that is held from above and below may be estimated by applying elasticity theory [25]. One finds that τ_{max} is independent of the height of the cylinder and obeys a relation of the form $\tau_{\text{max}} \sim rg\Delta\rho/6$. Calculating the surface shear stress for the value $\Delta\rho_{\text{deform}} = 0.034 \text{ g cm}^{-3}$ at which the cylinder began to deform at 32.5°C, we find $\tau_{\text{max}} \sim 1 \text{ dyn cm}^{-2}$. This is smaller than, but of the same magnitude as the measured yield stress $Y = (4 \pm 2) \text{ dyn cm}^{-2}$ at this temperature (cf. figure 5). The discrepancy may be due to temperature gradients in the Plateau tank (with some regions of the tank closer to the nematic-smectic A phase transition temperature), as well as to built-in stresses on formation of the cylinder. Additionally, we note that in the region $\Delta\rho_{\text{deform}} < \Delta\rho < \Delta\rho_{\text{collapse}}$ the smectic liquid crystal flows for a time, then stops. This strongly suggests that the liquid crystal deformation reduces the stress sufficiently to a value comparable to Y . This results in a significant slowing and ultimate cessation of flow.

Finally, it is important to comment on the length scales in the experiment. The behaviour of the smectic A phase often differs from that of an isotropic liquid. However, as the smectic domains are empirically of length scales of a few microns, the smectic would behave as a granular isotropic solid as long as the bridge has dimensions much larger than the domain size. This certainly is the case in our experiment, with one exception: when the bridge is just beyond the stability point, such that the (already pinched) collapsing bridge is just about to break into two smectic droplets. This

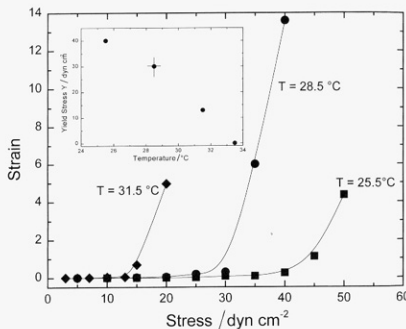


Figure 5. Strain versus shear stress at three different temperatures. The yield stress Y is the point at which flow begins, and corresponds to the sharp increase in slope. Inset corresponds to Y versus T .