mance. The concern for injecting late along the barrel is for mixing efficiency. Sometimes a mixer after the screw is helpful in blending the additives. One of the difficulties encountered when the additive is injected along the barrel is the need for a pump system to overcome the pressure in the barrel at the injection port. This pressure can be substantial, up to 5000 psi, so the pump system must be specified to meet the injection rate goal and to perform against whatever pressure is present. An additional advantage to injecting the additive later along the barrel is that the injected material does not remain in the barrel as long as the main polymer and is affected less by heat and shear. This is important where heat-sensitive materials, such as some liquid colors, are injected.

Melting Considerations

As solid material is conveyed from the feed throat and travels through the feed section of the screw, some compaction takes place. When it reaches the heated barrel, a melt film immediately forms on the barrel I.D. The melt film grows in thickness as the material moves down the barrel until it is thicker than the screw flight clearance with the barrel. Then the melt begins to collect at the rear of the screw channel (the pushing side of the flight). As the melt film goes through this thickness growth, transporting forces are developed by the shearing of the melt film. This conveying mechanism is termed *viscous drag*. (The material in the channel during the early melting process is sketched in Fig. 4-4.) The shearing of the melt film creates most of the energy for melting of the material at moderate to high screw speeds. The higher the viscosity of the melted material, the more heat is generated via melt film shearing. Stiffer materials such as rigid polyvinyl chloride (PVC) or high-density polyethylene (HDPE) generate much heat in the melt film, and the melt temperature reflects that fact as screw speed is pushed to moderate to high levels. Low viscosity materials exhibit much lower melt temperature rises as the screw speed is increased.

The barrel heat contribution at high or moderate screw speeds is often minimal, with melt film shear producing enough energy for the entire melting process. In fact, many extrusion situations require some of the barrel zones (especially those farthest from the feed area) to be cooled to remove excess heat created by the melt film. Barrel cooling has only a modest effect on lowering melt temperature levels in high-speed extrusion of high viscosity materials because of the short residence time in the barrel and poor conductivity of most polymers.

The screw designer's typical goal is to design a screw geometry to maximize output and control the melt temperature level required for the particular process. The discussion of "Extruder Screws" later in the chapter will further expound on melt temperature controlling factors.

Melt Pool Development. As the solid bed moves along the screw, the energy from the barrel heaters and the shearing of the melt film contribute to further melting. The melt being scraped off the barrel wall as the flight passes is trapped on the pushing side of the channel (rear) and forms a melt pool. The idealized

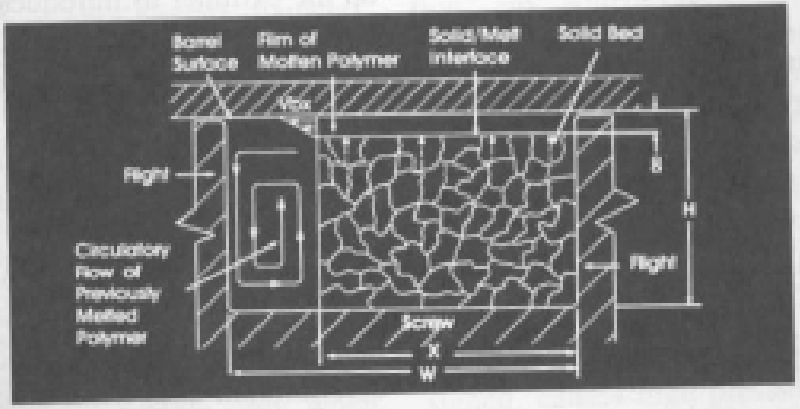

Fig. 4-4. Melting in channel. (*Courtesy Davis-Standard*)