and many of the processors using large volumes of this material produce some or all of their extruded product from powder. The negative aspects of powder include the requirement of a vented extruder (see below) and extra plant maintenance caused by fine powder that travels through the air and can corrode electrical components such as drive systems and temperature control circuitry. Producers of PVC profiles who can dedicate an extruder to a small number of items can use a vented extruder and powder feed material. When part versatility is required, a vented extruder has operational problems due to varying restrictions on the extruder; it is recommended that producers choose PVC in pellet or cube form. Producers of thin, clear PVC sheet typically use pellets on nonvented single screw extruders; the melting mechanics and shear input of the single screw extruder better fit the higher temperature processing. Also, the high die pressures (5000–8000 psi) would preclude effective venting on this type of extruder. Economics provides the strongest driving force in the selection of the material's feed form as long as the processing considerations are not highly negative for the lowest-priced material.

Melt Pumping

Pumping of the material against the die resistance can begin back near the screw's feed section, especially when the die pressure levels are high. Melting starts early on the screw in most cases, and pressurization of the melt can begin there. In actuality the three basic functions of the extruder—solids conveying, melting, pumping—cannot be separated into three discrete regions along the extruder. The functions intermesh so strongly that they all must be studied together. As the material advances down the screw toward the die, more melt is present, and the predictions of the pumping theory developed many years ago can be understood. This theory is well known,* and includes the prediction of the pumping capacity of a simple metering section against no die resistance (drag flow) and the output-reducing tendencies of the die resistance (pressure flow). These equations reduce to fairly simple terms and give a form of rough output calculation for conventional metering screws with materials that feed well. The conclusions of the melt pumping analysis are stated below:

$$OUTPUT = Q_{drag} - Q_{pressure}$$

$$Q_d = \frac{F_d \pi^2 D^2 N h \left(1 - \frac{ne}{t}\right) \sin\phi \cos\phi}{2}$$

$$Q_p = \frac{F_p \pi D h^3 \left(1 - \frac{ne}{t}\right) \sin^2\phi}{12 \mu L} \Delta P$$

where:

Q_d = Drag flow pumping term
Q_p = Pressure flow resisting pumping
$F_d = .140(h/w)^2 - .645(h/w) + 1$ (channel correction factor)
$F_p = .162(h/w)^2 - .742(h/w) + 1$ (channel correction factor)
D = screw diameter
N = screw speed (rpm)
h = screw's meter section channel depth
w = screw channel width (normal direction, not along axis)
n = number of flights on the screw
e = thickness of flight
t = flight lead (pitch)
ϕ = flight helix angle
μ = viscosity of melt (shear rate $= \pi N D / h$)
L = length of the metering section being investigated

This estimation of the output pumping of a screw is applied to the shallowest section of the screw because that is the region that limits the screw's output. Several simplifying assumptions were used to derive this flow estimation, including (1) a Newtonian material, (2) a fully developed melt flow situation, (3) no screw flight-to-barrel clearances, and (4) some other factors that help make the equation work rea-

*See E. C. Bernhardt, *Processing of Thermoplastic Materials*, Van Nostrand Reinhold, New York, 1959.