A.4 Processing Chamber Pumping Capacity Design Calculations

Note: The description and calculations in this section were generated by D. Hill and are included here to provide a more complete description of the design of the original Directed Vapor Deposition system. Simulation of the reconfigured DVD system in Chapter 10 suggests that the calculations of this subsection may not be entirely correct. The Chapter 10 simulations suggest that the required pumping capacity does not go through a maximum at Mach 1.0 as shown in Fig. A.9 below. Instead the required pumping capacity appears to continue to increase as the Mach number is increased. Equations A.2 and A.3 were used to calculate required pumping capacity in Chapter 10.

During the design of the original DVD system, the following equations describing carrier gas flow through the DVD processing chamber were used. They employ the flow's desired Mach number at the tube exit, the stagnation temperature of the carrier gas (helium), and the inside diameter of the inlet flow tube to determine required pumping capacity. This analysis assumed that the inlet flow tube was smooth and not excessively long (< 2 m). Thus, friction and heat transfer through the pipe wall were assumed to be negligible. Fig. A.8 shows the assumed geometry of the modeled system.

Important flow geometry features assumed in the analysis included:

1. The inside diameter of the settling chamber was at least five times that of the flow tube, ensuring nearly zero velocity and stagnation conditions in the chamber.
2. The diameter of the chamber pump inlet was at least three times the diameter of the inlet flow tube, ensuring that the at-pump gas velocity is extremely low.
3. The inlet flow tube was straight.

The controlling variables for pumping capacity are Mach number (at the pipe exit), stagnation temperature (in the settling chamber), and pipe diameter. Equations (2.19), (2.20),

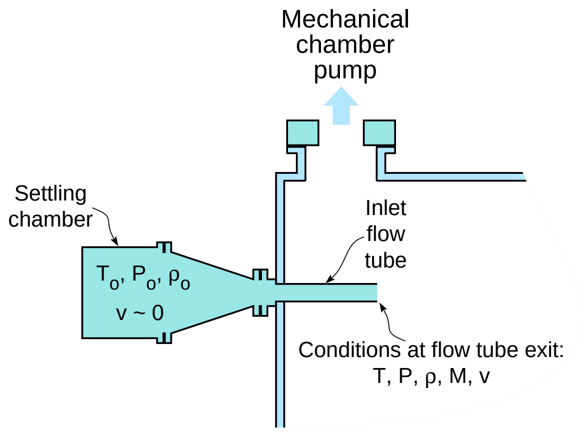

Figure A.8 **Estimation of chamber pumping requirements.** Isentropic flow calculations provide a means for estimating the chamber vacuum pumping capacity required in the DVD system.

and (8.1) were used in conjunction with the following equation to compute the necessary pumping capacity.

$$\frac{\rho_o}{\rho} = \left[1 + \frac{\gamma - 1}{2}M^2\right]^{\frac{1}{\gamma - 1}} . \tag{A.1}$$

where ρ_o = Settling chamber gas density and

ρ = Downstream gas density (e.g. in the inlet flow tube).

The necessary chamber pumping capacity ($\dot{U}_{pump}$) was computed from the following equation:

$$\dot{U}_{pump} = \dot{U}_{pipe}\frac{\rho_{pipe}}{\rho_{pump}} \tag{A.2}$$

where

$$\dot{U}_{pipe} = A_{pipe}U_{pipe} \tag{A.3}$$

with A_{pipe}= Area of the inlet flow tube and

U_{pipe}= Velocity of the carrier gas through the inlet flow tube.

The calculated required pumping capacity for the original DVD processing chamber pump system is shown in Fig. A.9.

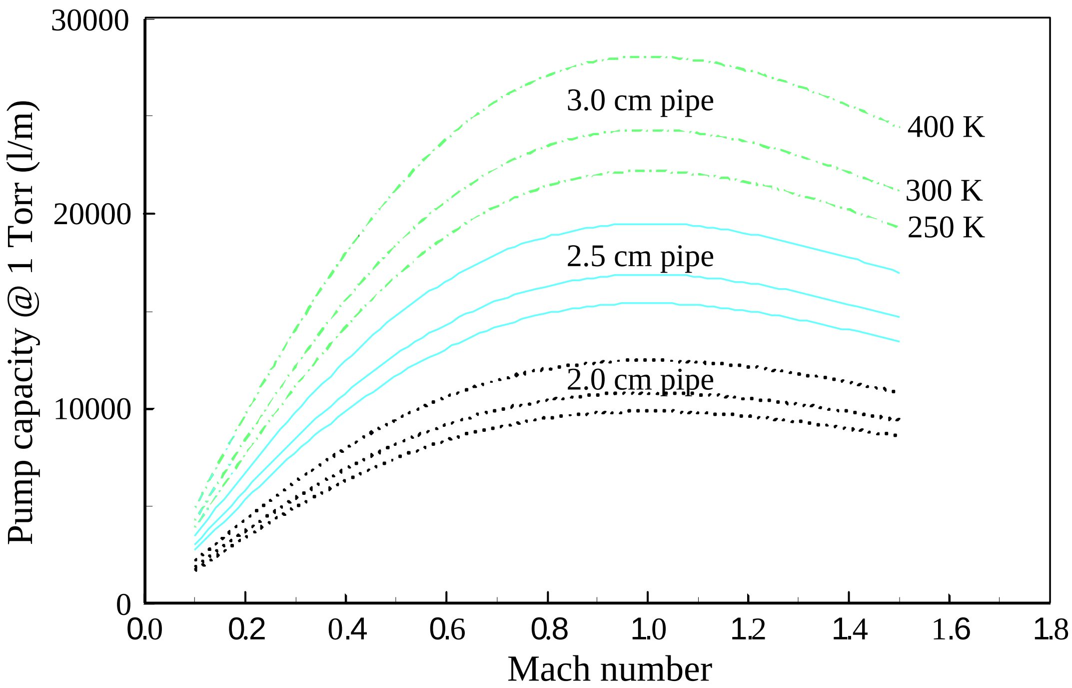

Figure A.9 **Achievable gas flow velocity for various pumping configurations.** The results of the isentropic flow calculations show the pumping capacity required to achieve supersonic carrier gas flows in the original DVD system under typical processing conditions.