Appendix A - DVD Specifications

The following pages contain engineering drawings of the e-beam gun, the processing chamber, and the water-cooled crucible as provided by the various manufacturing companies. Clearly the schematic illustrations do not provide all of the design details necessary to reconstruct the DVD system. However, these diagrams, in combination with the system description of Chapter 4, should provide sufficient information to allow critical evaluation of the design of the first generation DVD system. These diagrams should also represent a reasonable departure point for someone interested in further developing DVD technology.

A.1 E-beam Gun Design Drawings

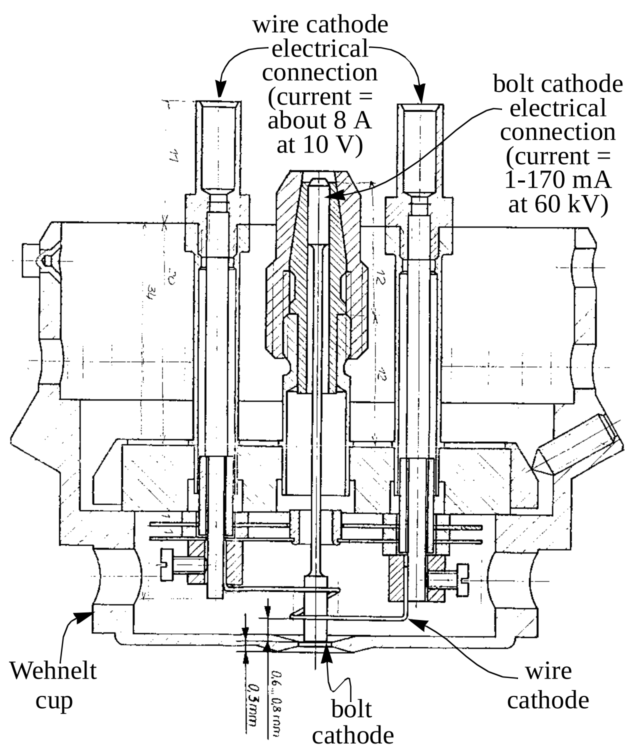

Figure A.1 Wehnelt cup assembly which generates the e-beam.

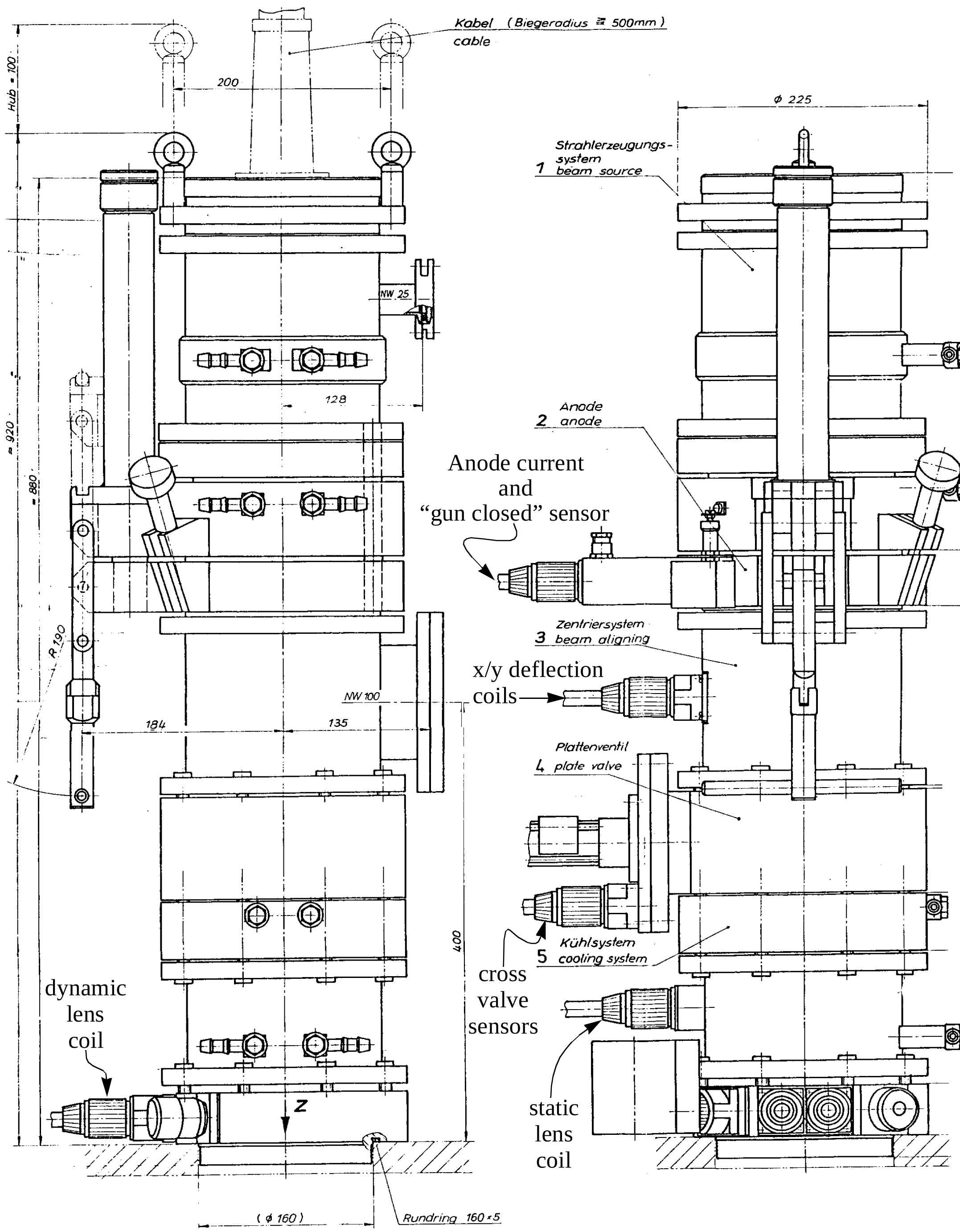

Figure A.2 **Overview drawing of traditional components of DVD e-beam gun.** The pressure decoupling system unique to the DVD system is not shown.

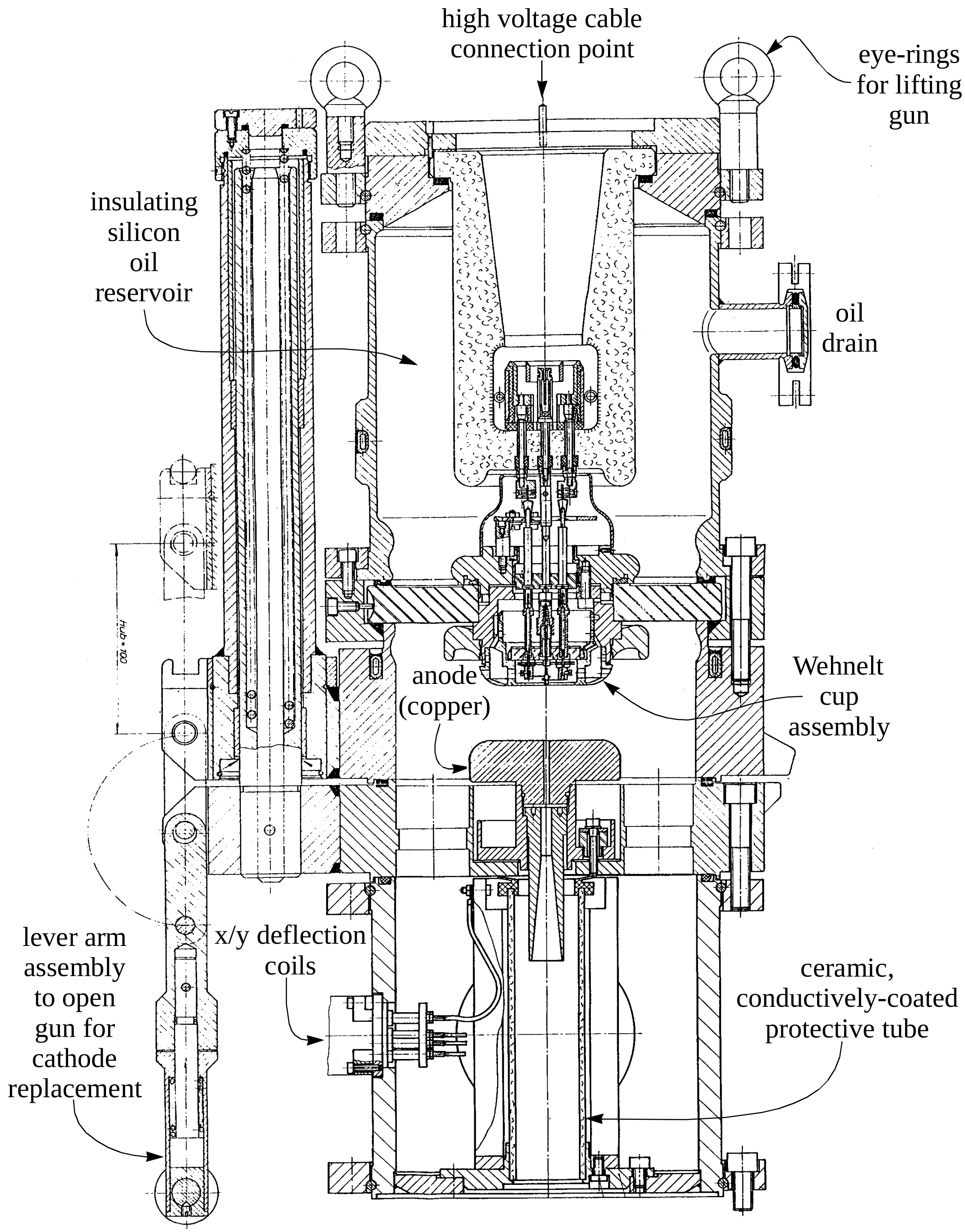

Figure A.3 **Beam Generating Assembly, top portion of DVD e-beam gun.**

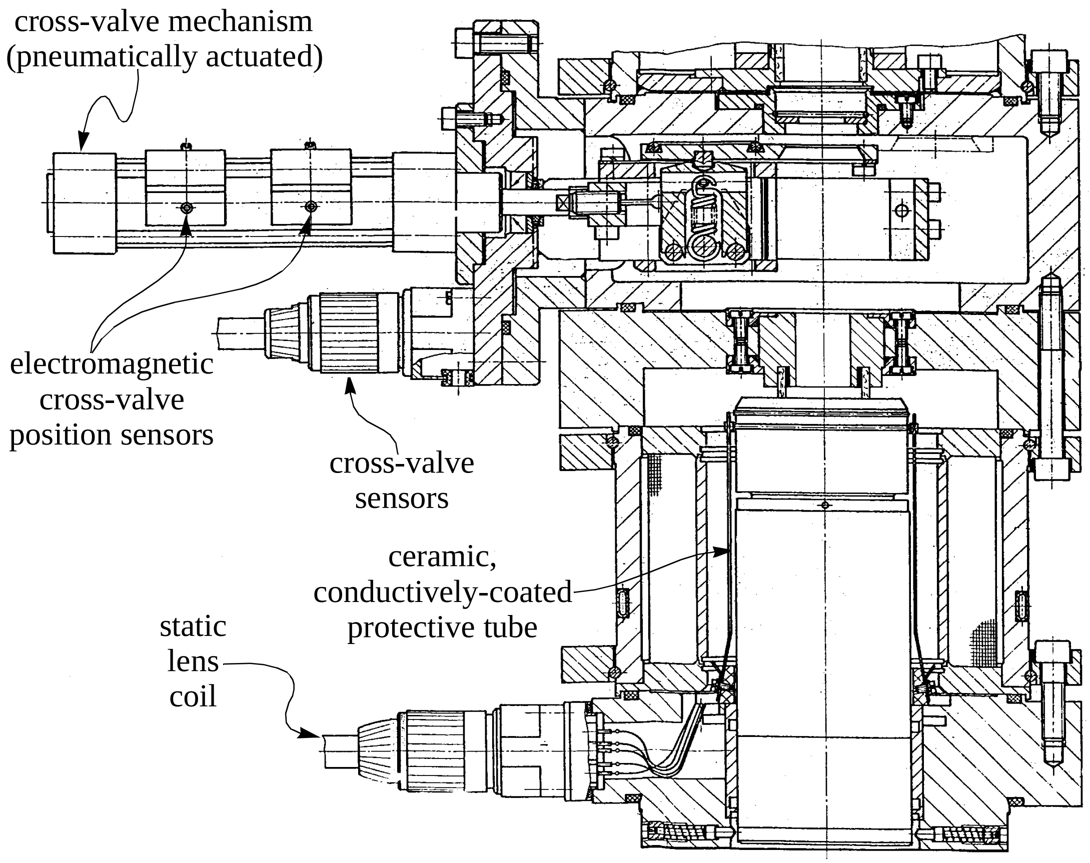

Figure A.4 **Beam Guidance System, center section of DVD e-beam gun.**

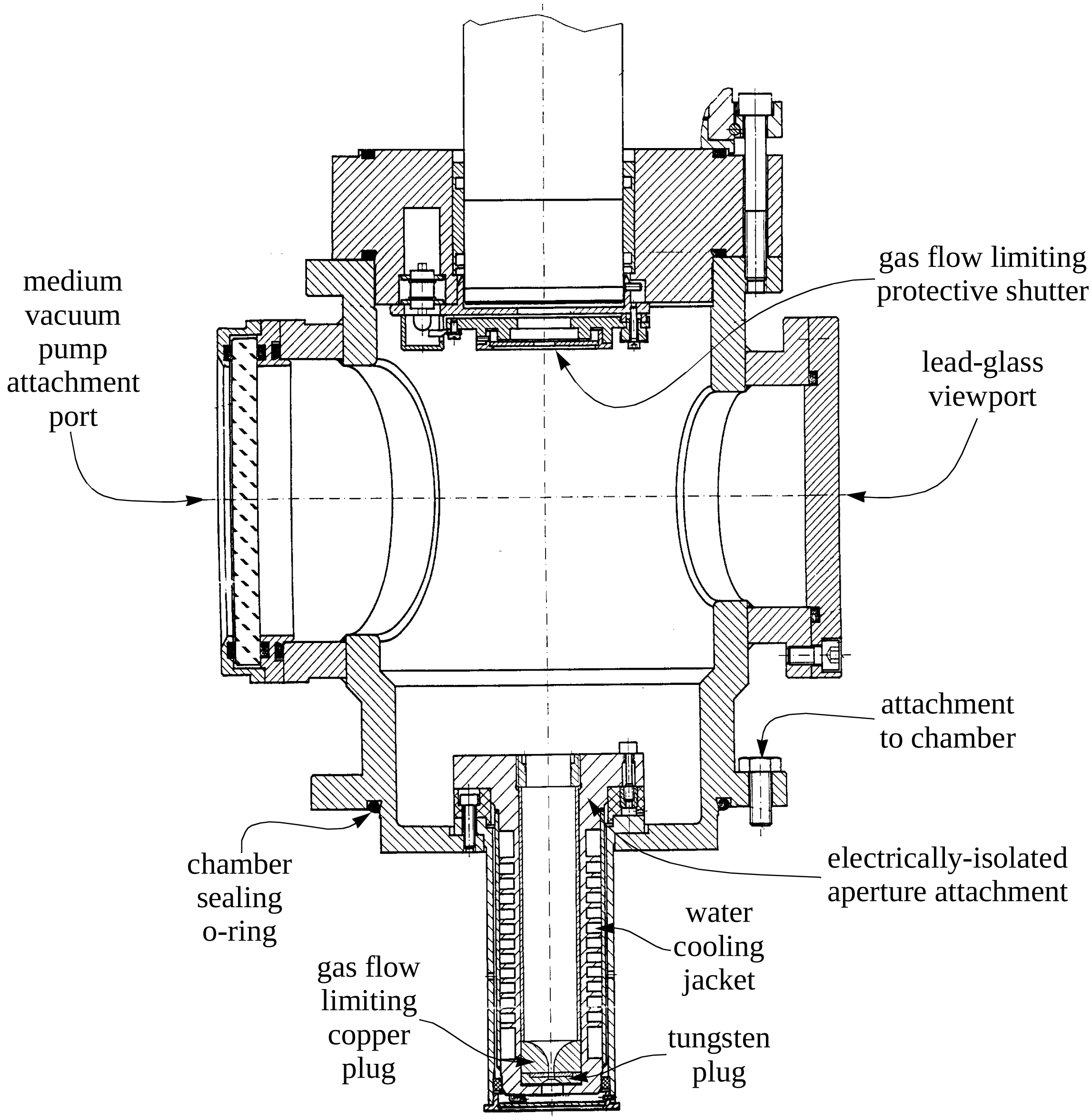

Figure A.5 **Pressure Decoupling Chamber, bottom section of DVD e-beam gun.**

A.2 Processing Chamber Design Drawings

Note: These drawings incorrectly indicate that the hinged door assembly is opposite the wall containing the two angled vapor source introduction ports. The final design actually placed the door opposite the wall containing the chamber pump port.

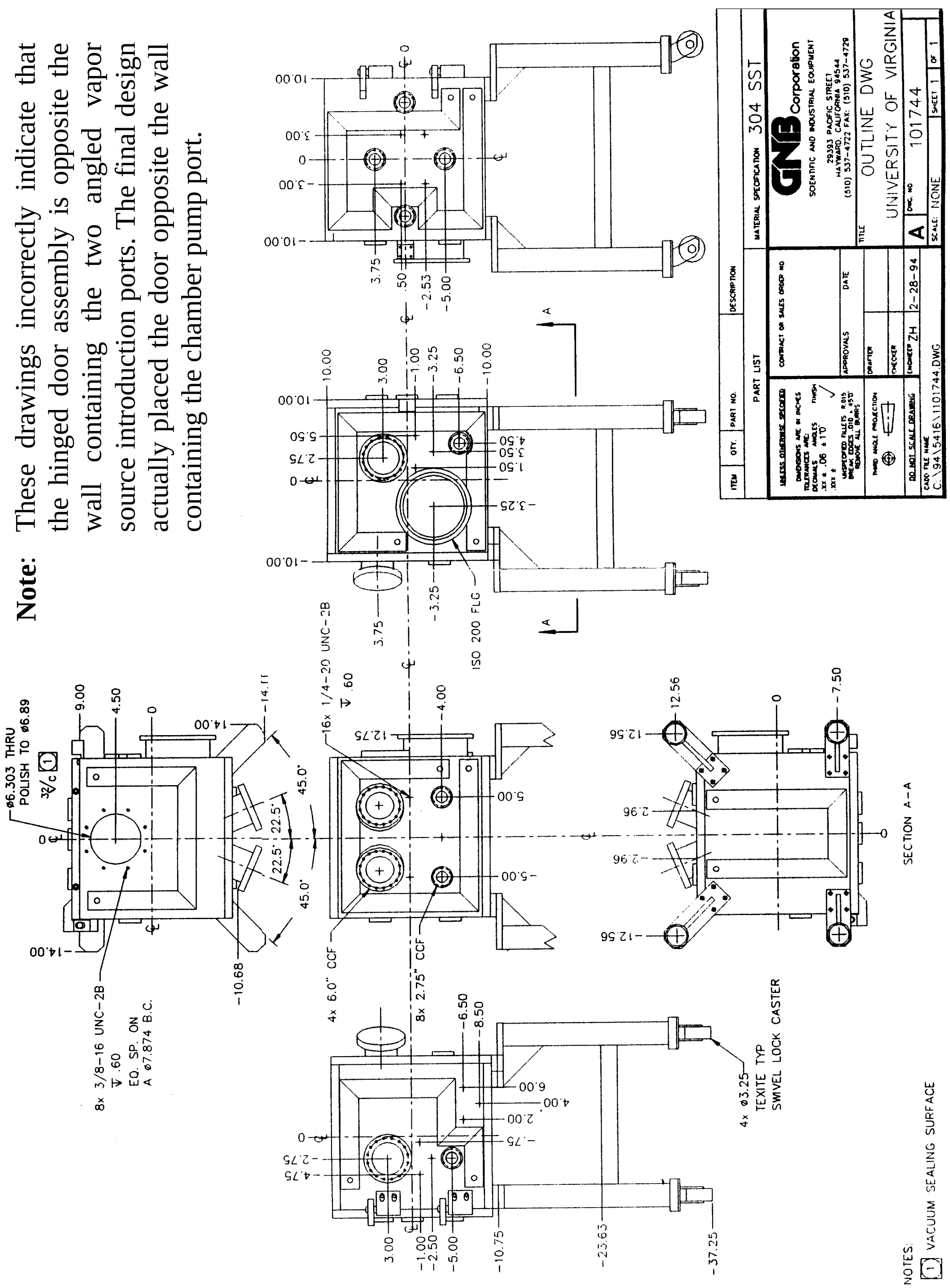

Figure A.6 **Stainless steel processing chamber with 2.54 cm thick walls.**

A.3 Water-Cooled Crucible Design Drawings

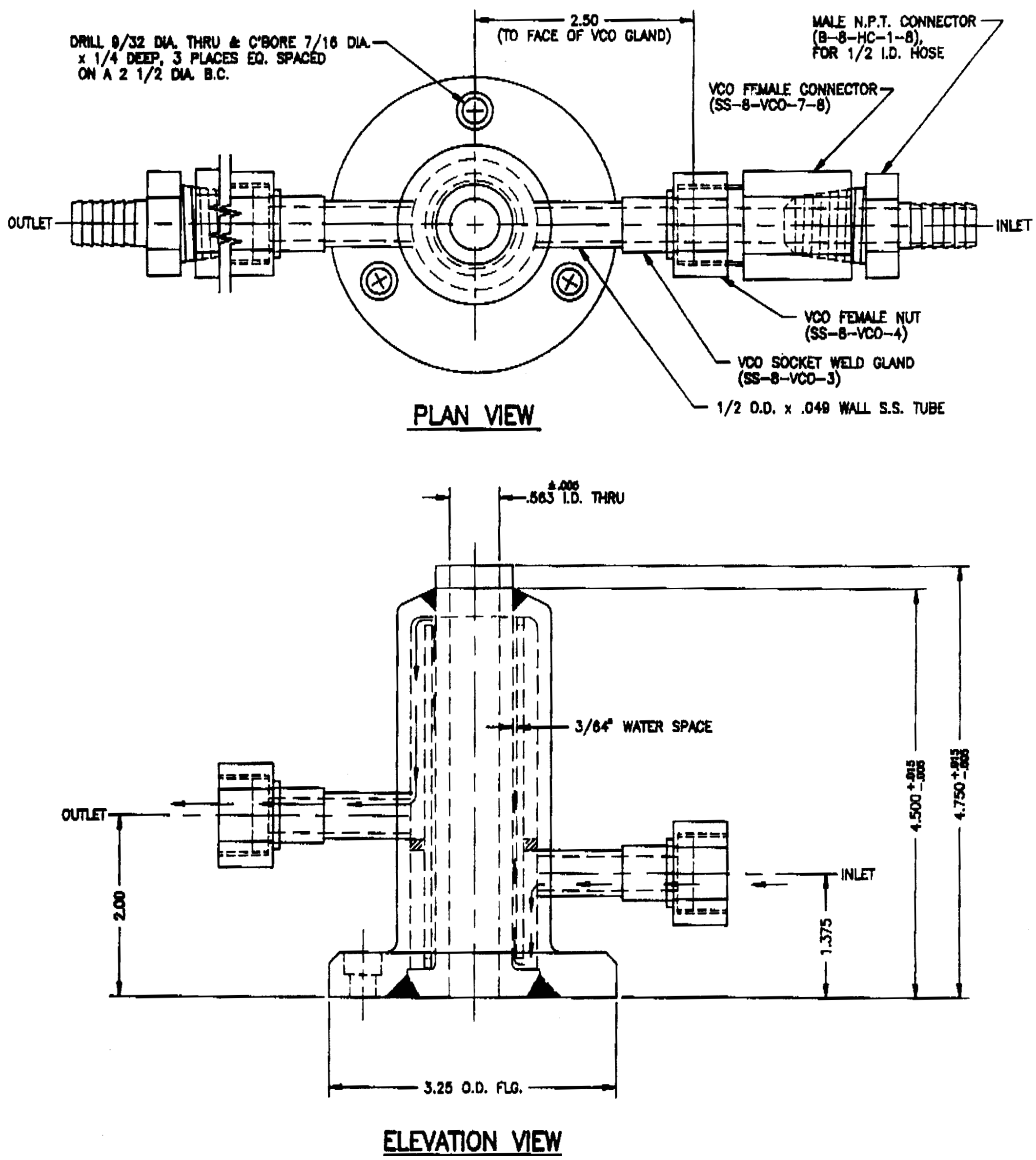

Figure A.7 **Specially designed DVD water-cooled crucible.**

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),

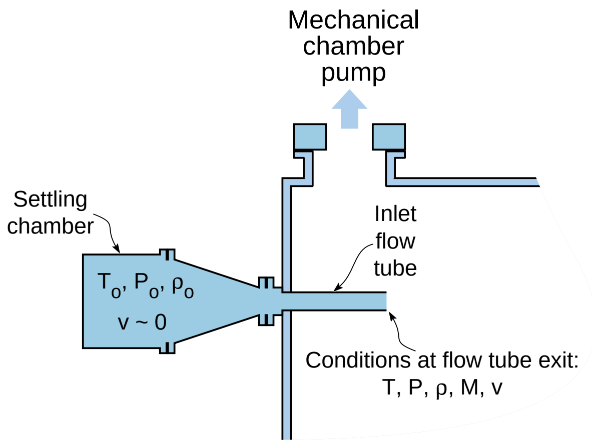

Figure A.8 **Estimation of chamber pumping requirements.** Isentropic flow calculations provide a means for estimating the chamber vacuum pumping capacity required in the DVD system.

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

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

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.

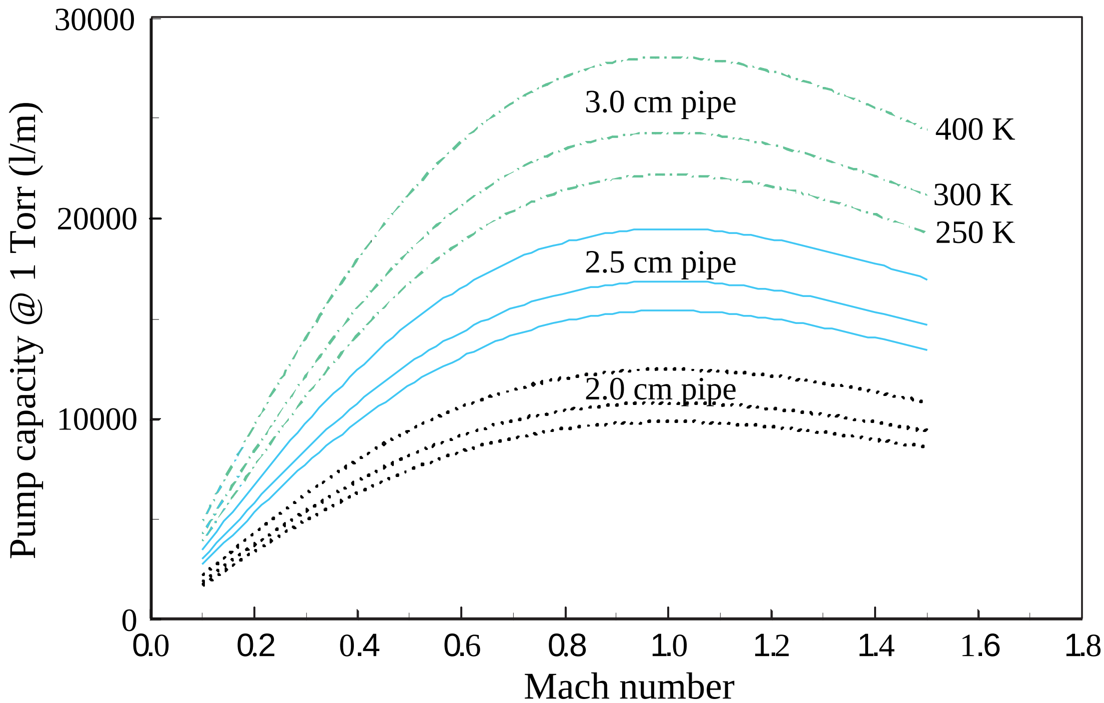

Figure A.9 **Achievable gas flow velocity for various pumping configurations.** The results of the isentropic flow calculations show the pumping capacity required to achieve supersonic carrier gas flows in the original DVD system under typical processing conditions.