

High Vacuum System Engineering Calculations
2.75" Conflat High Vacuum System
Design Iteration #4
Molecular Flow with Argon at 20C

CONDUCTANCE CALCULATIONS – MOLECULAR FLOW
(For Use with Argon-Ion Beam Systems @ < 10⁻³ Torr)

1.) Diffusion Pump

→ Max Pumping Speed of Diffusion Pump (Air)

→ **$S_{diff} = 600 \text{ l/sec}$**

2.) Diffusion Pump to Water Cooled Baffle Adapter (@ 20C)

→ Conductance of a Tube

$$C_m = 3.8 \left(\frac{T}{M} \right)^{\frac{1}{2}} \frac{D^3}{L}$$

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 39.948 (average AMU of argon)

D = diameter (cm) = 10.668

L = length (cm) = 1.27

$C_m = 9840.708 \text{ l/sec}$

→ Conductance of a Short Tube

$$C_{short} = C_m \left(1 + \frac{4D}{3L} \right)^{-1}$$

C_{short} = conductance of short tube (l/sec)

C_m = conductance of a long tube (l/sec) = 9840.708

D = diameter (cm) = 10.668

L = length (cm) = 1.27

$C_{short} = 806.615 \text{ l/sec}$

→ for $L/D < 5$, above equation is valid for short pipes, with error

$$L/D = 0.119$$

~+12% error max:

$$C_{shortFinal} = C_{short} \times 0.88$$

$C_{shortFinal} = 709.822 \text{ l/sec}$

→ Correction for Extended Baffle Fins

$$C_{shortFinal} = C_{short} \times 0.50$$

$C_{shortFinal} = 354.911 \text{ l/sec}$

→ **$C_{baffle_adapter} = 354.911 \text{ l/sec}$**

3.) Water Cooled Baffle (@ 20C)

→ Conductance of a Tube

$$C_m = 3.8 \left(\frac{T}{M} \right)^{\frac{1}{2}} \frac{D^3}{L}$$

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 39.948 (average AMU of argon)

D = diameter (cm) = 10.605

L = length (cm) = 2.032

$$C_m = \mathbf{6042.120 \text{ l/sec}}$$

→ Conductance of a Short Tube

$$C_{short} = C_m \left(1 + \frac{4D}{3L} \right)^{-1}$$

C_{short} = conductance of short tube (l/sec)

C_m = conductance of a long tube (l/sec) = 6042.120

D = diameter (cm) = 10.605

L = length (cm) = 2.032

$$C_{short} = \mathbf{759.188 \text{ l/sec}}$$

→ for $L/D < 5$, above equation is valid for short pipes, with error

$$L/D = 0.192$$

~+12% error max:

$$C_{shortFinal} = C_{short} \times 0.88$$

$$C_{shortFinal} = \mathbf{688.085 \text{ l/sec}}$$

→ Correction for Baffle Fins

$$C_{shortFinal} = C_{short} \times 0.50$$

$$C_{shortFinal} = \mathbf{304.043 \text{ l/sec}}$$

→ **$C_{baffle} = 304.043 \text{ l/sec}$**

4.) Diffusion Pump to 2.75" Conflat Adapter Plate

→ Conductance of a Tube

$$C_m = 3.8 \left(\frac{T}{M} \right)^{\frac{1}{2}} \frac{D^3}{L}$$

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 39.948 (average AMU of argon)

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$$C_m = \mathbf{182.235 \text{ l/sec}}$$

→ Conductance of a Short Tube

$$C_{short} = C_m \left(1 + \frac{4D}{3L} \right)^{-1}$$

C_{short} = conductance of short tube (l/sec)

C_m = conductance of a long tube (l/sec) = 182.235

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$$C_{short} = \mathbf{63.570 \text{ l/sec}}$$

→ for $L/D < 5$, above equation is valid for short pipes, with error

$$L/D = 0.714$$

~+12% error max:

$$C_{shortFinal} = C_{short} \times 0.88$$

$$C_{shortFinal} = 55.942 \text{ l/sec}$$

→ **$C_{plate\ adapter} = 55.942 \text{ l/sec}$**

5.) 2.75" Conflat 4-Way Cross

→ Conductance of a Tube

$$C_m = 3.8 \left(\frac{T}{M} \right)^{\frac{1}{2}} \frac{D^3}{L}$$

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 39.948 (average AMU of argon)

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$$C_m = 37.054 \text{ l/sec}$$

→ Conductance of a Short Tube

$$C_{short} = C_m \left(1 + \frac{4D}{3L} \right)^{-1}$$

C_{short} = conductance of short tube (l/sec)

C_m = conductance of a long tube (l/sec) = 37.054

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$$C_{short} = 26.859 \text{ l/sec}$$

→ for $L/D < 5$, above equation is valid for short pipes, with error

$$L/D = 3.5$$

~+9% error max:

$$C_{shortFinal} = C_{short} \times 0.91$$

$$C_{shortFinal} = 24.442 \text{ l/sec}$$

→ **$C_{cross} = 24.442 \text{ l/sec}$**

6.) 2.75" Conflat Gate Valve

→ Conductance of a Tube

$$C_m = 3.8 \left(\frac{T}{M} \right)^{\frac{1}{2}} \frac{D^3}{L}$$

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 39.948 (average AMU of argon)

D = diameter (cm) = 3.810

L = length (cm) = 5.050

$$C_m = 112.071 \text{ l/sec}$$

→ Conductance of a Short Tube

$$C_{short} = C_m \left(1 + \frac{4D}{3L}\right)^{-1}$$

C_{short} = conductance of short tube (l/sec)

C_m = conductance of a long tube (l/sec) = 112.071

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$$C_{short} = 56.035 \text{ l/sec}$$

→ for $L/D < 5$, above equation is valid for short pipes, with error

$$L/D = 1.333$$

~+12% error max:

$$C_{shortFinal} = C_{short} \times 0.88$$

$$C_{shortFinal} = 49.311 \text{ l/sec}$$

→ $C_{gate_valve} = 49.311 \text{ l/sec}$

7.) TOTAL SYSTEM CONDUCTANCE

→ Conductance of Pipeline

$$\frac{1}{C_{pipeline}} = \frac{1}{C_{baffle_adapter}} + \frac{1}{C_{baffle}} + \frac{1}{C_{plate_adapter}} + \frac{1}{C_{cross}} + \frac{1}{C_{gate_valve}}$$
$$\frac{1}{C_{pipeline}} = \frac{1}{354.911} + \frac{1}{304.043} + \frac{1}{55.942} + \frac{1}{24.442} + \frac{1}{49.311}$$
$$C_{pipeline} = 11.741 \text{ l/sec}$$

→ $C_{pipeline} = 11.741 \text{ l/sec}$

→ Effective Pumping Speed of the System

$$\frac{1}{S_e} = \frac{1}{C_{pipeline}} + \frac{1}{S_{diff}}$$

$$S_e = \frac{C_{pipeline} \times S_{diff}}{C_{pipeline} + S_{diff}}$$

$$C_{pipeline} = 12.647 \text{ l/s}$$

$$S_{diff} = 600 \text{ l/s}$$

$$S_e = 11.516 \text{ l/s}$$

→ $S_e = 11.516 \text{ l/sec}$