

High Vacuum System Engineering Calculations
2.75" Conflat High Vacuum System
Design Iteration #2
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 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

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

→ 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

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

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

$$L/D = 0.714$$

~+12% error max:

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

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

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

3.) 2.75" Conflat Inline Poppet 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) = 3.556

L = length (cm) = 4.336

$$C_m = 106.752 \text{ l/sec}$$

→ 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) = 106.752

D = diameter (cm) = 3.556

L = length (cm) = 4.336

$$C_{short} = 50.993 \text{ l/sec}$$

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

$$L/D = 1.219$$

~+12% error max:

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

$$C_{shortFinal} = 44.874 \text{ l/sec}$$

→ for $L/D < 5$, max +8% error for equivalent length straight tube

$$L/D = 1.219$$

~+8% error max:

$$C_{shortFinal} = C_{short} \times 0.92$$

$$C_{shortFinal} = 41.284 \text{ l/sec}$$

→ Total Conductance of x2 Equivalent 90 Degree Bends in Series

$$C_{poppet_valve} = \frac{C_{bend_1} \times C_{bend_2}}{C_{bend_1} + C_{bend_2}}$$

$$C_{bend_1} = C_{bend_2} = C_{shortFinal} = 41.484 \text{ l/sec}$$

$$C_{poppet_valve} = 20.642 \text{ l/sec}$$

→ **$C_{poppet_valve} = 20.642 \text{ l/sec}$**

4.) 2.75" Conflat Butterfly 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) = 3.556

L = length (cm) = 2.54

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

→ 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) = 271.333

D = diameter (cm) = 3.556

L = length (cm) = 2.54

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

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

$$L/D = 0.714$$

~+12% error max:

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

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

→ Correction for Equivalent Cross-sectional Obstructed Area of Butterfly Valve at Max Open Position

$$Area_{short_tube} = \pi r^2$$

$$r = 1.778 \text{ cm}$$

$$Area_{short_tube} = 9.931 \text{ cm}^2$$

$$Area_{butterfly_valve_open_cross_section} = \pi r^2 - L_1 W_1 - L_2 W_2$$

$$r = 1.778 \text{ cm}$$

L_1 = cross-sectional length of butterfly valve shaft = 3.556 cm

W_1 = cross-sectional width of butterfly valve shaft = 0.397 cm

L_2 = cross-sectional length of butterfly valve in max open position from above = 3.556 cm

W_2 = cross-sectional width of butterfly valve in max open position from above = 0.556 cm

$$Area_{butterfly_valve_open_cross_section} = 6.543 \text{ cm}^2$$

$$Ratio_{butterfly_valve_to_unimpeded_pipe} = Area_{butterfly_valve_open_cross_section} / Area_{short_tube}$$

$$Ratio_{butterfly_valve_to_unimpeded_pipe} = 0.658$$

→ Corrected Conductance for Butterfly Valve at Max Open Position

$$C_{butterfly_valve} = C_{short_final} \times Ratio_{butterfly_valve_to_unimpeded_pipe}$$

$$C_{butterfly_valve} = 55.942 \times 0.658$$

$$C_{butterfly_valve} = 36.810 \text{ l/sec}$$

→ $C_{butterfly_valve} = 36.810 \text{ l/sec}$

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:

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

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

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

6.) TOTAL SYSTEM CONDUCTANCE

→ Conductance of Pipeline

$$\frac{1}{C_{pipeline}} = \frac{1}{C_{adapter}} + \frac{1}{C_{poppet_valve}} + \frac{1}{C_{butterfly_valve}} + \frac{1}{C_{cross}}$$

$$\frac{1}{C_{pipeline}} = \frac{1}{55.942} + \frac{1}{20.642} + \frac{1}{36.810} + \frac{1}{24.442}$$

$$C_{pipeline} = 7.440 \text{ l/sec}$$

$$\rightarrow C_{pipeline} = 7.440 \text{ l/sec}$$

→ Effective Pumping Speed of the System

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

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

$$C_{pipeline} = 7.440 \text{ l/s}$$

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

$$S_e = 7.349 \text{ l/s}$$

$$\rightarrow S_e = 7.349 \text{ l/sec}$$