

High Vacuum System Engineering Calculations
2.75" Conflat High Vacuum System
Design Iteration #3
Molecular Flow with Deuterium at 20C

CONDUCTANCE CALCULATIONS – MOLECULAR FLOW
(For Use with Injected Deuterium Beam Neutron Systems @ <10⁻³ Torr)

1.) Diffusion Pump

→ Max Pumping Speed of Diffusion Pump (Hydrogen)

→ **$S_{diff} = 800 \text{ l/sec}$**

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 = 2.014 (average AMU of deuterium)

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$C_m = 811.616 \text{ l/sec}$

→ 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) = 811.616

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$C_{short} = 283.122 \text{ l/sec}$

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

$$L/D = 0.714$$

~+12% error max:

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

$C_{shortFinal} = 249.147 \text{ l/sec}$

→ **$C_{adapter} = 249.147 \text{ l/sec}$**

3.) 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 = 2.014 (average AMU of deuterium)

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$C_m = 165.026 \text{ l/sec}$

→ 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

$C_{short} = 119.623 \text{ l/sec}$

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

$$L/D = 3.5$$

~+9% error max:

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

$$C_{shortFinal} = 108.857 \text{ l/sec}$$

→ **$C_{cross} = 108.857 \text{ l/sec}$**

4.) 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 = 2.014 (average AMU of deuterium)

D = diameter (cm) = 3.810

L = length (cm) = 5.080

$C_m = 499.126 \text{ l/sec}$

→ 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) = 499.126

D = diameter (cm) = 3.810

L = length (cm) = 2.54

$C_{short} = 249.563 \text{ l/sec}$

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

$$L/D = 0.714$$

~+12% error max:

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

$$C_{shortFinal} = 219.615 \text{ l/sec}$$

→ **$C_{butterfly\ valve} = 219.615 \text{ l/sec}$**

5.) TOTAL SYSTEM CONDUCTANCE

→ Conductance of Pipeline

$$\frac{1}{C_{pipeline}} = \frac{1}{C_{adapter}} + \frac{1}{C_{cross}} + \frac{1}{C_{gate_valve}}$$
$$\frac{1}{C_{pipeline}} = \frac{1}{249.147} + \frac{1}{108.857} + \frac{1}{219.615}$$
$$C_{pipeline} = 56.327 \text{ l/sec}$$

→ $C_{pipeline} = 56.327 \text{ l/sec}$

→ Effective Pumping Speed of the System

$$\frac{1}{S_e} = \frac{1}{C_{pipeline}} + \frac{1}{S_{diff}}$$
$$S_e = \frac{C_{pipeline} \times S_{diff}}{C_{pipeline} + S_{diff}}$$
$$C_{pipeline} = 56.327 \text{ l/s}$$
$$S_{diff} = 800 \text{ l/s}$$
$$S_e = 52.622 \text{ l/s}$$

→ $S_e = 52.622 \text{ l/sec}$