High Vacuum System Engineering Calculations
2.75" Conflat High Vacuum System
Design Iteration #4
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)

→ $\boldsymbol{S_{diff} = 800\ l/sec}$

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

→ Conductance of a Tube

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

C_m = conductance (l/sec)

T = temperature (K) = 293.15

M = molecular mass = 2.014 (average AMU of deuterium)

D = diameter (cm) = 10.668

L = length (cm) = 1.27

$\boldsymbol{C_m = 43827.239\ l/sec}$

→ Conductance of a Short Tube

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

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

C_m = conductance of a long tube (l/sec) = 43827.239

D = diameter (cm) = 10.668

L = length (cm) = 1.27

$\boldsymbol{C_{short} = 3592.397\ l/sec}$

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

$L/D = 0.119$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 3161.309\ l/sec}$

→ Correction for Extended Baffle Fins

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

$\boldsymbol{C_{shortFinal} = 1580.655\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 1580.655\ l/sec}$

3.) Water Cooled Baffle (@ 20C)

→ Conductance of a Tube

$C_m = 3.8(\frac{T}{M})^{\frac{1}{2}}\frac{D^3}{L}$
C_m = conductance (l/sec)
T = temperature (K) = 293.15
M = molecular mass = 2.014 (average AMU of deuterium)
D = diameter (cm) = 10.605
L = length (cm) = 2.032
$\boldsymbol{C_m = 26909.593\ l/sec}$

→ Conductance of a Short Tube
$C_{short} = C_m(1 + \frac{4}{3}\frac{D}{L})^{-1}$
C_{short} = conductance of short tube (l/sec)
C_m = conductance of a long tube (l/sec) = 26909.593
D = diameter (cm) = 10.605
L = length (cm) = 2.032
$\boldsymbol{C_{short} = 3381.171\ l/sec}$

→ for L/D < 5, above equation is valid for short pipes, with error
$L/D = 0.192$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 2975.430\ l/sec}$

→ Correction for Baffle Fins
$C_{shortFinal} = C_{short} \times 0.50$
$\boldsymbol{C_{shortFinal} = 1487.715\ l/sec}$

→ $\boldsymbol{C_{baffle} = 1487.715\ l/sec}$

4.) Diffusion Pump to 2.75" Conflat Adapter Plate
→ Conductance of a Tube
$C_m = 3.8(\frac{T}{M})^{\frac{1}{2}}\frac{D^3}{L}$
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
$\boldsymbol{C_m = 811.616\ l/sec}$

→ Conductance of a Short Tube
$C_{short} = C_m(1 + \frac{4}{3}\frac{D}{L})^{-1}$
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
$\boldsymbol{C_{short} = 283.122\ l/sec}$

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

$L/D = 0.714$

~+12% error max:

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

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

→ $\boldsymbol{C_{plate\_adapter} = 249.147\ l/sec}$

5.) 2.75" Conflat 4-Way Cross

→ Conductance of a Tube

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

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

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

→ Conductance of a Short Tube

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

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

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

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

$L/D = 3.5$

~+9% error max:

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

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

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

6.) 2.75" Conflat Gate Valve

→ Conductance of a Tube

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

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

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

→ Conductance of a Short Tube

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

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

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

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

$L/D = 0.714$

~+12% error max:

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

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

→ $\boldsymbol{C_{butterfly\_valve} = 219.615\ l/sec}$

7.) TOTAL SYSTEM CONDUCTANCE

→ Conductance of Pipeline

$$\frac{1}{C_{pipeline}} = \frac{1}{C_{baffle\_adapter}} + \frac{1}{C_{baffle}} + \frac{1}{C_{plate\_adapter}} + \frac{1}{C_{cross}} + \frac{1}{C_{gate\_valve}}$$

$$\frac{1}{C_{pipeline}} = \frac{1}{1580.655} + \frac{1}{1487.715} + \frac{1}{249.147} + \frac{1}{108.857} + \frac{1}{219.615}$$

$\boldsymbol{C_{pipeline} = 52.471\ l/sec}$

→ $\boldsymbol{C_{pipeline} = 52.471\ l/sec}$

→ Effective Pumping Speed of the System

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

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

$C_{pipeline} = 52.471\ l/s$

$S_{diff} = 800\ l/s$

$\boldsymbol{S_e = 49.241\ l/s}$

→ $\boldsymbol{S_e = 49.241\ l/sec}$