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

CONDUCTANCE CALCULATIONS – MOLECULAR FLOW
(For Use with General Pump-Down @ < 10^-3 Torr)

1.) Diffusion Pump
→ Max Pumping Speed of Diffusion Pump (Air)

→ $\boldsymbol{S_{diff} = 600\ l/sec}$

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 = 18.020 (average AMU of air)
D = diameter (cm) = 10.668
L = length (cm) = 1.27

$\boldsymbol{C_m = 14651.985\ l/sec}$

→ 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) = 14651.985
D = diameter (cm) = 10.668
L = length (cm) = 1.27

$\boldsymbol{C_{short} = 1200.982\ l/sec}$

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

$L/D = 0.119$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 1056.864\ l/sec}$

→ Correction for Extended Baffle Fins

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

$\boldsymbol{C_{shortFinal} = 528.432\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 528.432\ l/sec}$

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 = 18.020 (average AMU of air)
D = diameter (cm) = 10.605
L = length (cm) = 2.032
$\boldsymbol{C_m = 8996.208\ l/sec}$

→ 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) = 8996.208
D = diameter (cm) = 10.605
L = length (cm) = 2.032
$\boldsymbol{C_{short} = 1130.367\ l/sec}$

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

$L/D = 0.192$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 994.723\ l/sec}$

→ Correction for Baffle Fins

$C_{shortFinal} = C_{short} \times 0.50$
$\boldsymbol{C_{shortFinal} = 392.255\ l/sec}$

→ $\boldsymbol{C_{baffle} = 497.128\ l/sec}$

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 = 18.020 (average AMU of water vapor)
D = diameter (cm) = 3.556
L = length (cm) = 2.54
$\boldsymbol{C_m = 271.333\ l/sec}$

→ 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) = 271.333
D = diameter (cm) = 3.556
L = length (cm) = 2.54
$\boldsymbol{C_{short} = 94.561\ l/sec}$

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

$L/D = 0.714$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 83.293\ l/sec}$

→ $\boldsymbol{C_{plate\_adapter} = 83.293\ l/sec}$

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 = 18.020 (average AMU of water vapor)

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$\boldsymbol{C_m = 55.170\ l/sec}$

→ 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) = 43.511

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$\boldsymbol{C_{short} = 39.991\ l/sec}$

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

$L/D = 3.5$

~+9% error max:

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

$\boldsymbol{C_{shortFinal} = 36.392\ l/sec}$

→ $\boldsymbol{C_{cross} = 36.392\ l/sec}$

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 = 18.020 (average AMU of water vapor)

D = diameter (cm) = 3.810

L = length (cm) = 5.050

$\boldsymbol{C_m = 166.864\ l/sec}$

→ 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) = 166.864

D = diameter (cm) = 3.556

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 83.432\ l/sec}$

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

$L/D = 0.714$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 73.420\ l/sec}$

→ $\boldsymbol{C_{gate\_valve} = 73.420\ l/sec}$

7.) TOTAL SYSTEM CONDUCTANCE

→ Conductance of Pipeline

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

$$\frac{1}{C_{pipeline}} = \frac{1}{528.432} + \frac{1}{497.128} + \frac{1}{83.293} + \frac{1}{36.392} + \frac{1}{73.420}$$

$\boldsymbol{C_{pipeline} = 17.541\ l/sec}$

→ $\boldsymbol{C_{pipeline} = 17.541\ l/sec}$

→ Effective Pumping Speed of the System

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

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

$C_{pipeline} = 17.541\ l/s$

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

$\boldsymbol{S_e = 17.043\ l/s}$

→ $\boldsymbol{S_e = 17.043\ l/sec}$