APPLIED ION SYSTEMS

High Vacuum Engineering Calculations

Small-Scale Multipurpose High Vacuum System V5 Design

System Conductance and Effective Speed - Molecular Flow with Hydrogen at 20C

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 = 1.008 (average AMU of hydrogen)

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_m = 52260.761\ l/sec}$

→ 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) = 52260.761

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 6816.621\ l/sec}$

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

$L/D = 0.200$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 5998.626\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 5998.626\ l/sec}$

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 = 1.008 (average AMU of hydrogen)

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_m = 79661.731\ l/sec}$

→ 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) = 79661.731

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_{short} = 13656.297\ l/sec}$

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

$L/D = 0.276$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 12017.541\ l/sec}$

→ Correction for Baffle Fins

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

$\boldsymbol{C_{shortFinal} = 6008.771\ l/sec}$

→ $\boldsymbol{C_{baffle} = 6008.771\ l/sec}$

4.) Diffusion Pump to 6" 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 = 1.008 (average AMU of hydrogen)

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_m = 26757.509\ l/sec}$

→ 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) = 26757.509

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 4224.870\ l/sec}$

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

$L/D = 0.250$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 3717.886\ l/sec}$

→ $\boldsymbol{C_{plate\_adapter} = 3717.886\ l/sec}$

5.) 6" to 2.75" Conflat Zero Clearance Reducer

→ 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 = 1.008 (average AMU of hydrogen)
D = diameter (cm) = 3.988
L = length (cm) = 1.918

$\boldsymbol{C_m = 2142.965\ l/sec}$

→ 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) = 2142.965
D = diameter (cm) = 3.988
L = length (cm) = 1.918

$\boldsymbol{C_{short} = 568.074\ l/sec}$

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

$L/D = 0.481$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 499.905\ l/sec}$

→ $\boxed{\boldsymbol{C_{reducer} = 499.905\ l/sec}}$

6.) 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 = 1.008 (average AMU of hydrogen)
D = diameter (cm) = 3.556
L = length (cm) = 12.492

$\boldsymbol{C_m = 233.266\ l/sec}$

→ 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

$\boldsymbol{C_{short} = 169.089\ l/sec}$

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

$L/D = 3.5$
~+9% error max:
$C_{shortFinal} = C_{short} \times 0.91$
$\boldsymbol{C_{shortFinal} = 153.871\ l/sec}$

→ $\boldsymbol{C_{cross} = 153.871\ l/sec}$

7.) 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 = 1.008 (average AMU of hydrogen)
D = diameter (cm) = 3.810
L = length (cm) = 5.080
$\boldsymbol{C_m = 705.520\ l/sec}$

→ Conductance of a Short Tube

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

C_{short} = conductance of short tube (l/sec)
C_m = conductance of a long tube (l/sec) = 705.520
D = diameter (cm) = 3.810
L = length (cm) = 2.54
$\boldsymbol{C_{short} = 352.760\ l/sec}$

→ for L/D < 5, above equation is valid for short pipes, with error
$L/D = 0.714$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 310.429\ l/sec}$

→ $\boldsymbol{C_{butterfly\_valve} = 310.429\ l/sec}$

8.) TOTAL SYSTEM CONDUCTANCE

→ **Conductance of Pipeline**

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

$$\frac{1}{C_{pipeline}} = \frac{1}{5998.626} + \frac{1}{6008.771} + \frac{1}{3717.886} + \frac{1}{499.905} + \frac{1}{153.871} + \frac{1}{310.429}$$

$$\boldsymbol{C_{pipeline} = 81.151\ l/sec}$$

→ $\boldsymbol{C_{pipeline} = 81.151\ l/sec}$

→ **Effective Pumping Speed of the System**

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

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

$C_{pipeline} = 81.151\ l/s$

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

$\boldsymbol{S_e = 73.677\ l/s}$

→ $\boxed{\boldsymbol{S_e = 73.677\ l/sec}}$