APPLIED ION SYSTEMS

High Vacuum Engineering Calculations

Small-Scale Multipurpose High Vacuum System V5 Design

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

1.) Diffusion Pump

→ Max Pumping Speed of Diffusion Pump (Derived Estimate for Water Vapor)

→ $\boldsymbol{S_{diff} = 624\ l/sec}$

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 water vapor)

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_m = 12360.288\ l/sec}$

→ 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) = 12360.288

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 1612.212\ l/sec}$

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

$L/D = 0.200$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 1418.746\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 1418.746\ l/sec}$

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 water vapor)

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_m = 18840.942\ l/sec}$

→ 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) = 18840.942

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_{short} = 3229.876\ l/sec}$

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

$L/D = 0.276$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 2842.291\ l/sec}$

→ Correction for Baffle Fins

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

$\boldsymbol{C_{shortFinal} = 1421.145\ l/sec}$

→ $\boxed{\boldsymbol{C_{baffle} = 1421.145\ l/sec}}$

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 = 18.020 (average AMU of water vapor)

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_m = 6328.468\ l/sec}$

→ 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) = 6328.468

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 999.232\ l/sec}$

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

$L/D = 0.250$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 879.324\ l/sec}$

→ $\boxed{\boldsymbol{C_{plate\_adapter} = 879.324\ l/sec}}$

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 = 18.020 (average AMU of water vapor)

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_m = 506.837\ l/sec}$

→ 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) = 506.837

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_{short} = 134.356\ l/sec}$

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

$L/D = 0.481$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 118.234\ l/sec}$

→ $\boldsymbol{C_{reducer} = 118.234\ l/sec}$

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 = 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:
$C_{shortFinal} = C_{short} \times 0.91$
$\boldsymbol{C_{shortFinal} = 36.392\ l/sec}$

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

7.) 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:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 73.420\ l/sec}$

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

8.) TOTAL SYSTEM CONDUCTANCE

→ **Conductance of Pipeline**

$$\frac{1}{C_{pipeline}} = \frac{1}{C_{baffle\_adapter}} + \frac{1}{C_{baffle}} + \frac{1}{C_{plate\_adapter}} + \frac{1}{C_{reducer}} + \frac{1}{C_{cross}} + \frac{1}{C_{gate\_valve}}$$
$$\frac{1}{C_{pipeline}} = \frac{1}{1418.746} + \frac{1}{1421.145} + \frac{1}{879.324} + \frac{1}{118.234} + \frac{1}{36.392} + \frac{1}{73.420}$$
$$\boldsymbol{C_{pipeline} = 19.193\ l/sec}$$

→ $\boldsymbol{C_{pipeline} = 19.193\ l/sec}$

→ **Effective Pumping Speed of the System**

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

$C_{pipeline} = 19.193 \ l/s$
$S_{diff} = 624 \ l/s$
$\boldsymbol{S_e = 18.620 \ l/s}$

→ $\boxed{\boldsymbol{S_e = 18.620 \ l/sec}}$