APPLIED ION SYSTEMS

High Vacuum Engineering Calculations

Small-Scale Multipurpose High Vacuum System V5 Design

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

1.) Diffusion Pump

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

→ $\boldsymbol{S_{diff} = 583\ l/sec}$

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 = 39.948 (average AMU of argon)

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_m = 8301.536\ l/sec}$

→ 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) = 8301.536

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 1082.809\ l/sec}$

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

$L/D = 0.200$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 952.872\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 952.872\ l/sec}$

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 = 39.948 (average AMU of argon)

D = diameter (cm) = 18.415

L = length (cm) = 5.08
$\boldsymbol{C_m = 12654.136\ l/sec}$

→ 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) = 12654.136
D = diameter (cm) = 18.415
L = length (cm) = 5.08
$\boldsymbol{C_{short} = 2169.280\ l/sec}$

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

$L/D = 0.276$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 1908.967\ l/sec}$

→ Correction for Baffle Fins

$C_{shortFinal} = C_{short} \times 0.50$
$\boldsymbol{C_{shortFinal} = 1908.967\ l/sec}$

→ $\boldsymbol{C_{baffle} = 954.483\ l/sec}$

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 = 39.948 (average AMU of argon)
D = diameter (cm) = 10.16
L = length (cm) = 2.54
$\boldsymbol{C_m = 4250.387\ l/sec}$

→ 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) = 4250.387
D = diameter (cm) = 10.16
L = length (cm) = 2.54
$\boldsymbol{C_{short} = 671.114\ l/sec}$

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

$L/D = 0.250$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 590.580\ l/sec}$

→ $\boldsymbol{C_{plate\_adapter} = 590.580\ l/sec}$

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 = 39.948 (average AMU of argon)

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_m = 340.407\ l/sec}$

→ 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) = 340.407

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_{short} = 90.238\ l/sec}$

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

$L/D = 0.481$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 79.409\ l/sec}$

→ $\boxed{\boldsymbol{C_{reducer} = 79.409\ l/sec}}$

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 = 39.948 (average AMU of argon)

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$\boldsymbol{C_m = 37.054\ l/sec}$

→ 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

$\boldsymbol{C_{short} = 26.859\ l/sec}$

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

$L/D = 3.5$
~+9% error max:
$C_{shortFinal} = C_{short} \times 0.91$
$\boldsymbol{C_{shortFinal} = 24.442\ l/sec}$

→ $\boldsymbol{C_{cross} = 24.442\ l/sec}$

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 = 39.948 (average AMU of argon)
D = diameter (cm) = 3.810
L = length (cm) = 5.050
$\boldsymbol{C_m = 112.071\ l/sec}$

→ 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) = 112.071
D = diameter (cm) = 3.556
L = length (cm) = 2.54
$\boldsymbol{C_{short} = 56.035\ l/sec}$

→ for L/D < 5, above equation is valid for short pipes, with error
$L/D = 1.333$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 49.311\ l/sec}$

→ $\boldsymbol{C_{gate\_valve} = 49.311\ l/sec}$

8.) TOTAL SYSTEM CONDUCTANCE

→ **Conductance of Pipeline**

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

$$\frac{1}{C_{pipeline}} = \frac{1}{952.872} + \frac{1}{954.483} + \frac{1}{590.580} + \frac{1}{79.409} + \frac{1}{24.442} + \frac{1}{49.311}$$

$$\boldsymbol{C_{pipeline} = 12.891\ l/sec}$$

→ $\boldsymbol{C_{pipeline} = 12.891\ l/sec}$

→ **Effective Pumping Speed of the System**

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

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

$C_{pipeline} = 12.891\ l/s$
$S_{diff} = 583\ l/s$
$\boldsymbol{S_e = 12.612\ l/s}$

→ $\boxed{\boldsymbol{S_e = 12.612\ l/sec}}$