APPLIED ION SYSTEMS

High Vacuum Engineering Calculations

Small-Scale Multipurpose High Vacuum System V5 Design

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

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 = 28.971 (average AMU of air)

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_m = 9748.196\ l/sec}$

→ 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) = 9748.196

D = diameter (cm) = 12.70

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 1271.504\ l/sec}$

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

$L/D = 0.200$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 1118.923\ l/sec}$

→ $\boldsymbol{C_{baffle\_adapter} = 1118.923\ l/sec}$

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 = 28.971 (average AMU of air)

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_m = 14859.297\ l/sec}$

→ 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) = 7095.044

D = diameter (cm) = 18.415

L = length (cm) = 5.08

$\boldsymbol{C_{short} = 2547.308\ l/sec}$

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

$L/D = 0.276$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 2241.631\ l/sec}$

→ Correction for Baffle Fins

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

$\boldsymbol{C_{shortFinal} = 1120.816\ l/sec}$

→ $\boxed{\boldsymbol{C_{baffle} = 1120.816\ l/sec}}$

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 = 28.971 (average AMU of air)

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_m = 4991.076\ l/sec}$

→ 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) = 213.992

D = diameter (cm) = 10.16

L = length (cm) = 2.54

$\boldsymbol{C_{short} = 788.065\ l/sec}$

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

$L/D = 0.250$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 693.497\ l/sec}$

→ $\boxed{\boldsymbol{C_{plate\_adapter} = 693.497\ l/sec}}$

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 = 28.971 (average AMU of air)

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_m = 399.727\ l/sec}$

→ 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) = 399.727

D = diameter (cm) = 3.988

L = length (cm) = 1.918

$\boldsymbol{C_{short} = 105.963\ l/sec}$

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

$L/D = 0.481$

~+12% error max:

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

$\boldsymbol{C_{shortFinal} = 93.247\ l/sec}$

→ $\boxed{\boldsymbol{C_{reducer} = 93.247\ l/sec}}$

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 = 28.971 (average AMU of air)

D = diameter (cm) = 3.556

L = length (cm) = 12.492

$\boldsymbol{C_m = 43.511\ l/sec}$

→ 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

$\boldsymbol{C_{short} = 31.540\ l/sec}$

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

$L/D = 3.5$
~+9% error max:
$C_{shortFinal} = C_{short} \times 0.91$
$\boldsymbol{C_{shortFinal} = 28.701\ l/sec}$

→ $\boldsymbol{C_{cross} = 28.701\ l/sec}$

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 = 28.971 (average AMU of air)
D = diameter (cm) = 3.810
L = length (cm) = 5.080
$\boldsymbol{C_m = 131.601\ l/sec}$

→ 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) = 213.992
D = diameter (cm) = 3.556
L = length (cm) = 2.54
$\boldsymbol{C_{short} = 65.800\ l/sec}$

→ for L/D < 5, above equation is valid for short pipes, with error
$L/D = 1.333$
~+12% error max:
$C_{shortFinal} = C_{short} \times 0.88$
$\boldsymbol{C_{shortFinal} = 57.904\ l/sec}$

→ $\boldsymbol{C_{gate\_valve} = 57.904\ l/sec}$

8.) TOTAL SYSTEM CONDUCTANCE

→ **Conductance of Pipeline**

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

$$\frac{1}{C_{pipeline}} = \frac{1}{1118.923} + \frac{1}{1120.816} + \frac{1}{693.497} + \frac{1}{93.247} + \frac{1}{28.701} + \frac{1}{57.904}$$

$$\boldsymbol{C_{pipeline} = 15.137\ l/sec}$$

→ $\boldsymbol{C_{pipeline} = 15.137\ l/sec}$

→ **Effective Pumping Speed of the System**

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

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

$$C_{pipeline} = 15.137\ l/s$$
$$S_{diff} = 600\ l/s$$
$$\boldsymbol{S_e = 14.765\ l/s}$$

→ $\boxed{\boldsymbol{S_e = 14.765\ l/sec}}$