Foreline Parameters and Roughing Pumpdown Times
From Atmosphere to Rough Vacuum
2.75” Conflat Multipurpose High Vacuum Chamber V4

1.) Foreline Parameters

a.) Determination of Roughing Flow Regime

$for: D\overline{p} > 5 \times 10^{-1}\ Torr \cdot cm \rightarrow flow\ is\ purely\ viscous$
$for: D\overline{p} < 1.5 \times 10^{-2}\ Torr \cdot cm \rightarrow flow\ is\ purely\ molecular$
$for: 1.5 \times\ 10^{-2}\ Torr \cdot cm <\ D\overline{p} < 5 \times 10^{-1}\ Torr \cdot cm \rightarrow flow\ is\ transitional$
$D = diameter\ of\ roughing\ line\ (cm) = \mathbf{2.210\ cm}$
$\overline{p} = mean\ gas\ pressure\ (torr) = \frac{1}{2}(P_1 + P_2) = \frac{1}{2}(760 + 0.02) = \mathbf{380.010\ Torr}$
$\boldsymbol{D\overline{p} = 839.822\ Torr \cdot cm \rightarrow flow\ is\ purely\ viscous}$

b.) Conductance for Viscous Flow

$C_\eta = \frac{\pi}{128}\frac{D^4}{L\eta}\overline{p}\ L/s$
$D = diameter\ of\ roughing\ line\ (cm) = \mathbf{2.210\ cm}$
$L = length\ of\ roughing\ line\ (cm) = \mathbf{39.767\ cm}$
$\eta = viscosity\ of\ gas$
$\overline{p} = mean\ gas\ pressure\ (torr) = \frac{1}{2}(P_1 + P_2) = \frac{1}{2}(760 + 0.02) = \mathbf{380.010\ Torr}$
$for: AIR\ @\ 20C,$
$C_\eta = \frac{182D^4\overline{p}}{L}\ L/s$
$\boldsymbol{C_\eta = 41487.062\ L/s}$

c.) Effective Pumping Speed of Forepump in Viscous Flow

$S_{e(\eta)} = \frac{C_\eta \times S_{forepump}}{C_\eta + S_{forepump}}$
$S_{forepump} = speed\ of\ forepump\ (L/s) = 6\ cfm = \mathbf{2.830\ L/s}$
$C_\eta = conductance\ for\ viscous\ flow\ of\ foreline\ (L/s) = \mathbf{41487.062\ L/s}$
$\boldsymbol{S_{e(\eta)} \approx 2.83\ L/s \rightarrow conductance\ of\ foreline\ is\ negligeable\ to\ pumping\ speed}$

2.) Pumpdown Time for Rotary Pumps in the Roughing Region

$for: pressures\ of\ 760\ Torr -\ 10^{-2}\ Torr, Q_{outgassing}\ is\ negligeable$
$for: good\ design\ of\ forelines, effective\ speed\ (S_e) = speed\ at\ pump\ throat\ (S_b)$

$$\tau = -\frac{V}{S_b}\int_{P_1}^{P_2}\frac{dp}{P - P'_u} \rightarrow$$

$$\boldsymbol{\tau = \frac{V}{S_b}\ln\left[\frac{P_1 - P'_u}{P_2 - P'_u}\right]}$$

$V = volume\ (liters)$

$S_b = speed\ at\ pump\ throat\ (L/s) = \mathbf{2.83\ L/s}$
$P_1 = starting\ pressure\ (Torr) = \mathbf{760\ Torr}$
$P_2 = ending\ pressure\ (Torr) = \mathbf{0.020\ Torr}$
$P_u' = ultimate\ pressure\ attainable\ by\ forepump\ (Torr) = \mathbf{0.015\ Torr}$

$for: V\ is\ volume\ of\ entire\ system\ from\ roughing\ pump\ to\ the\ chamber,$
$V_{total} = V_{foreline} + V_{diffusion\_pump} + V_{pipeline} + V_{chamber}$

$V_{foreline} = V_{trap} + V_{bellows} + V_{KF25\_tee} + V_{valve}$
$V_{foreline} = 152.545\ cm^3$
$\mathbf{V_{foreline} = 0.153\ L}$

$V_{diffusion\_pump} = V_{roughing\_inlet} + V_{body}$
$V_{diffusion\_pump} = 4388.187\ cm^3$
$\mathbf{V_{diffusion\_pump} = 4.388\ L}$

$V_{pipeline} = V_{baffle\_adapter} + V_{baffle} + V_{plate\_adapter} + V_{cross} + V_{valve}$
$V_{pipeline} = 613.237\ cm^3$
$\mathbf{V_{pipeline} = 0.613\ L}$

$V_{chamber} = V_{chamber}$
$V_{chamber} = 310.160\ cm^3$
$\mathbf{V_{chamber} = 0.310\ L}$

$\mathbf{V_{total} = 5.464\ L}$

$$\boldsymbol{\tau = \frac{V}{S_b} \ln\left[\frac{P_1 - P_u'}{P_2 - P_u'}\right]}$$

$V = volume\ (liters) = \mathbf{5.464\ L}$
$S_b = speed\ at\ pump\ throat\ (L/s) = \mathbf{2.830\ L/s}$
$P_1 = starting\ pressure\ (Torr) = \mathbf{760\ Torr}$
$P_2 = ending\ pressure\ (Torr) = \mathbf{0.020\ Torr}$
$P_u' = ultimate\ pressure\ attainable\ by\ forepump\ (Torr) = \mathbf{0.015\ Torr}$

$\mathbf{\tau = 23.037\ seconds}$