Total Design Optimization with Static Losses Consideration

PROCESS VACUUM

PV Vacuum Engineering Pte Ltd
(A member of Darco Water Technologies Limited)

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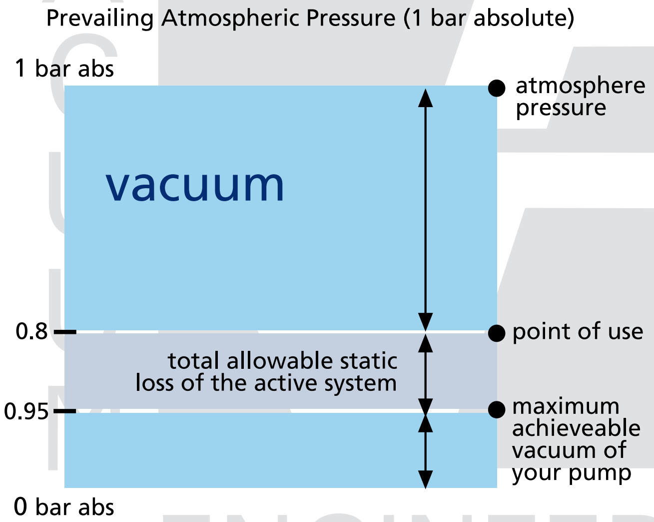
A subsidiary of PV Vacuum Engineering Pte Ltd

Total Design optimization with Static Losses consideration

Putting emphasis in Static Losses calculation is a key factor in both Design and Cost optimization for any Centralized Vacuum system.

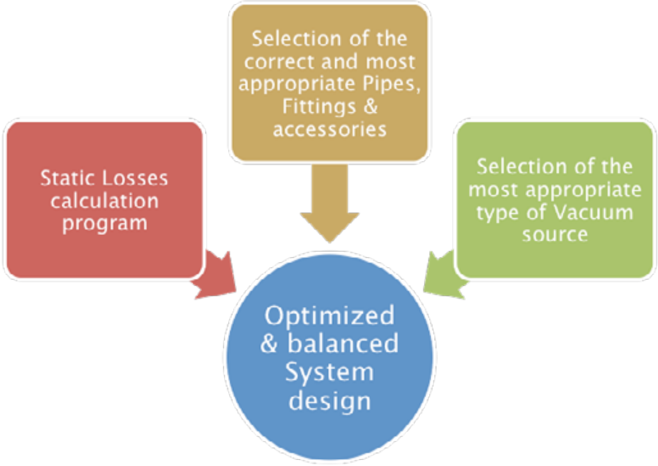
In most scenario, the Vacuum requirement at the Point-of-Use will be the starting point of any system design while working backwards to the Vacuum source. This is to mean that the system will have to work with what is left of the available pressure between the Point-of-Use and the Vacuum Source.



As illustrated in the graph, this available pressure isn't a lot considering the pipe network need to serve the entire plant.

It is therefore crucial to be able to calculate the System Static Losses accurately. A system with high static losses due to inaccurate calculation will result in either adding more powerful vacuum producers which will be a expensive and cost ineffective solution or unable to meet the vacuum requirement at the Point-of-Use.

PV adopt a system approach by using our proven and formulated Static Losses calculation program to determine the actual losses with consideration of the material/type of pipe & fittings, the Central Vacuum sources equipments for a well balanced and cost optimized design for our client.



ENGINEERING COMPUTATION SHEET

Project Name: XXXXXX

Project No: NA Date:XX-X-XXXX

Subject: Process Vac Sys-Pipe Losses-3rd Flr Point A1 + 20% Spare

Given the following parameter for Air at Standard Condition:

Density of Air is $\rho := 1.2 \cdot \frac{kg}{m^3}$

Viscosity Of Air is $\mu := \left(18.17 \cdot 10^{-6}\right) \cdot \frac{kg}{m \cdot s}$

Gas Constant is $R := 287.096$ J/kg K

Max Vacuum Level in Absolute Term At Pt Of Use $P := 115.791$ mbar

Temperature of Air is $T := 293.15$ Kelvin

The Relative Roughness Factor will be determine by the Material of Construction Of This Sectior of Pipe, which could be:

R1: Uncoated Carbon Steel; PVC Plastic Pipe;Aluminium
R2: Galvanized Steel-Continuously Rolled Longitudinal Seam & Spiral Seams
R3: Galvanized Steel, Sheets Hot Dipped Longitudinal Seams
R4: Fibrous Glass Duct, Rigid, Fibrous Glass Duct Air Side With Facing Material
R5: Fibrous Glass Duct Liner, Air Side Spray Coated, Flexible Duct-Metallic,
R6: Flexible Duct, All Types Of Fabric & Wire & Concrete

Detail Of System Pipe Configuration:

Type	Main	Sub-Main	Branch	Sub-Branch	Hook Up
Length-m:	$L := 22$	$L1 := 110$	$L2 := 58.5$	$L3 := 1$	$L4 := 1$
Diameter-mm:	$D := 350$	$D1 := 250$	$D2 := 150$	$D3 := 32$	$D4 := 25$
Roughness Factor:	$k := R2$	$k1 := R1$	$k2 := R1$	$k3 := R1$	$k4 := R6$

Nos of Fully Open (Isolation) Valve in the Pipe Line:	$G := 1$	$G1 := 1$	$G2 := 1$	$G3 := 0$
Nos of Fully Open Ball Valve in the Pipe Line:	$B1 := 0$	$B11 := 0$	$B12 := 0$	$B13 := 1$
Nos of 90 Deg Short Radius Elbow in the Pipe Line:	$E1 := 3$	$E11 := 10$	$E12 := 5$	$E13 := 2$
Nos of 90 Deg Long Radius Elbow in the Pipe Line:	$E2 := 0$	$E21 := 0$	$E22 := 0$	$E23 := 0$
Nos of 45 Deg Elbow in the Pipe Line:	$E3 := 0$	$E31 := 0$	$E32 := 0$	$E33 := 0$
Nos of Tee Junction in the Pipe Line:	$T1 := 1$	$T11 := 2$	$T12 := 1$	$T13 := 1$
Nos of Smooth Tee Junction in the Pipe Line:	$T2 := 0$	$T21 := 0$	$T22 := 0$	$T23 := 0$

X-Section Area of the Individual Section Of The Pipe is:

Main	Sub-Main	Branch	Sub-Branch	Hook Up
$A = 0.096\,m^2$	$A1 = 0.049\,m^2$	$A2 = 0.018\,m^2$	$A3 = 8.042 \times 10^{-4}\,m^2$	$A4 = 4.909 \times 10^{-4}$

Therefore, if we were to constraints ourselves to the above mentioned pipe sizes and allows for the appropriate static losses it creates accordingly, taking note that:

Main	Sub-Main	Branch	Sub-Branch	Hook Up
$Vm := 14.6699 \cdot \frac{m}{s}$	$V1m := 7.74 \cdot \frac{m}{s}$	$V2m := 3.28865 \cdot \frac{m}{s}$	$V3m := 8.005 \cdot \frac{m}{s}$	$V4m := 12.62 \cdot \frac{m}{s}$

The Corresponding **Maximum Flow At these Velocity** are:-

Main	$Qm = 5.081 \times 10^{3} \frac{m^{3}}{hr}$
Sub-Main	$Q1m = 1.368 \times 10^{3} \frac{m^{3}}{hr}$
Branch	$Q2m = 209.215 \frac{m^{3}}{hr}$
Sub-Branch	$Q3m = 23.177 \frac{m^{3}}{hr}$
Hook Up Connection	$Q4m = 22.301 \frac{m^{3}}{hr}$

Friction caused by conduit-wall shearing stresses and losses from conduit-section changes, is the loss of energy per unit mass (J/Kg) of flowing fluid.

In real fluid flow, a frictional shear occurs at bounding walls, gradually influencing the flow further away from the boundary. While the loss in fully developed conduit flow is evaluated through the Darcy-Weisbach relation, nature of the conduit wall surface is an additional consideration point.

This mode of variation is complex and best expressed in Chart Form (Moody 1944). The Values of Frictional factor between the values for smooth tubes and those for the fully rough regime are best represented by Colebrook's natural roughness function.

While the preceeding discussion has been focused on circular pipes and ducts, air ducts which are rectangular in cross-section, should be computed for their equivalent circular conduit sizes for estimation of the factor.

Valve and Section changes (contractions, expansions and diffusers, elbows or bends, tees), as well as entrances, distort the fully developed velocity profiles and introduce extra flow losses into the pipelines system.

Hence, applying the Colebrook-White Equation, we compute the Δp, for the different section of the pipeline system in question, which is

Frictional Factor of Different Pipe Section of the System:

Main	Sub-Main	Branch	Sub-Branch	Hook Up
$f = 4.117 \times 10^{-3}$	$f1 = 4.454 \times 10^{-3}$	$f2 = 5.898 \times 10^{-3}$	$f3 = 7.192 \times 10^{-3}$	$f4 = 0.028$

Crane Co (1976) found a variation with the Reynolds number similar to that of the friction factor; Kittridge and Rowley (1957) observed it only with laminar flow.

Assuming that the Coefficient K varies with Reynold number similary to Frictional Factor, it is convenient to represent fittings losses as adding to the effective length of uniform conduit.

This assumes that each fitting loss is fully developed and its disturbance fully smoothed out before the next section change. Such an assumption is frequently wrong, and the total loss can be over estimated.

For elbows flows, the total loss of adjacent bends may be over- or underestimated. The Secondary flow pattern following a radius elbow is such that when one elbows follows another, perhaps in a different plane, the secondary flow production of the second flow may reinforce or partially cancel that of the first. Moving the second elbow a few diameters can reduce the total loss (from more than twice the amount) to less than the loss from one elbow.

Therefore, ulitmately in a system pipe work, the actual configuration of the pipe line is critical to ensure the accuracy of this computation here.

Accordingly, we compute the estimated total loss of each section of the System In Question as follow:

The **Total Loss of Different Pipe Section** of the System in term of pressure values are :

The Minimum Vacuum Required at the Vac Buffer Tank in mbar is: $Pi = 106.321$ mbar-abs