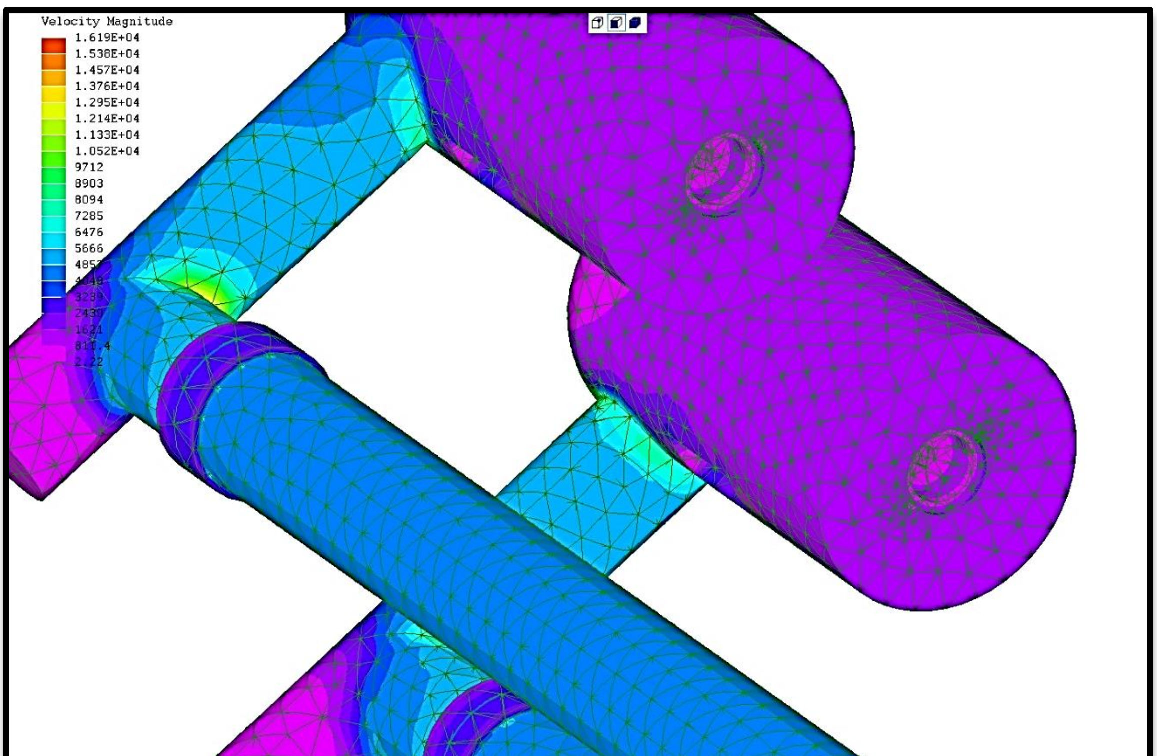
Dual Vacuum Particulate Extraction System
Fluid Flow FEA Analysis Report
for
System Vacuum Source Sizing
and
Pressure Drop Determination



Submitted by:
Ray M. Frey
R.J. Frey Technologies
Date: 10/25/2018

1.0 <u>Statement of the Problem</u>:

An automated pharmaceutical filling system incorporates a dual reagent tube air cleaning station prior to filling and check weighing operations for the product. This tube cleaning process includes (2) pressurized air nozzles inserted into the reagent tubes to eject particulates out of the tubes. (2) vacuum eject shrouds cover the top portion of the reagent tubes to remove any air borne particulates ejected by the pressurized air nozzles.

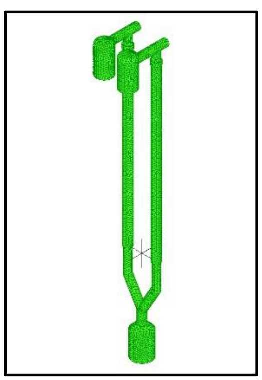
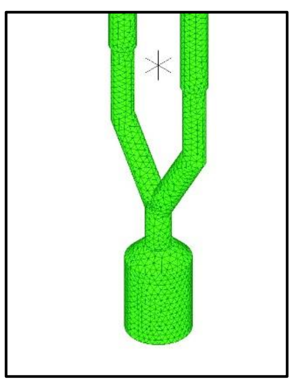
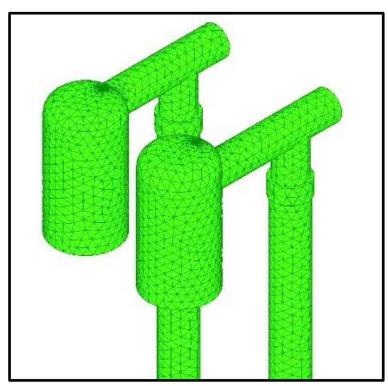
A potential problem exists because the vacuum generator source is <u>not</u> located close to the reagent tubes. It is remotely located below the operating deck of the filling system. The fluid pathway from the vacuum source to the dual vacuum eject zone around the top of the (2) reagent tubes splits into a wye and has a number of geometric transitions that will induce multiple pressure drops. The vacuum air velocity at the reagent tube and total pressure drops along the fluid pathway need to be evaluated to properly size the vacuum generator.

2.0 <u>Purpose of this Fluid Dynamics FEA Analysis</u>:

<u>FEA Analysis 1</u>: To evaluate the fluid velocities and pressure drops throughout the entire vacuum fluid pathway. Initially, a commercial vacuum generator will be analyzed with a vacuum source rated at (-7.0 kPa) with an unloaded flow rate of (74.16 CFM). The FEA analysis data will be used to determine the correct size vacuum generator for the system to meet the desired flow rate plus overcome the total pressure drops in the dual fluid pathway.

3.0 <u>Particulate Vacuum System Fluid Dynamics FEA Analysis 1 Parameters</u>:

<u>Model Mesh Data</u>: Nodes: (59,019) Elements: (33,639) DOF: (N/A)

<u>FEA Analysis Type</u>: Fluid Dynamics Potential Fluid Flow 3D

<u>Composite Materials Used</u>: No

<u>Fluid Media</u>: Air (clean and unlubricated)

Fluid Material Properties:

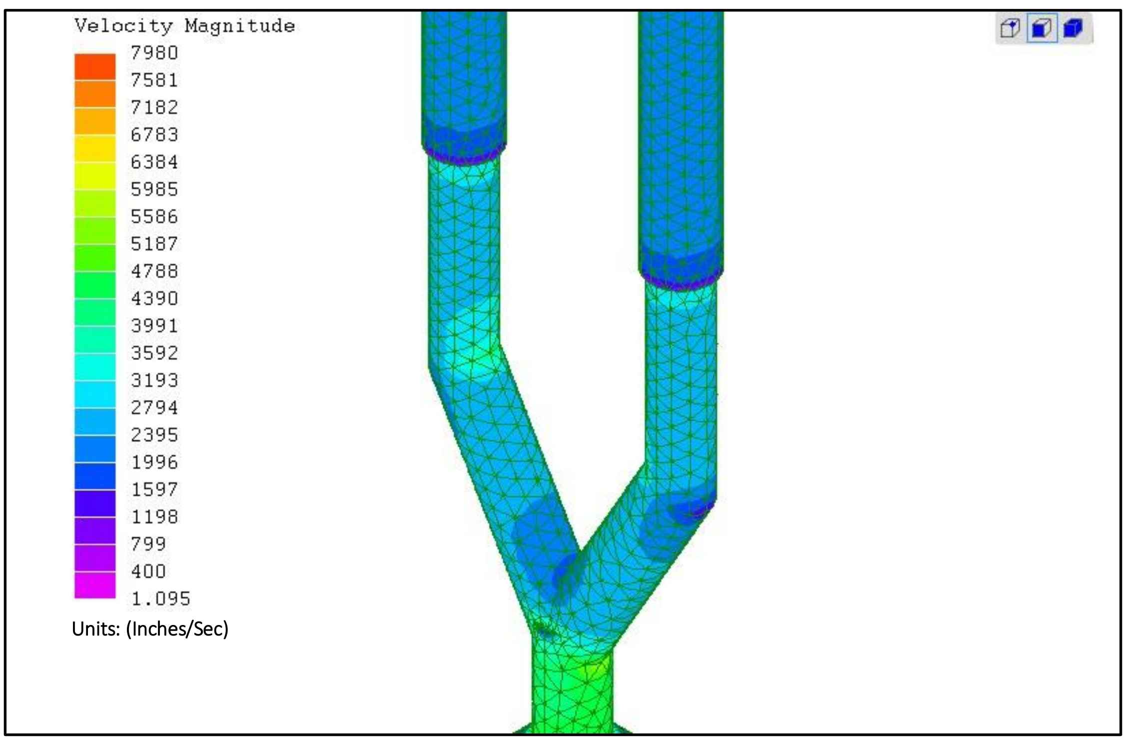
>Fluid Type:	Gas
>Classification:	Newtonian
>Weight Density:	4.670139E-05 (lbs/inch^3)
>Dynamic Viscosity:	0.01823 cP
>Kinematic Viscosity:	15.27 cSt
>Fluid Temperature:	72.0° F (22.2°C)

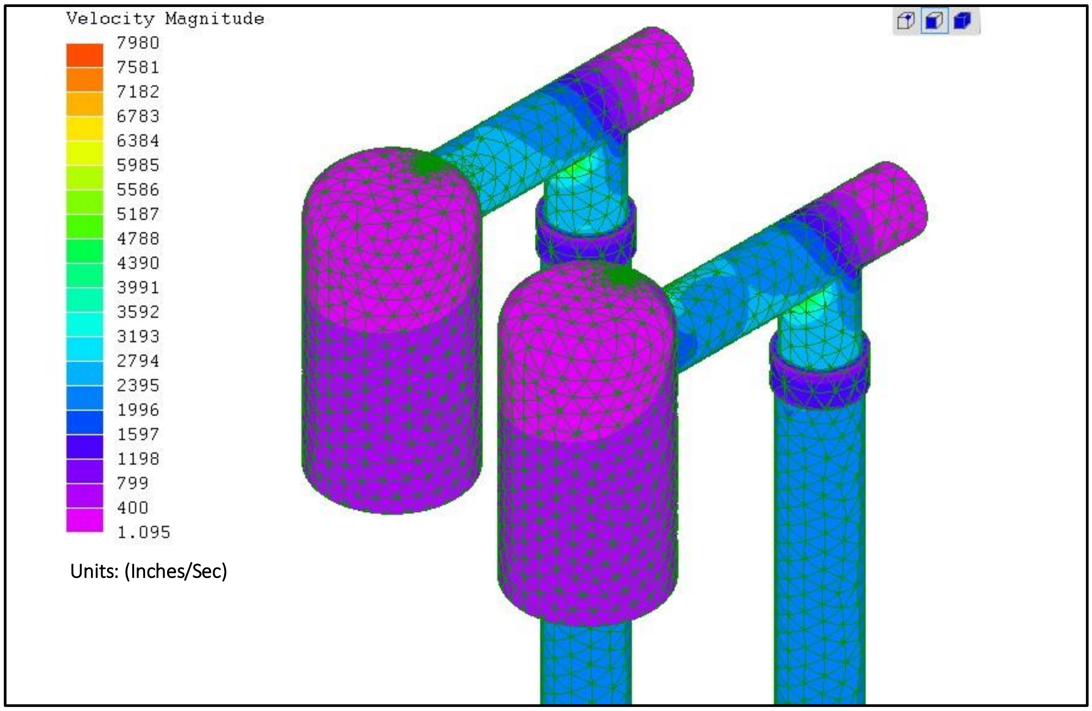
Fluid Dynamics Properties:

>Source Vacuum:	-7.0 kPa (-1.01526 psig)
>Initial Inlet Pressure:	Atmosphere
>Desired Flow Rate:	74.16 CFM (2135.81 in^3/sec)
>Pipe Roughness Factor:	0.00 inches (0.00 mm)

Ambient Temperature: 72.0° F (22.2°C)

4.0 Fluid Dynamics FEA Analysis 1 Results: (Air Velocity Magnitude)




Velocity Magnitude
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7182
6783
6384
5985
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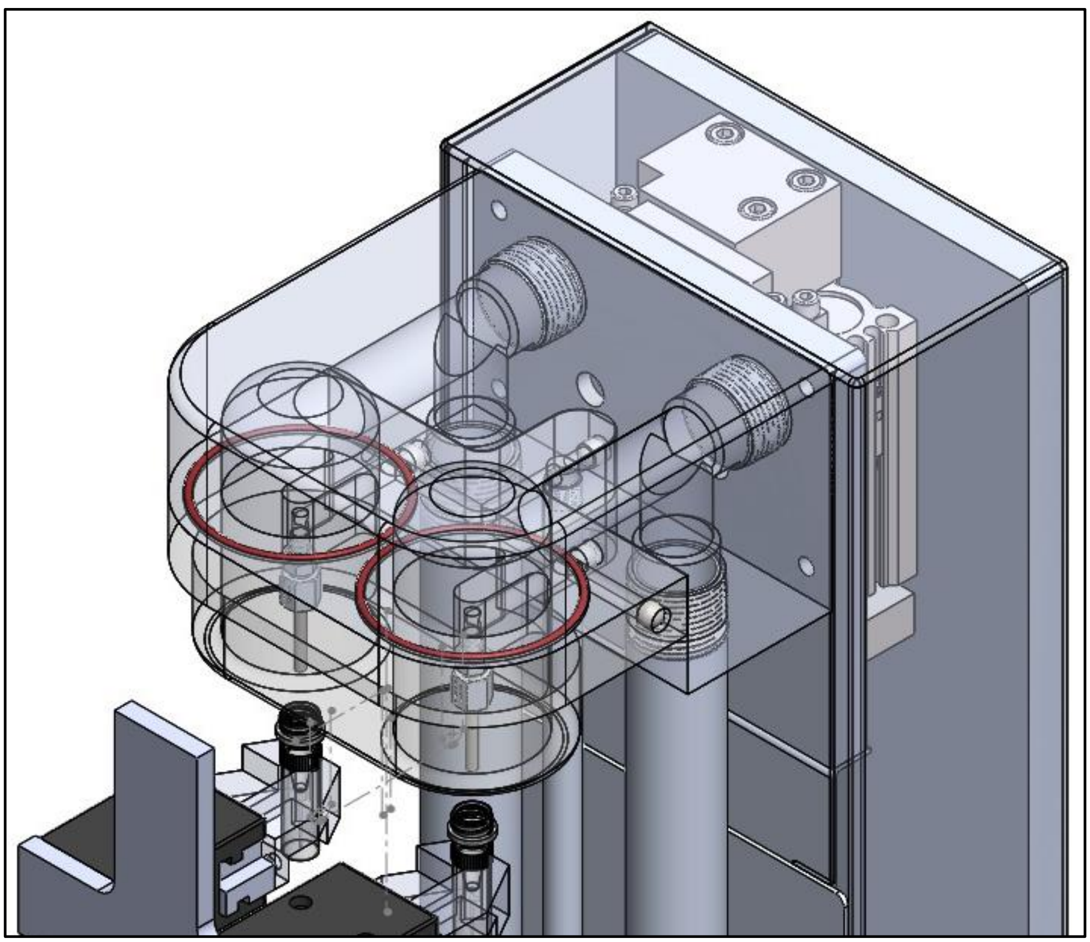
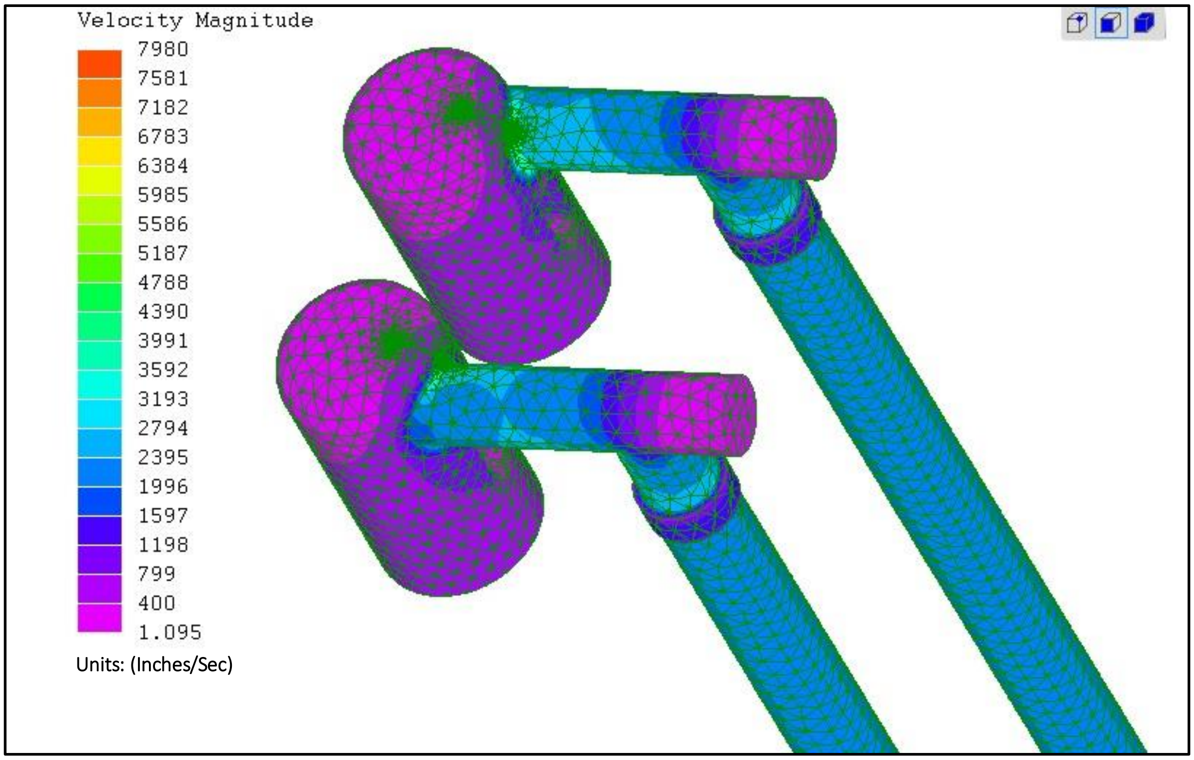
400
1.095
Units: (Inches/Sec)

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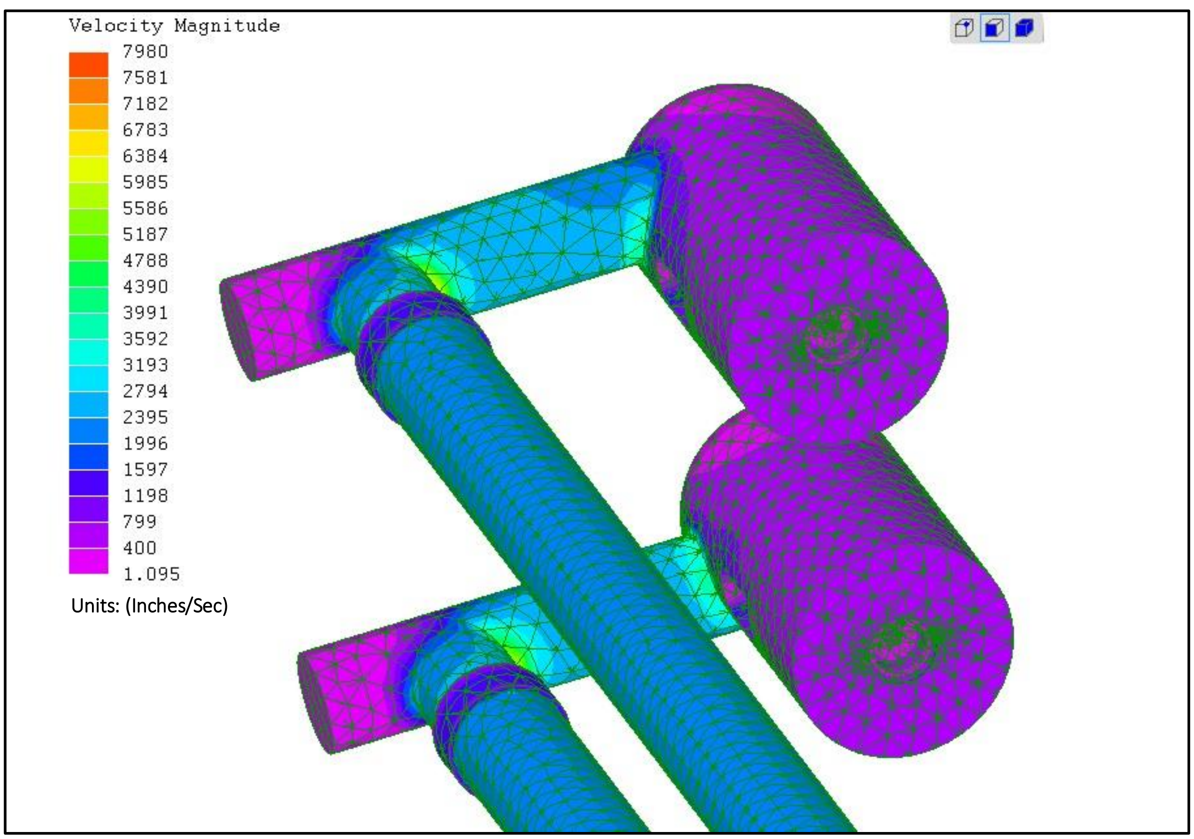
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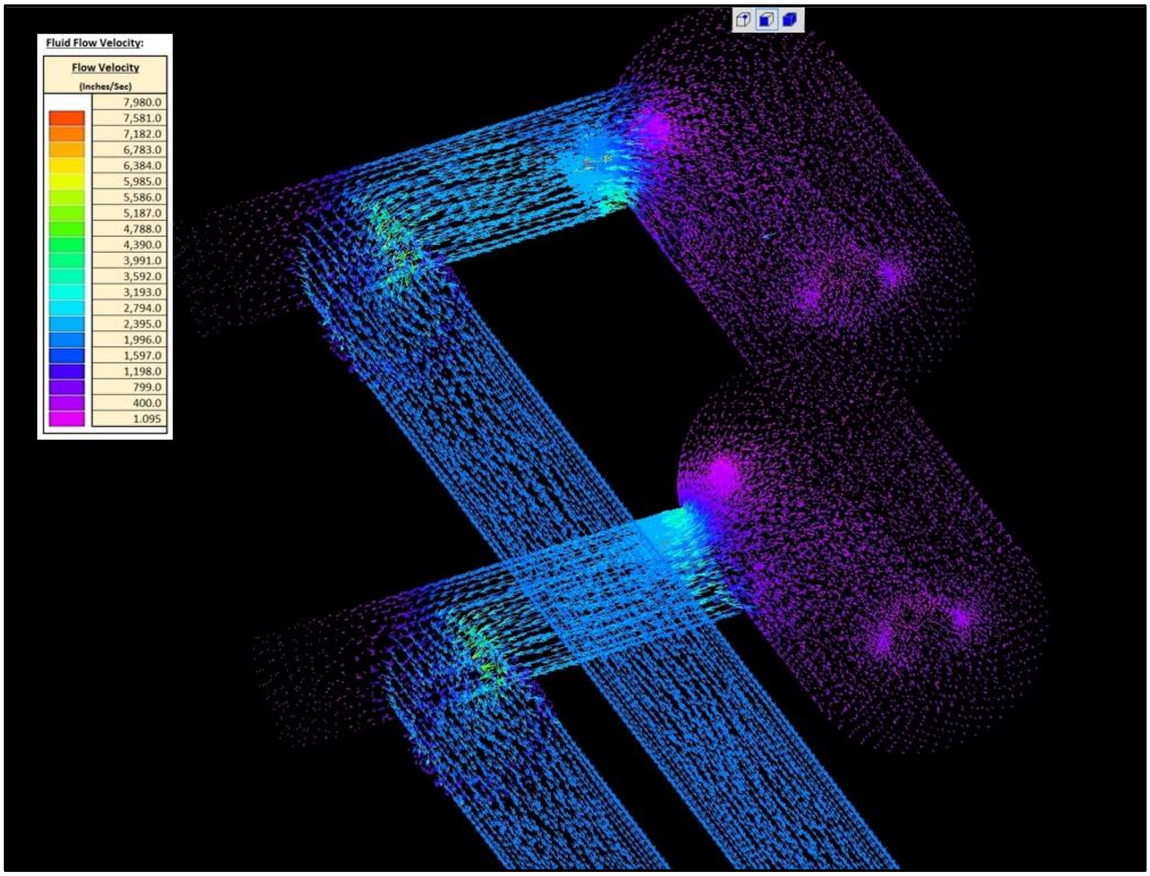
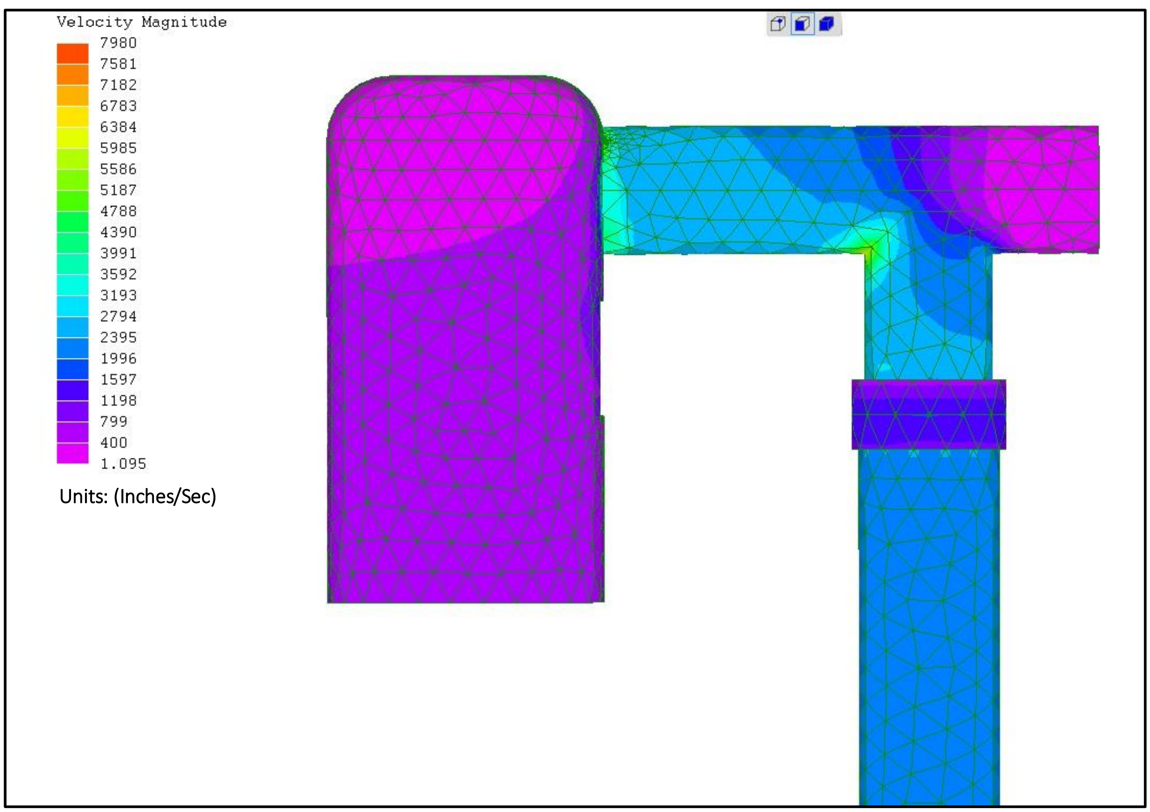
Units: (Inches/Sec)


Fluid Flow Velocity:
Flow Velocity
(Inches/Sec)
7,980.0
7,581.0
7,182.0
6,783.0
6,384.0
5,985.0
5,586.0
5,187.0
4,788.0
4,390.0
3,991.0
3,592.0
3,193.0
2,794.0
2,395.0
1,996.0
1,597.0
1,198.0
799.0
400.0
1.095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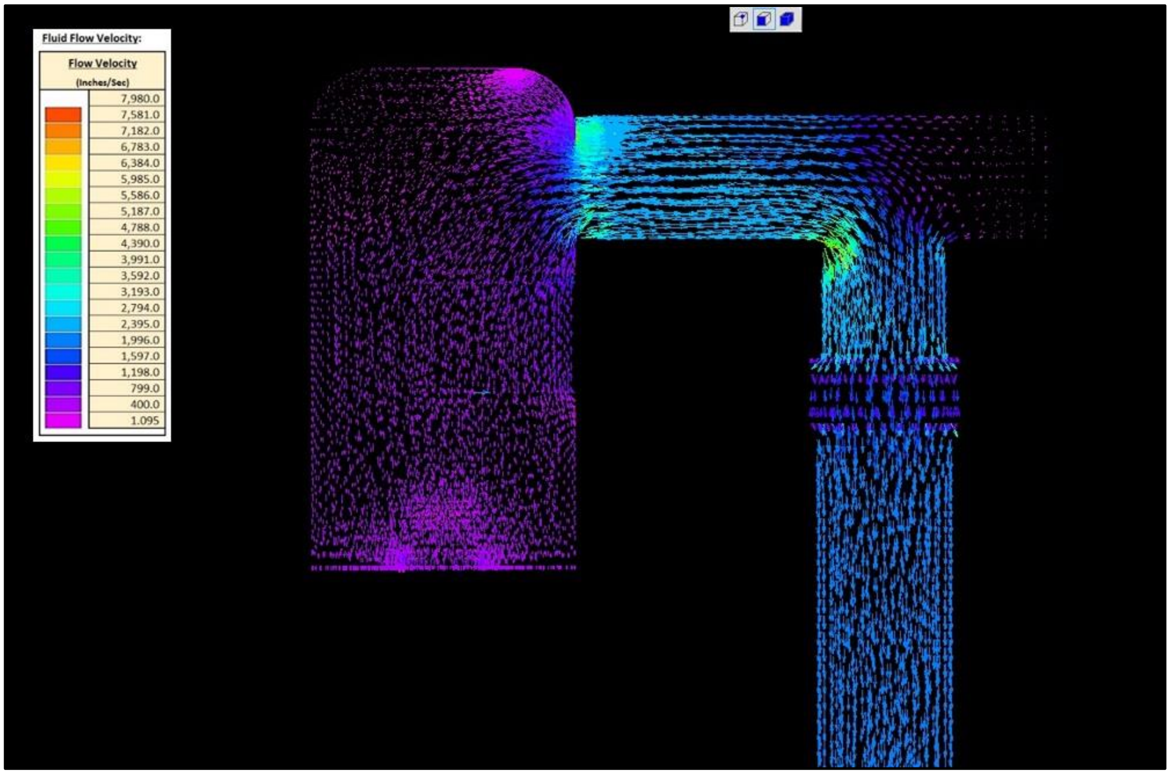

Fluid Flow Velocity:

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4,390.0
3,991.0
3,592.0
3,193.0
2,794.0
2,395.0
1,996.0
1,597.0
1,198.0
799.0
400.0
1.095

Flow Velocity (Feet/Sec)
665.0
631.8
598.5
565.3
532.0
498.8
465.5
432.3
399.0
365.8
332.6
299.3
266.1
232.8
199.6
166.3
133.1
99.8
66.6
33.3
0.09

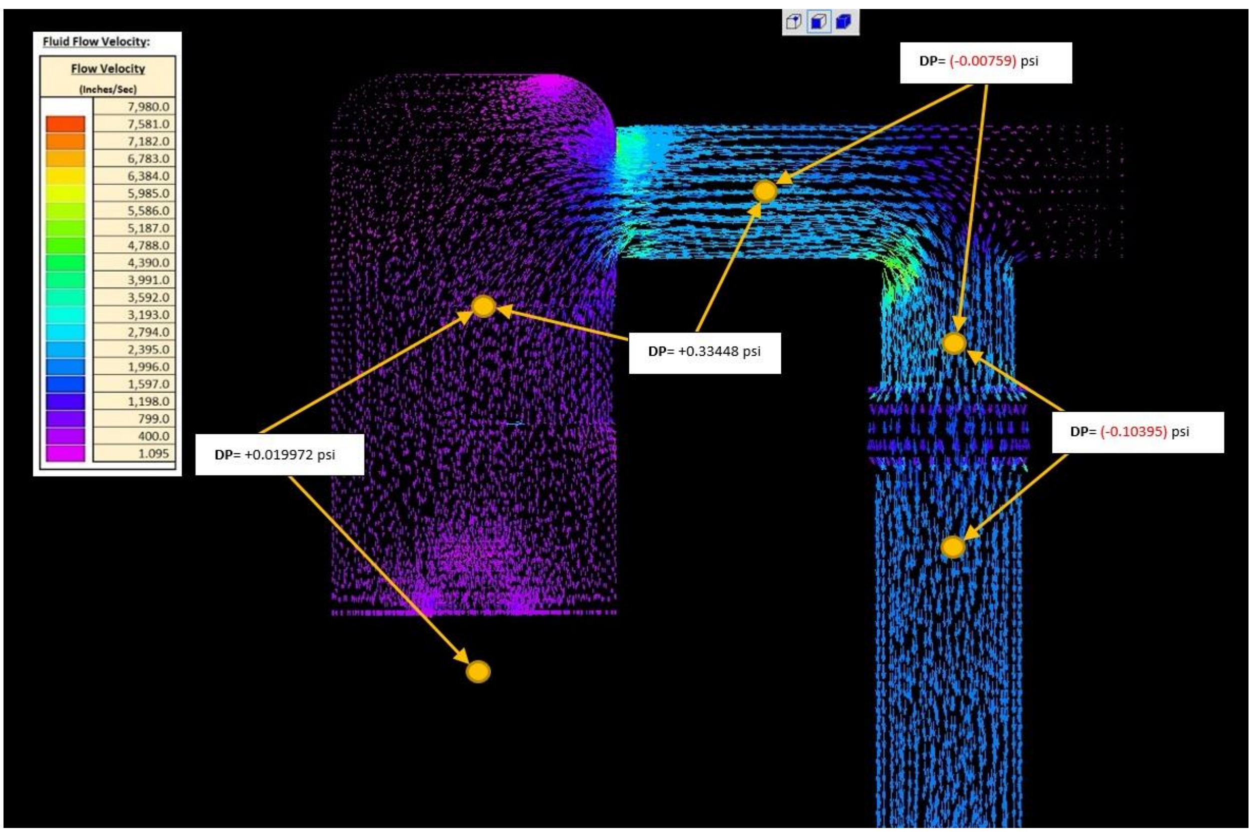
5.0 <u>Fluid Dynamic FEA Analysis 1 Results</u>: (Total Pressure Drops)

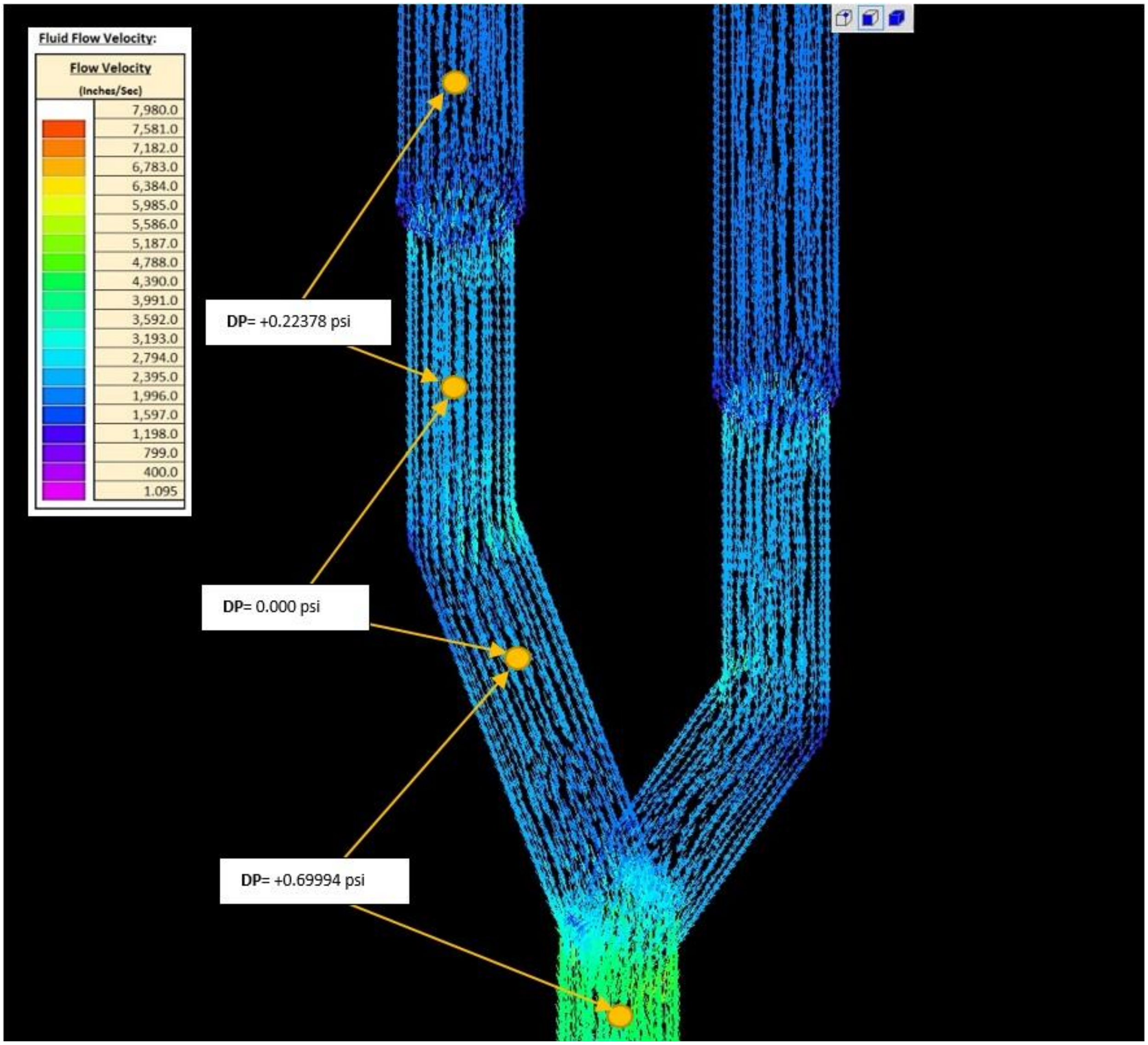
Pressure drops (DP) along the fluid pathway were calculated using Bernoulli's equation as a one-dimensional continuity equation using the fluid FEA velocity magnitude differentials at (2) points at various locations along the main fluid flow path. Boundary piping and manifold geometries were fixed.

In FEA fluid dynamic analysis at ambient temperatures, heavier gases such as air can be analyzed as incompressible fluids with minimal error if the flow velocities are less than Mach (1.0). FEA results with Air flow ranges up to Mach (0.5) are very accurate. FEA results with Air flow ranges from Mach (0.5 to 1.0) have minimal error. A (10-20%) factor of safety allowance can be added for gas flows in this velocity range to compensate for any errors.

The air flow velocities in this application were in the (Mach 0.18 – 0.35) range. Therefore, this FEA analysis ran Air as an incompressible fluid due to its low flow velocity, and the results were verified with manual calculations.

The individual pressure drops (DP) along the fluid pathway are shown in the fluid velocity magnitude vector images below: (DPs are for (1) fluid pathway leg only)





Total Pressure Drops (DP) for the System):

There are (2) legs in this vacuum system, therefore the pressure drop (DP) sum for one leg must be doubled to calculate the Total Pressure Drop (DP).

Total DP (psi) = 2 x (0.019972 + 0.33448 - 0.00759 – 0.10395 + 0.22378 + 0.00 + 0.69994)

Total DP (psi) = 2 x (1.166632)

Total DP = 2.333 psi (16.087 kPa)

**Note: (The Total Pressure Drop (DP) for the desired flow rate of (74.16 CFM) exceeds the (-7.0 kPa) rating of the initial vacuum generator selected.)

6.0 <u>Calculated Total Vacuum Requirement of the System</u>:

Total Vacuum Required (psi) = Total Vacuum (for desired flow) + Total System DP

Total Vacuum Required (psi) = (-1.01526 psi) + (-2.333 psi)

Total Vacuum Required (psi) = -3.348 psi (-23.085 kPa)

**<u>Note</u>: (The Total Vacuum Required for the desired flow rate of (74.16 CFM) exceeds the (-7.0 kPa) rating of the initial vacuum generator selected. Check if higher capacity vacuum generators are available from the manufacturer.)

7.0 <u>Conclusions</u>:

The fluid dynamic FEA analysis results for air velocities, dynamic pressures, and static pressure drops in this application appear to be valid as they are within typical known ranges for air flow in pipe. The FEA results were cross-checked and verified by manual calculations. Also, there were no errors in the mesh generation and the FEA solver processing.

Based on the FEA analysis data, the initial selection of the (-7.0 kPa) vacuum generator is grossly undersized. It will not overcome the pressure drops and still maintain the desired vacuum flow rate.

The vacuum generator manufacture has (2) higher capacity sizes at (24.9 kPa and 29.9 kPa) vacuum capacity. Either of these vacuum generators would provide adequate vacuum flow rate for this application. See chart below:

LINE VAC PERFORMANCE

80 PSIG (5.5 BAR)	Air Consumption		Vacuum		
Model #	SCFM	SLPM	"H_2O	kPa	
6058, 6058-316, 6078	5.60	158	-120	-29.9	
6059, 6059-316, 6079	7	198	-100	-24.9	**Required
6060, 6060-316, HT6060, HT6060-316, 6080	10.70	303	-72	-18	
6061, 6061-316, HT6061, HT6061-316, 6081	14.70	416	-42	-11	
6062, 6062-316, HT6062, HT6062-316, 6082	25.90	733	-42	-11	
6063, 6063-316, HT6063, HT6063-316, 6083	33	934	-36.8	-9	
6064, 6064-316, HT6064, HT6064-316, 6084	45	1,274	-28.5	-7	Initial Selection
6065, 6065-316, HT6065, HT6065-316, 6085	58.50	1,656	-23.5	-6	
6066, 6066-316, HT6066, HT6066-316, 6086	68.5	1,939	-14.7	-4	
6067, 6087	95	2,690	-13.6	-3.4	
6088	128	3,625	-10.5	-2.6	

8.0 FEA Analysis Disclaimer:

This FEA analysis is meant to be a design tool to help guide the final design of the overall system. At best, this FEA analysis is a close approximation of the actual physical conditions occurring in the mechanical or process system. The accuracy of this analysis is only as accurate as the available data. It is impossible to include and accurately simulate in an FEA analysis every physical factor or variable affecting the process. A liberal safety factor allowance must be incorporated in the application to minimize the adverse effects of these unknown variables and inaccuracies. Verification of the results must be validated by empirical testing

Therefore, R.J. Frey Technologies, nor their employees thereof, make any claim to the accuracy, warranty, nor assumes legal liability or responsibility for the usefulness of the information contained in this report. As stated previously, verification of the results must be validated by empirical testing.