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FINITE ELEMENT ANALYSIS OF AIR FLOW USING CFD ON VARIOUS CONTROL VALVES AND TO PREDICT MOST SUITABLE VALVE FOR THROTTLING OPERATION

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ABSTRACT

Valve is a device used in pipeline for turning on and shutting-off flow, for reducing and controlling flow by throttling to meet the requirements of service conditions. Valves can be operated manually or by remote control system. Valves are found in virtually every industrial process, including water and sewage processing, mining, power generation, processing of oil, gas and petroleum, food manufacturing, chemical and plastic manufacturing and many other fields.

It is important to choose the right valve which will be trouble free in operation and economical to install and operate. If a valve is selected wrongly and large quantities are ordered, the consequence of selection becomes serious. Hence, it is better to consult valve manufacturers or specialists in the field before placing a bulk order on a particular variety of valve on which the intender has a little or no knowledge regarding its suitability. This is particularly so with the availability of a large variety of valves.

INTRODUCTION

A Valve is an important device in a piping system, and in this field of engineering it is very important to optimise every aspect in the line. To do so, many losses are attempted to be minimised, by doing so overall performance is increased, maintenance and operational costs are minimised

In this paper, we will be characterising a valve‘s performance factors, such as pressure drop, flow coefficient and loss coefficient. It is necessary for fluid system designers to account for system requirements to properly operate the valve and prevent damage and which valve is best suited for the throttling operation for the specified scenario. How a valve will perform, while in operation at different opening angles and under different types of flow, is critical information for engineers planning and installing piping systems involving the valve. Finally a decision shall be made by judging the valve on the basis of market price, installation cost, operational cost and finally maintenance cost.

While these values can usually be obtained experimentally, it is often not feasible or possible to calculate the performance factors of throttling valves. Another method where valve performance factors can be obtained is by using Computational Fluid Dynamics (CFD)

software to simulate the physics of fluid flow in a piping system around a valve.

OBJECTIVES

In this study, the problem presented is of comparing the different types of valves on the basis of its performance parameters for different valves like Butterfly Valve, Ball Valve and Gate Valve for different valve openings ranging from fully open (0%) to almost closed (96.72%) to obtain the optimum range of fluid flow and throttling operation. The main objective of this study is to analyse the fluid flow using Computational Fluid Dynamics to determine most suitable Valve for this hypothetical scenario taken. The inputs given at the boundary conditions are inlet velocity of 10m/s and at gauge pressure, outlet is considered as an opening with gauge pressure equal to 0 (101325 Pa Absolute), this was to determine the correct velocity and pressure profiles of the outlet. The wall boundary conditions are given solid body, so are the valve outline, which by default in ANSYS FLUENT 15.0 is taken as Aluminium.

TYPES OF VALVES

A brief introduction, advantages, disadvantages and their applications to the various valves used in this study are as follows:

1. Gate Valve

A gate valve is a valve that operates by moving a round or rectangular gate/wedge/slider out of the path of the fluid. Gate valves are often used when unrestricted straight-line flow of fluid is desired. The gate faces can form a wedge like shape or they can be parallel plate, often used as a shut-off valve.

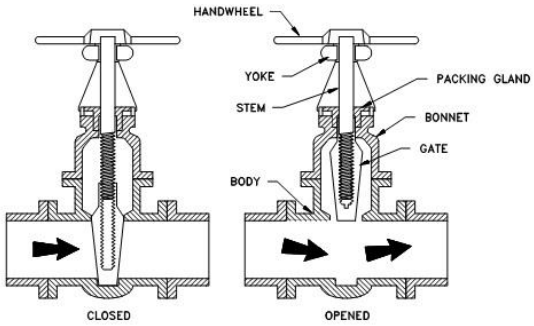


Fig.1: Example of a Gate Valve. (Wedge type, side view, opened and closed position.)

Gate valves are mostly used to permit or prevent the flow of viscous incompressible fluids. Ideally gate valves shouldn't be used for throttling operations, unless they are specially designed for that purpose.

Advantages of a Gate Valve:

- They have very well off characteristics.
- They are best suited for on-off valve operations and not throttling operations as there is a formation of vena contracta.
- They are most suited for viscous fluid throttling as they tend to 'Cut' the flow of fluid and also pressure loss through the valve is minimal.

Disadvantages of a Globe Valve:

- Are not quick opening or closing valves. Full-stem travel to open or close a gate valve requires many turns of its hand wheel or an actuator.
- The slow movement of the disc near the full-closed position results in high-fluid velocities, causing scoring of seating surfaces, referred to as wire drawing. It also causes galling of sliding parts.
- Some designs of gate valves are susceptible to thermal or pressure binding, depending upon the application.

Joe Joseph
2K14/ME/072

- Repair or machining of valve seats in place is difficult, and not cost effective

Gate Valve Applications

Socket/butt-welding end-gate valves in air, fuel gas, feed water, steam, lube oil, and other systems are typical applications. Threaded-end gate valves may be used in air, gaseous, or liquid systems. Concern for leakage from threaded connection can be addressed by seal welding the threaded connection or by using thread sealants, as appropriate. In low-pressure and low-temperature systems such as fire protection systems' water piping or water distribution pipelines, flanged gate valves are commonly used.

2. Ball Valve

A ball valve is a form of quarter-turn valve which uses a hollow and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is pivoted 90-degrees by the valve handle. The handle lies flat in alignment with the flow when open, and is perpendicular to it when closed, making for easy visual confirmation of the valve's status.

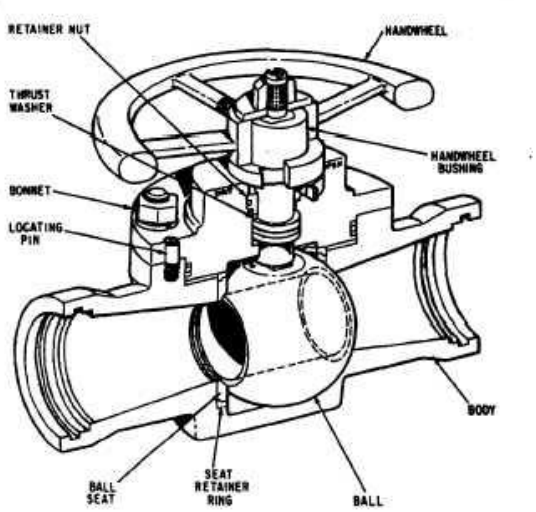


Fig.2: Example of a Ball Valve. (cut section view, position.)

Ball valves are durable, performing well after many cycles, and reliable, closing securely even after long periods of disuse. These qualities make them an excellent choice for shutoff applications, where they are often preferred to gates and globe valves, but they lack their fine control in throttling applications.

Advantages of Ball Valves:

- Smaller in size than a gate valve.
- Lighter in weight than a gate valve.
- Several designs of ball valves offer flexibility of selection.
- Can be used in clean and slurry applications.
- High-quality ball valves provide reliable service in high-pressure and high-temperature applications.
- Force required to actuate the valve is smaller than that required for a gate valve.

Disadvantages of Ball Valves:

- They are not suitable for sustained throttling applications.
- In slurry or other applications, the suspended particles can settle and become trapped in body cavities causing wear, leakage, or valve failure.

Typical Applications of Ball Valves:

- Air, gaseous, and liquid applications requiring bubble-tight service
- Low-point drains and high-point vents in liquid, gaseous, and other fluid services
- Instrument root valves
- Cooling water and feed water systems Steam service

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2K14/ME/072

3. Butterfly Valve

A butterfly valve is a valve which can be used for isolating or regulating flow. The closing mechanism takes the form of a disk. Operation is similar to that of a ball valve, which allows for quick shut off.

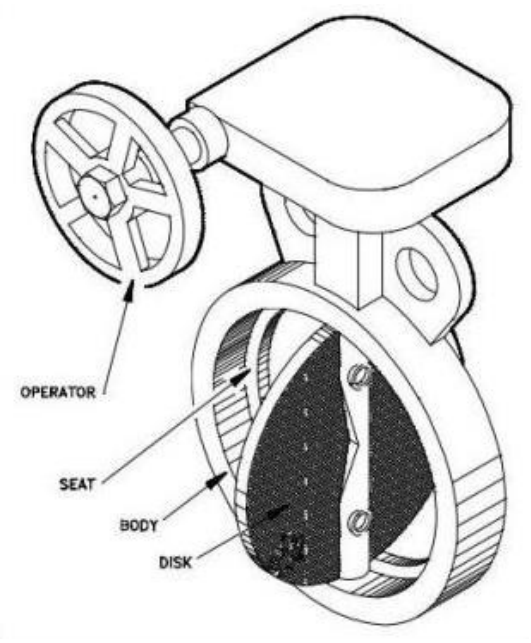


Fig.3: Example of a Butterfly Valve. (Simple disc type, exploded view of valve section, opened position.)

Butterfly valves are generally favoured because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required. The disc is positioned in the centre of the pipe; passing through the disc is a rod connected to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow.

Unlike a ball valve, the disc is always present within the flow, so a pressure drop is always induced in the flow, regardless of valve position.

Advantages of Butterfly Valves:

- The compact design requires considerably less space, compared to gate, globe, or other valves.
- Light in weight.
- Quick acting; as a quarter-turn valve, it requires less time to open or close.
- They have low-pressure drop and high-pressure recovery.
- Provide bubble-tight service.

Disadvantages of Butterfly Valves:

- Throttling service is limited to low differential pressure.
- Throttling is restricted to a 30- to 80-degree disc opening. Location of valve, pipe routing, free, and closed discharge are to be considered while using a butterfly valve in a throttling application.
- Cavitation and choked flow are two potential concerns.
- The disc movement is unguided and affected by flow turbulence.

Typical Applications of Ball Valves:

- Cooling water, air, gases, and other similar applications, such as fire protection, circulating water, etc.
- Slurry and similar services.
- High-pressure and high-temperature water and steam services.
- Throttling service involving low differential pressures, as in cooling water or air supply systems
- Vacuum service
- Food processing, chemical, and pharmaceutical services.

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2K14/ME/072

PERFORMANCE FACTORS

Characterising a valve involves evaluating the most common performance factors like; Pressure loss, Flow Coefficient, Flow factor, Loss Coefficient and Head Losses. The following gives the definition and a brief description on these performance parameters.

Pressure Loss

Pressure loss across a valve is often attributed to disruptions caused in the flow field such as obstruction, flow separation and mixing. For valves, pressure losses vary depending on the disk angle configuration, **θ**, and flow rate, **Q**. The pressure loss is represented by the absolute pressure differential between the measured pressure upstream, $\mathbf{P_{u\theta}}$ and the measured pressure downstream, $\mathbf{P_{d\theta}}$, as given in Eqn. 1.1 below:

$$\Delta P_\theta = P_{u\theta} - P_{d\theta}$$

The main determinants of resistance to fluid flow are fluid velocity through the pipe and fluid viscosity. Pressure drop increases proportional to the frictional shear forces within the piping network. A piping network containing a high relative roughness rating as well as many pipe fittings and joints, tube convergence, divergence, turns, surface roughness and other physical properties will affect the pressure drop. High flow velocities and / or high fluid viscosities result in a larger pressure drop across a section of pipe or a valve or elbow.

For a given flow rate, pressure losses will generally decrease as the valve's opening angle increases due to less interference in the flow. It should also be noted that this pressure loss represents a gross measurement instead of net measurement. This means that head losses due to pipe friction length between measurement points (which are minimal), are included in the ΔP_θ measurements, and thus affect other performance factors to be discussed.

Loss Coefficient (K_θ)

The flow resistance coefficient, commonly known as the loss coefficient, K_θ, is a dimensionless value commonly used in the design of thermal fluid systems to predict head losses present due to the presence of various components. The Loss Coefficient is shown below:

$$K_\theta = \frac{2\rho h_{L\theta}}{V_{avg}^{\ 2}}$$

Head Loss (h_L)

In any real moving fluid, energy is dissipated due to friction; turbulence dissipates even more energy for high Reynolds number flows. This dissipation, called head loss, is divided into two main categories, "major losses" associated with energy loss per length of pipe, and "minor losses" associated with bends, fittings, valves, etc.

$$h_L = \frac{\Delta P_\theta}{\rho g}$$

COMPUTATIONAL FLUID DYNAMICS (CFD)

Using general purpose analysis software ANSYS 15.0, the setup was modelled to match the general requirements of the study. ANSYS FLUENT 15.0 was used for this CFD study. Refer to Appendix B for more on ANSYS FLUENT 15.0 and its various programming capabilities.

Joe Joseph
2K14/ME/072

The overall approach to simulating the model consisted of: using a computer aided design model of the various valves in 2D form in the powerful CAD design software; Solidworks 2015. The appropriate dimensions and angles of valve openings were generated. The designs were then imported into ANSYS workbench 15.0 in the .STP format. ANSYS Workbench 15.0 comes with FLUENT 15.0 (CFD) setup. This setup includes the geometry design/import, wherein the valve models were imported and generated. Meshing tools are available for generating the appropriate mesh for the given CAD design, the various valve meshes have been shown in Appendix A. CFD setup and solution, which includes all the boundary conditions of the study.

The governing equations of fluid dynamics commonly referenced for incompressible isothermal fluids in CFD include the Navier-Stokes equations. The Navier-Stokes equations are a simplification of the conservation of momentum equations and the constitutive equations that define the relationship between shear and strain for a Newtonian fluid.

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j}(u_j u_i) = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \nu \frac{\partial^2 u_i}{\partial {x_j}^2}$$

While many laminar solutions (low Reynolds number flows) are possible using above. Nonlinearities and instability arise due to turbulence. Turbulence is often characterized as irregular and random flow, with three-dimensional vertical fluctuations.

Most methods of analysing turbulence results in more unknowns than available equations, and thus results in an equation closure problem. Some techniques used include focusing on the mean flow and the effects of turbulence on mean flow properties by using what are called the unsteady Reynolds-averaged Navier-Stokes (RANS) equations:

$$\frac{\partial \overline{u_i}}{\partial t} + \overline{u_j}\frac{\partial \overline{u_i}}{\partial x_j} = \frac{1}{\rho}\frac{\partial}{\partial x_j}(-\overline{p}\delta_{ij} + \mu\frac{\partial \overline{u_i}}{\partial x_j} + \tau'_{ij})$$

Where ζ_{ij} is the Reynolds stress tensor that attempts to describe the diffusive nature of turbulence, which is given as:

$$\tau'_{ij} = -\rho\overline{u'_i u'_j} = -\rho\begin{bmatrix} \overline{u'^2} & \overline{u'v'} & \overline{u'w'} \\ \overline{v'u'} & \overline{v'^2} & \overline{v'w'} \\ \overline{w'u'} & \overline{w'v'} & \overline{w'^2} \end{bmatrix}$$

Some of the turbulence models included in ANSYS FLUENT 15.0 are:

- Mixing length
- Spalart-Allmaras (1 eqn)
- K-Epsilon (2 eqn)
- K-Omega (2 eqn)
- Transition K-KL- Omega (3 eqn)
- Transition SST (4 eqn)
- Reynolds stress (5 eqn)
- Scale Adaptive Simulation.

While each turbulence model has its strengths, weaknesses, and variations, this study will focus on using the k-Epsilon model only.

Reasons for choosing the k-Epsilon turbulence model include the following:

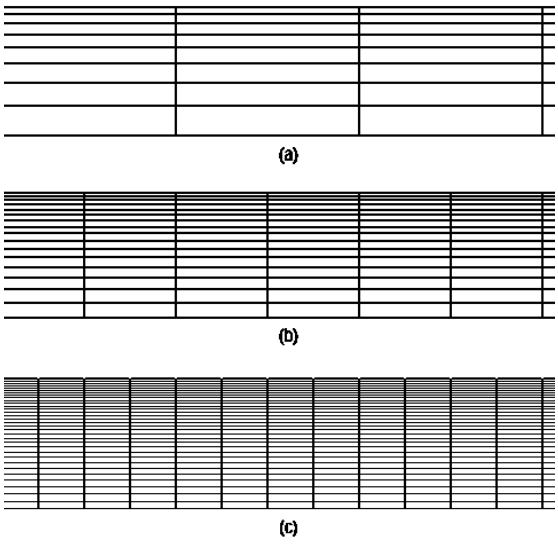
- Simple turbulence model to use for which only initial and/or boundary conditions need to be supplied,
- Excellent performance for many industrially relevant flows, and well established as the most widely validated turbulence model.
- Since the initial and/or boundary conditions are only required, they can

Joe Joseph
2K14/ME/072

be easily extracted from the periodic flow cases with ease

While many variations of the K-Epsilon turbulence model are commonly used, they all derive from the standard K-Epsilon model. In this study, we have taken a step further and opted for the Enhanced Wall Treatment in the K-Epsilon Model.

Enhanced Wall Treatment uses a two-layer model with enhanced wall functions. If the near-wall mesh is fine enough to be able to resolve the laminar sub layer. However, this model demands the refinement of grid near the boundary walls to get more accurate solution.



In ANSYS FLUENT 15.0, near-wall model, the viscosity-affected near-wall region is completely resolved all the way to the viscous sub layer. The two-layer approach is an integral part of the enhanced wall treatment and is used to specify both Epsilon and the turbulent viscosity in the near-wall cells. In this approach, the whole domain is subdivided into a viscosity-affected region and a fully-turbulent region. The demarcation of the two regions is determined by a wall-distance-based, turbulent Reynolds number.

The standard K-Epsilon model uses the following transport equations for the turbulent kinetic energy, k, and turbulent dissipation rate, ϵ, respectively:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho k u_j) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + 2\mu_t S_{ij} S_{ij} - \rho\epsilon$$

$$\frac{\partial}{\partial t}(\rho\epsilon) + \frac{\partial}{\partial x_j}(\rho\epsilon u_j) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial \epsilon}{\partial x_j}\right] + C_{1\epsilon}\frac{\epsilon}{k}2\mu_t S_{ij} S_{ij} - C_{2\epsilon}\rho\frac{\epsilon^2}{k}$$

Where $C_{1\epsilon}$ $C_{2\epsilon}$ C_μ σ_k, and are empirical constants and μ_t, the turbulent viscosity, is modelled as

$$\mu_t = \rho C_\mu \frac{k^2}{\epsilon}$$

CAD DESIGN

Computer Aided Design or CAD for short is the Software generated model of the required object. In this study, the models are taken to be 2 Dimensional due to the axial symmetry that can be assumed in the valves geometries that are being chosen.

The geometries with the labelled dimensions of the Valves employed in this study are:

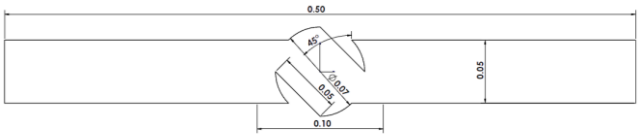


Fig.4: Screen Capture of a Ball Valve with its dimensions specified in (m).

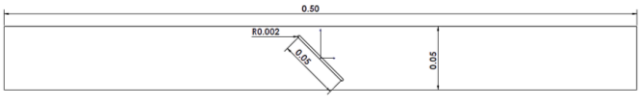


Fig.5: Screen Capture of a Butterfly Valve with its dimensions specified in (m).

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2K14/ME/072

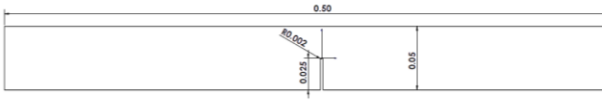


Fig.6: Screen Capture of a Gate Valve with its dimensions specified in (m).

The geometric dimensions to be considered are the pipe length, diameter, valve plate thickness (for Butterfly and Gate Valve) and Ball Diameter (for Ball Valve, which are listed as follows.

Dimension	Value (mm)
Pipe length	500
Pipe diameter	50
Plate thickness	2
Plate edge radius	1
Ball diameter	70.71

Taking these required dimensions and using Solidworks 2015 the models were generated and the surface was saved in .STP (Step file) format.

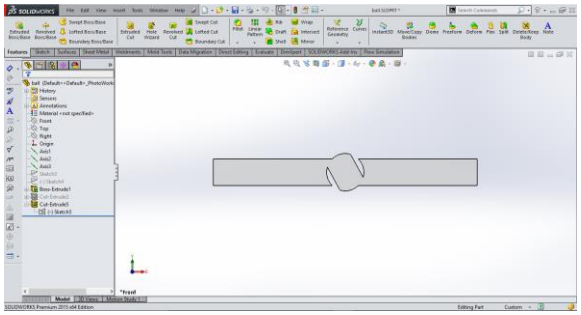


Fig.7: Screen Capture of a Valve being designed in Solidworks 2015.

The generated CAD model was then imported into ANSYS Design Modeller 15.0 and the required surfaces were generated using the Surface from Edge tool and a Face Split tool was used to divide the surface into 3 parts which was necessary for the easy meshing which will be covered in the next subheading.

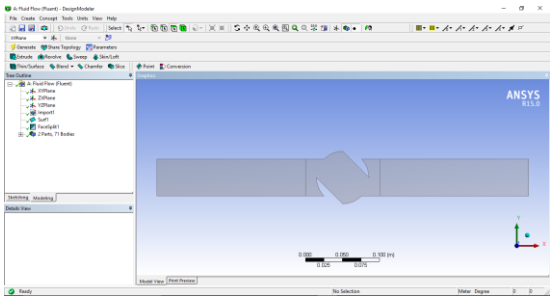


Fig.8: Screen Capture of a Valve being imported and surfaces generated in ANSYS Design Modeller 15.0.

MESHING

Meshing is the process of dividing the model into discrete control volumes to create a grid which represents the Computational domain. The surface mesh represents the entire simulated flow field inside the experimental continuum.

In this Study, A hybrid Grid was made taking into consideration the complex valve geometry and the need for near wall grid Refinement for the better solution of the K-Epsilon -Enhanced Wall Treatment model. A hybrid mesh consists of both structured and unstructured tri/quad cells which are used for their advantages and disadvantages. Structured mesh are better for faster and accurate computation whereas unstructured can be formed in any geometry. Due to advancements in computational methods, hybrid meshes are equally good to obtain accurate results.

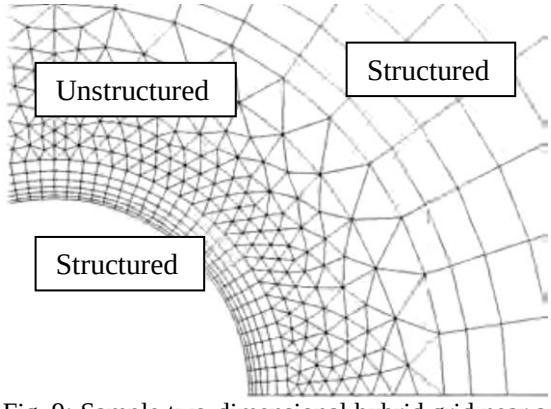


Fig. 9: Sample two-dimensional hybrid grid near a curved surface; two structured regions and one unstructured region are labelled.

Joe Joseph
2K14/ME/072

In this Study ANSYS Meshing 15.0 was used for generating the required mesh. With its user friendly approach to the meshing process, required grids could be easy made.

The process involved importing the geometry and defining the edges with their appropriate names like INLET, OUTLET, WALL and VALVE. These will later represent the boundary conditions of the valve.

Edge sizing tool was used to define the number of cells/elements on the boundary wall (or geometry can be selected too). Since a near wall refinement was needed, a Bias was added to create a smooth transition between the centre and the end of the boundary wall. This Bias was used only for the INLET and OUTLET walls.

The average number of nodes created after mesh generation were 50,000. This degree of refinement was taken to be suitable for the study.

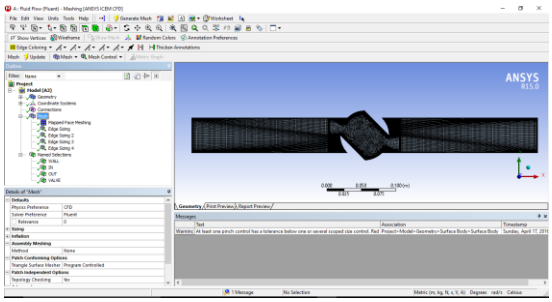


Fig.10: Screen Capture of Valve geometry imported and mesh being generated with its hybrid structured mesh and Named boundary walls in ANSYS Meshing 15.0.

FLUENT SETUP

The solution setup is the easiest process of this study as the required model has been defined, and the boundary conditions have been formulated. For the ease of understanding the following list describes the property and value (input) that was given during the setup process.

Property	Value (Input)
General Solver	Pressure- Based (steady)
Models	Standard K- Epsilon, Enhanced Wall Function
Materials	Air (fluid) Aluminium (solid)
INLET	Velocity-in (10m/s) (Gauge pressure 0 Pa)
OUTLET	Outflow (Gauge pressure 0 Pa)
WALL	Wall (no slip condition)
Solution Methods	SIMPLE
Spatial discretisation	
Gradient	Least Square Cell Based
Pressure	Second Order
Momentum	Second Order Unwind
Turbulent Kinetic Energy	First order Upwind
Turbulence dissipation Rate	First order Upwind
Solution initialisation	Standard (from INLET)

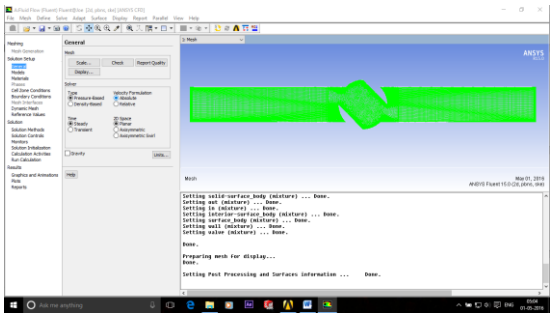


Fig.11: Screen Capture of Valve geometry imported and meshed being generated and ready for CFD setup to be initialised in ANSYS FLUENT 15.0.

Finally the calculation was done and the results were tabulated. The necessary contours of the velocity and relative pressure were obtained using CFD- POST.

Joe Joseph
2K14/ME/072

COMPARISON OF RESULTS

The following are the final results obtained from ANSYS FLUENT 15.0 Solution plots. Appendix D contains the tabulated raw results which were parameters which obtained from the FLUENT solution.

Property	**Description**
Angle (θ)	The opening of the valve (in Degrees)
Percentage Open (%)	The opening of the valve (in percentage)
Inlet Pressure ($P_{u\theta}$)	The gauge Pressure of the inlet boundary (in Pascals)
Outlet Pressure ($P_{d\theta}$)	The gauge Pressure of the outlet boundary (in Pascals)
Velocity (V_{avg})	The velocity magnitude of the outlet boundary (in m/s)
Pressure Loss (ΔP_θ)	The Pressure Loss of the valve for the opening angle (in Pascals)
Head Loss (h_L)	The Pressure head loss of the valve for the opening angle (in meters)
Loss Coefficient (K_θ)	The Loss Coefficient of the valve for opening angle (dimensionless)

BUTTERFLY VALVE

θ	%	$P_{u\theta}$	$P_{d\theta}$	V_{avg}	ΔP_θ	h_L	K_θ
0	4	81.29175294	47.27019749	8.431153137	34.02155545	2.83105997	0.781401278
15	28.84	50.44998265	-6.409035922	8.491935294	56.85901858	4.73145009	1.287300428
30	52	36.34174255	-149.9191631	8.492676863	186.2609057	15.4994617	4.216250614
45	71.88	1078.849229	150.2088558	8.433704706	928.6403736	77.2756141	21.31594969
60	87.12	27.69412941	-3360.858235	8.423782941	3388.552364	281.974026	77.96393897
75	96.72	13.58841961	-45814.40195	8.429008824	45827.99037	3813.51727	1053.105069

BALL VALVE

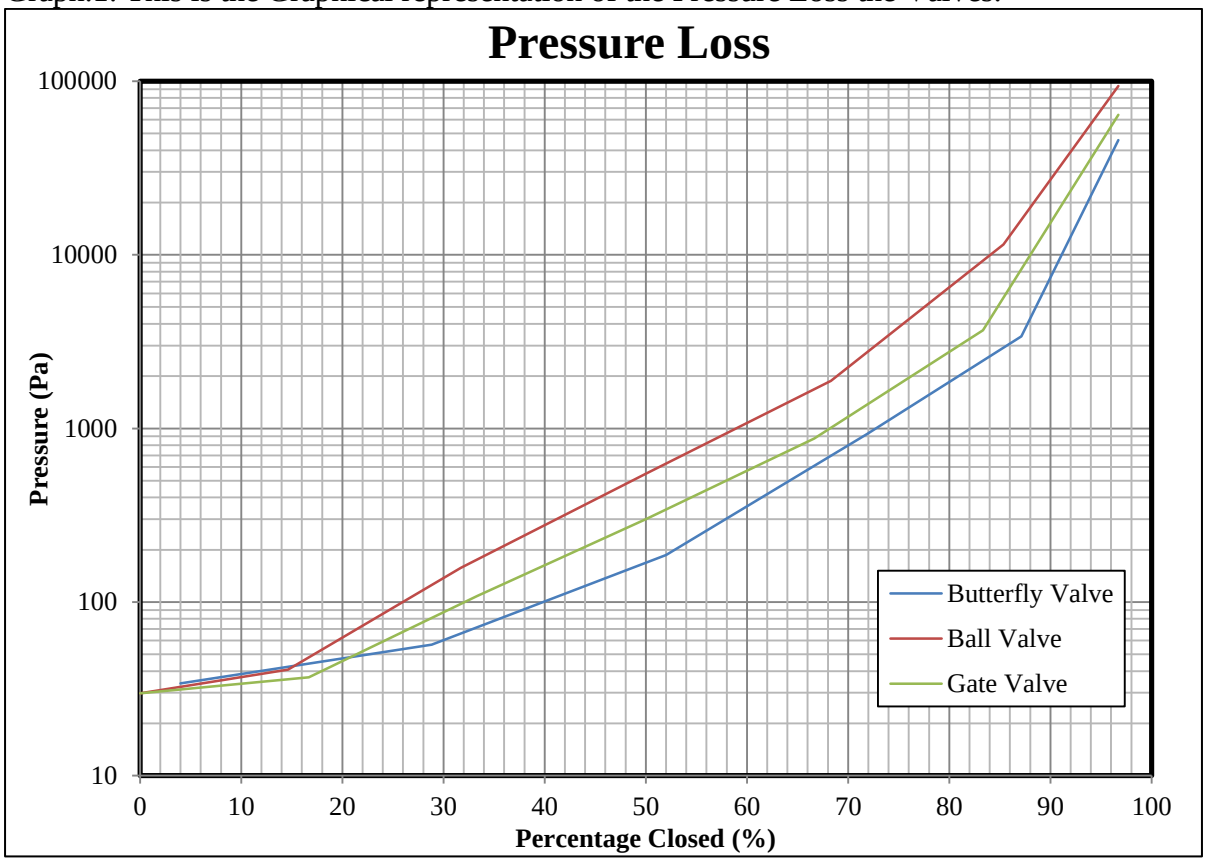
θ	%	$P_{u\theta}$	$P_{d\theta}$	V_{avg}	ΔP_θ	h_L	K_θ
0	0	66.36177902	36.51574171	7.51810949	29.84603731	2.4835996	0.10765405
15	14.64	87.21264118	46.47397845	8.436843725	40.73866273	3.39001541	0.116683043
30	31.7	212.007502	54.76280257	8.429708039	157.2446994	13.0849154	0.451140625
45	50	663.7846529	115.0070624	8.42408549	548.7775905	45.6658213	1.5765648
60	68.3	1826.664514	-48.60270016	8.42493098	1875.267214	156.047949	5.38631125
75	85.36	7342.707455	-4131.658827	8.425577255	11474.36628	954.82463	32.95265166
84.23	96.72	42185.66085	-51398.32938	8.427972941	93583.99023	7787.47136	268.6063539

GATE VALVE

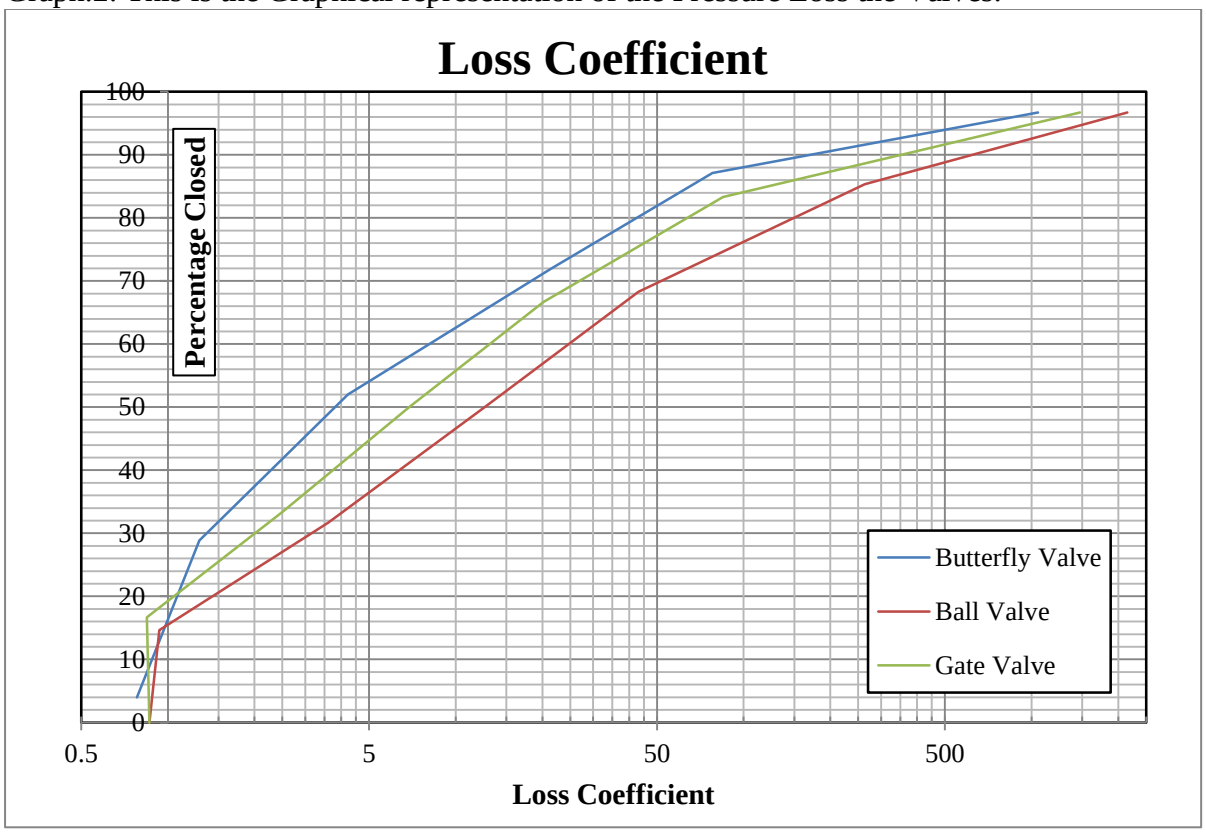
θ	%	$P_{u\theta}$	$P_{d\theta}$	V_{avg}	ΔP_θ	h_L	K_θ
0	0	66.36177902	36.51574171	7.51810949	29.84603731	2.4835996	0.10765405
15	16.666	96.81719608	59.95401416	8.433196078	36.86318192	3.06752226	0.105674308
30	33.33	180.7179588	72.39112333	8.427569412	108.3268355	9.01427827	0.310951294
45	50	596.9770961	296.8251426	8.423492549	300.1519535	24.9767587	0.862417917
60	66.66	120.1894078	-756.4868419	8.420239804	876.6762497	72.9514864	2.520874987
75	83.3333	82.64274314	-3593.232543	8.417021373	3675.875286	305.883233	10.57803249
87.048	96.72	64022.69317	118.6861561	8.418845882	63904.00702	5317.68974	183.8162748

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Graph.1: This is the Graphical representation of the Pressure Loss the Valves.



Graph.2: This is the Graphical representation of the Pressure Loss the Valves.



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CONCLUSION

After the compilation of the results and extensive study on the valve's manufacturing and operational ease, it was determined that the most suitable valve for this scenario was the Butterfly valve. The reasons for option this valve was as follows:

1. Lesser Pressure Loss and head Loss for same opening angle as compared to the other Ball Valve and Gate Valve.
2. Lesser Loss Coefficients for same opening angle as compared to the other Ball Valve and Gate Valve.
3. Ease of operation with better response time and ease of manufacturing and maintenance the Butterfly valve as compared to the ball valve and gate valve.

After studying the Flow Visuals of the Velocity and Pressure contours, it was understood why the results were as stated above. The Butterfly valve at any opening angle does not form large violent Turbulence Eddies after the fluid has encountered valve. This is due to the geometry of the Butterfly Valve Plate, unlike the gate valve and ball valve. These valves don't have a gradual increase in area of cross section and this causes the flow to suddenly expand and cause Eddies which are not desirable. The Ball Valve has two locations where there is a sudden change in the area hence this sudden expansion and contraction causes the minor losses to be significantly higher than the gate and butterfly valve.

As a closing remark, it can be said that, Computational fluid dynamics continues to be an impressive tool in helping model real world problems. However, it has its limitations which are mainly centred in turbulence modelling. It is worth noting however, that despite the relative differences that may occur between the simulated and experimental values, CFD simulations can be used to predict values on or near the same order of magnitude and range of the real life values one is seeking. This can be especially useful if experimental models are not available.

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APPENDIX A

This appendix provides additional details regarding the specific options and parameters of the ANSYS FLUENT 15.0 meshing models used in this study. Additional information is available in the ANSYS FLUENT 15.0 user's manual.

The discretization of the flow domain is carried out with 2D quadrilateral elements. A structured hybrid mesh has chosen for the analysis. The region around the valve disc has been meshed with a very fine hybrid mesh structure, so that the flow details are captured accurately, the rest of the pipe consisted of a highly structured mesh for quicker computational time and accurate results.

Here are the meshes that were generated using the ANSYS Workbench software and screen captured in ANSYS CFD-Post.



Scale for measure

BUTTERFLY VALVE

The following are the meshes generated for the Butterfly Valve at different valve opening (in degrees).

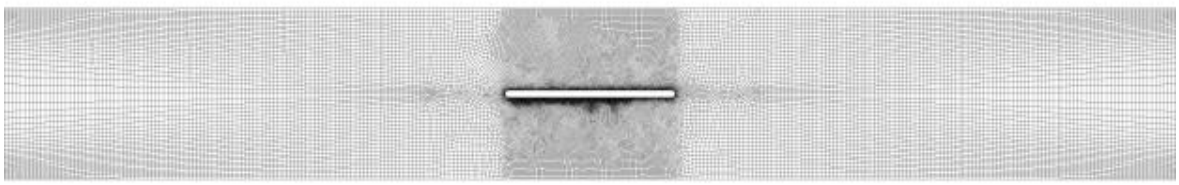


Fig.A.1: Generated Mesh for Butterfly Valve open at 0°.

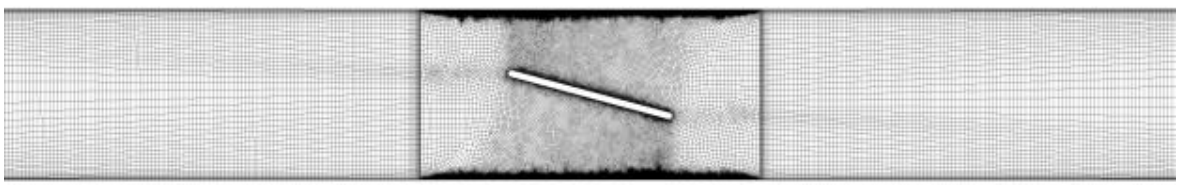


Fig.A.2: Generated Mesh for Butterfly Valve open at 15°.

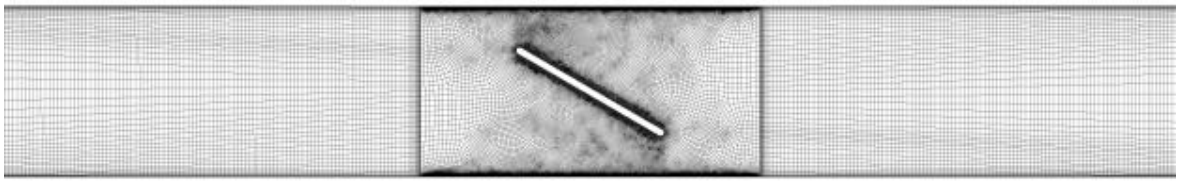


Fig.A.3: Generated Mesh for Butterfly Valve open at 30°.

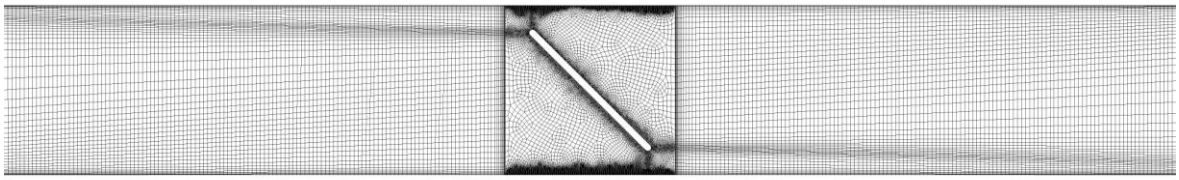


Fig.A.4: Generated Mesh for Butterfly Valve open at 45°.

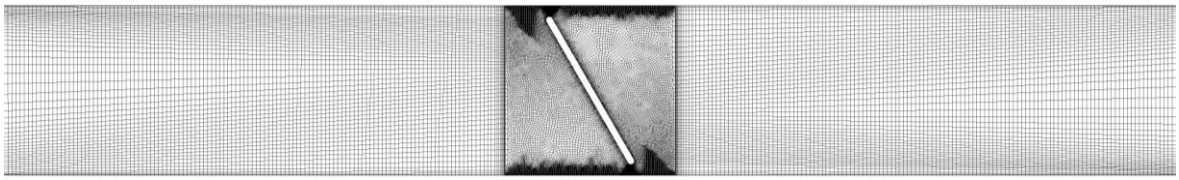


Fig.A.5: Generated Mesh for Butterfly Valve open at 60°.

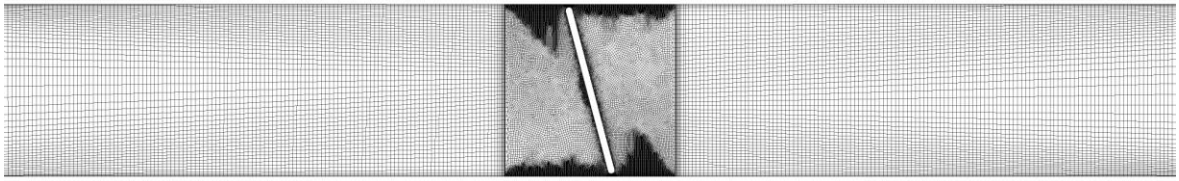


Fig.A.6: Generated Mesh for Butterfly Valve open at 75°.

GATE VALVE

The following are the meshes generated for the Gate Valve at different valve opening (in percentage).

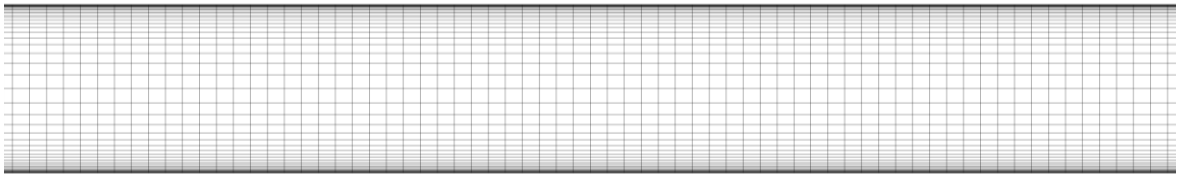


Fig.A.7: Generated Mesh for Gate Valve open at 0%.

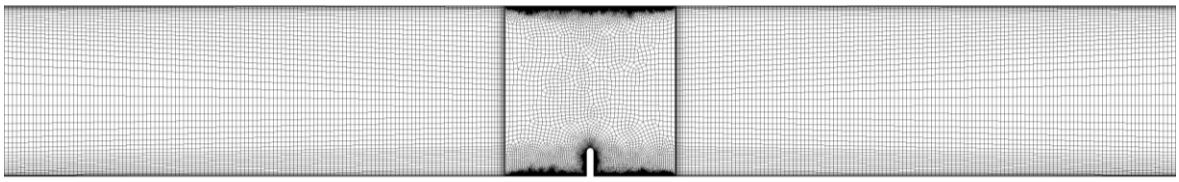


Fig.A.8: Generated Mesh for Gate Valve open at 16.67%.

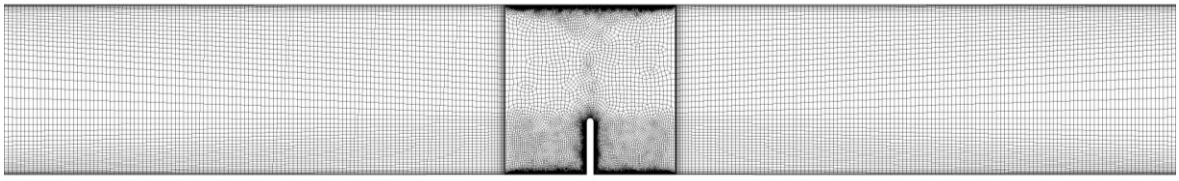


Fig.A.9: Generated Mesh for Gate Valve open at 33.34%.

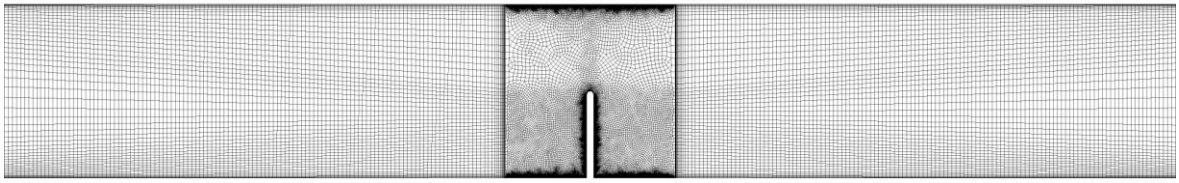


Fig.A.10: Generated Mesh for Gate Valve open at 50%.

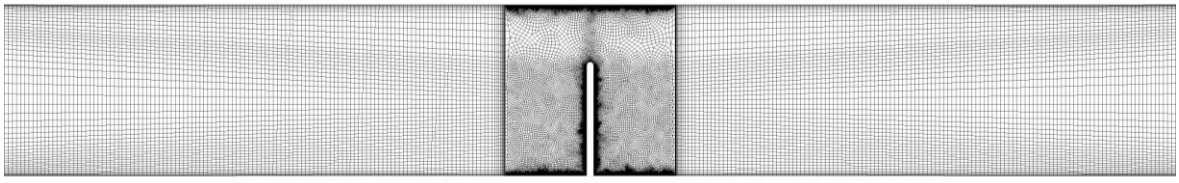


Fig.A.11: Generated Mesh for Gate Valve open at 66.64%.

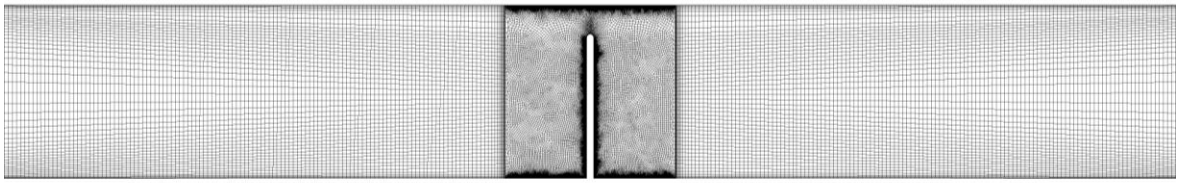


Fig.A.12: Generated Mesh for Gate Valve open at 83.34%.

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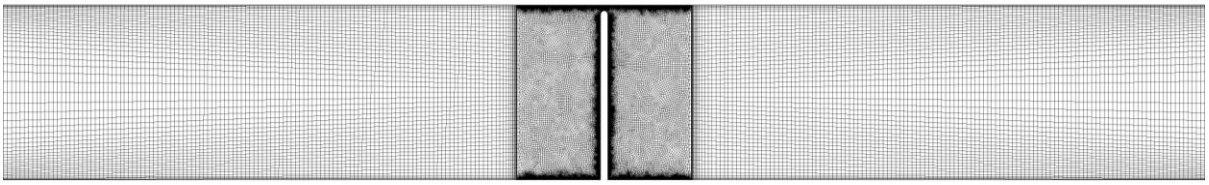


Fig.A.13: Generated Mesh for Gate Valve open at 96.72%.

BALL VALVE

The following are the meshes generated for the Ball Valve at different valve opening (in percentages).

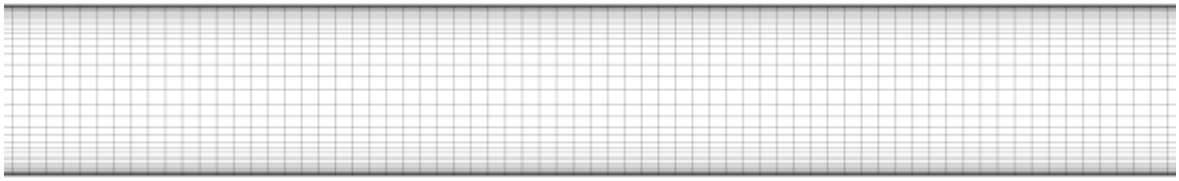


Fig.A.14: Generated Mesh for Ball Valve open at 0%.

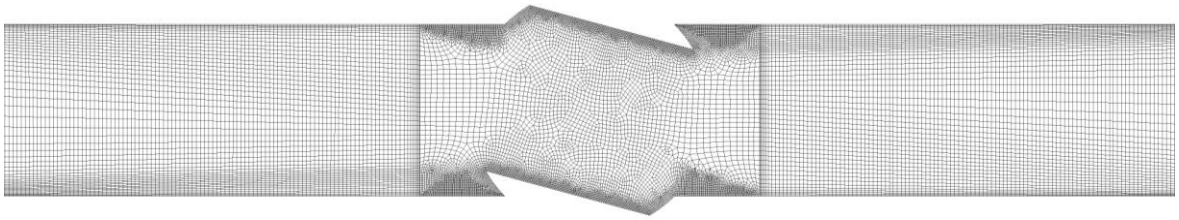


Fig.A.15: Generated Mesh for Ball Valve open at 14.64%.

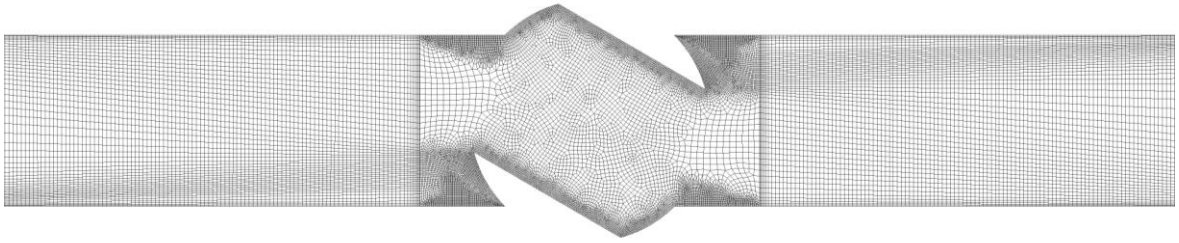


Fig.A.16: Generated Mesh for Ball Valve open at 31.7%.

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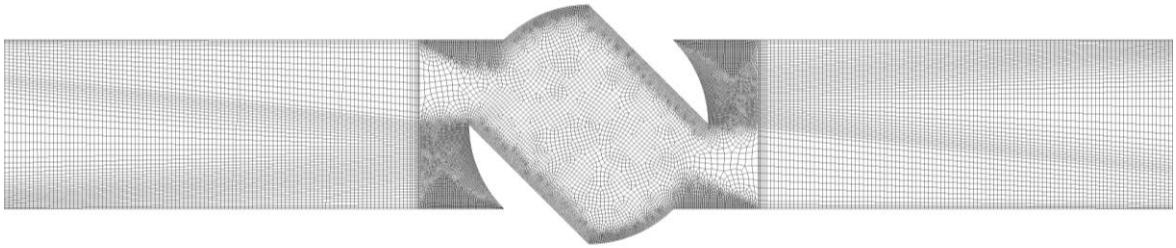


Fig.A.17: Generated Mesh for Ball Valve open at 50%.

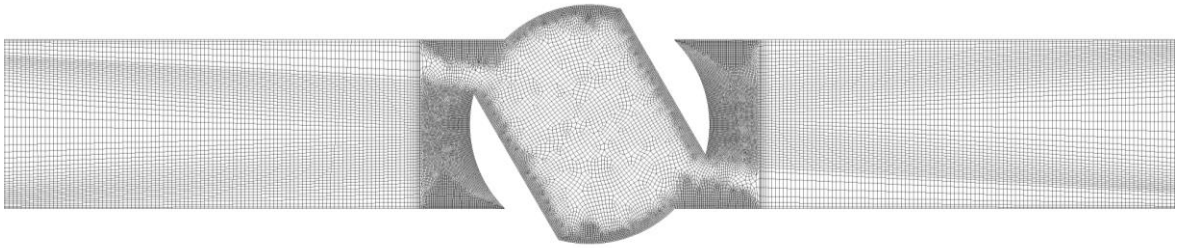


Fig.A.18: Generated Mesh for Ball Valve open at 68.3%.

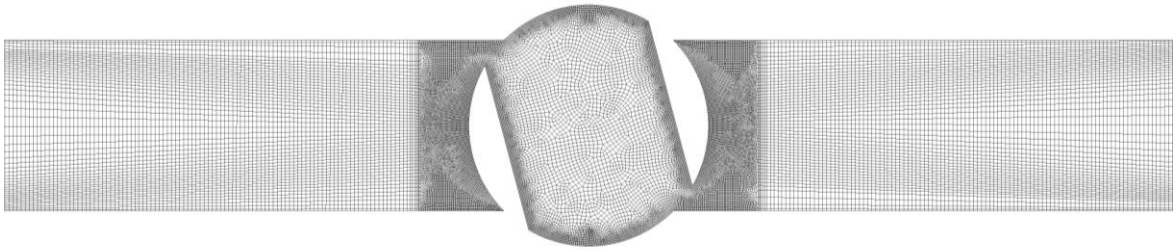


Fig.A.19: Generated Mesh for Ball Valve open at 85.36%

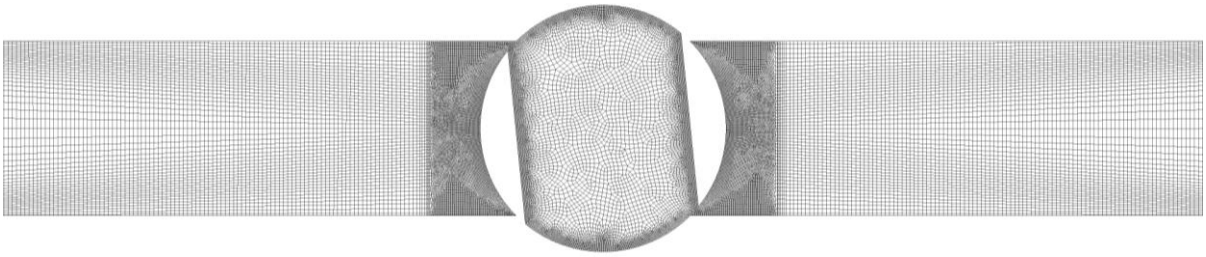


Fig.A.20: Generated Mesh for Ball Valve open at 96.72%

APPENDIX B

ANSYS FLUENT 15.0

ANSYS FLUENT is a state-of-the-art computer program for modelling fluid flow, heat transfer, and chemical reactions in complex geometries.

ANSYS FLUENT is written in the C computer language and makes full use of the flexibility and power offered by the language. Consequently, true dynamic memory allocation, efficient data structures, and flexible solver control are all possible.

In addition, ANSYS FLUENT uses a client/server architecture, which enables it to run as separate simultaneous processes on client desktop workstations and powerful computer servers. This architecture allows for efficient execution, interactive control, and complete flexibility between different types of machines or operating systems.

ANSYS FLUENT provides complete mesh flexibility, including the ability to solve your flow problems using unstructured meshes that can be generated about complex geometries with relative ease. Supported mesh types include 2D triangular/quadrilateral, 3D tetrahedral/ hexahedral/ pyramid/ wedge/ polyhedral, and mixed (hybrid) meshes.

ANSYS FLUENT also enables you to refine or coarsen your mesh based on the flow solution. After a mesh has been read into ANSYS FLUENT, all remaining operations are performed within ANSYS FLUENT. These include setting boundary conditions, defining fluid properties, executing the solution, refining the mesh, and post processing and viewing the results.

The ANSYS FLUENT serial solver manages file input and output, data storage, and flow field calculations using a single solver process on a single computer.

ANSYS FLUENT also uses a utility called cortex that manages ANSYS FLUENT's user interface and basic graphical functions.

ANSYS FLUENT's parallel solver enables you to compute a solution using multiple processes that may be executing on the same computer, or on different computers in a network.

Parallel processing in ANSYS FLUENT involves an interaction between ANSYS FLUENT, a host process, and a set of compute-node processes.

ANSYS FLUENT interacts with the host process and the collection of compute nodes using the cortex user interface utility.

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PROGRAM CAPABILITIES

The ANSYS FLUENT solver has the following modelling capabilities:

- 2D planar, 2D axisymmetric, 2D axisymmetric with swirl (rotationally symmetric), and 3D flows
- Quadrilateral, triangular, hexahedral (brick), tetrahedral, prism (wedge), pyramid, polyhedral, and mixed element meshes
- Steady-state or transient flows
- Incompressible or compressible flows, including all speed regimes (low subsonic, transonic, supersonic, and hypersonic flows)
- Inviscid, laminar, and turbulent flows
- Newtonian or non-Newtonian flows
- Ideal or real gases
- Heat transfer, including forced, natural, and mixed convection, conjugate (solid/fluid) heat transfer, and radiation
- Chemical species mixing and reaction, including homogeneous and heterogeneous combustion models and surface deposition/reaction models
- Free surface and multiphase models for gas-liquid, gas-solid, and liquid-solid flows
- Lagrangian trajectory calculation for dispersed phase (particles/droplets/bubbles), including coupling with continuous phase and spray modelling
- Cavitation model
- Phase change model for melting/solidification applications
- Porous media with non-isotropic permeability, inertial resistance, solid heat conduction, and porous face pressure jump conditions
- Lumped parameter models for fans, pumps, radiators, and heat exchangers
- Acoustic models for predicting flow-induced noise
- Inertial (stationary) or non-inertial (rotating or accelerating) reference frames
- Multiple reference frame (MRF) and sliding mesh options for modelling multiple moving frames
- Mixing-plane model for modelling rotor-stator interactions, torque converters, and similar turbo machinery applications with options for mass conservation and swirl conservation
- Dynamic mesh model for modeling domains with moving and deforming mesh
- Volumetric sources of mass, momentum, heat, and chemical species
- Material property database
- Extensive customization capability via user-defined functions
- Dynamic (two-way) coupling with GT-Power and WAVE

APPENDIX C

CFD Flow Visualizations

This appendix provides a visual representation of the flow field for the absolute Velocity and Relative Pressure (gauge Pressure) for the different valves, Butterfly, Ball and Gate Valve, for every valve opening angle simulated, presented in the 2 Dimensional side view as it was simulated. An accurate range alongside the colour legend is also represented in the screen captures with the minimum and maximum values also being specified. ANSYS CFD-Post 15.0 provided with the screen captures of the Velocity and Pressure contours. The Velocity contours are shown in Fig.B.1 - Fig.B-20 and the Pressure contours are shown in Fig.B.21 – Fig.B.40.

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VELOCITY CONTOURS

BUTTERFLY VALVE

The following are the velocity contours generated for the Butterfly Valve at different valve opening (in degrees)



Fig C.1: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 0 degree open case.

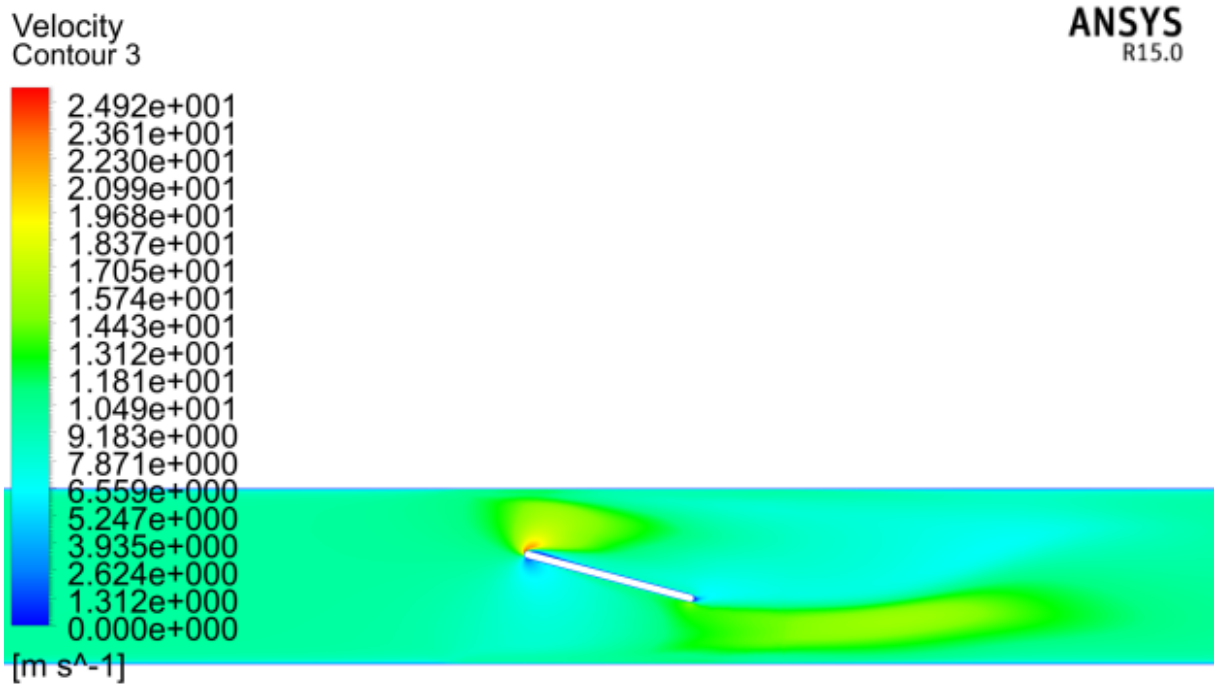


Fig C.2: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 15 degree open case.

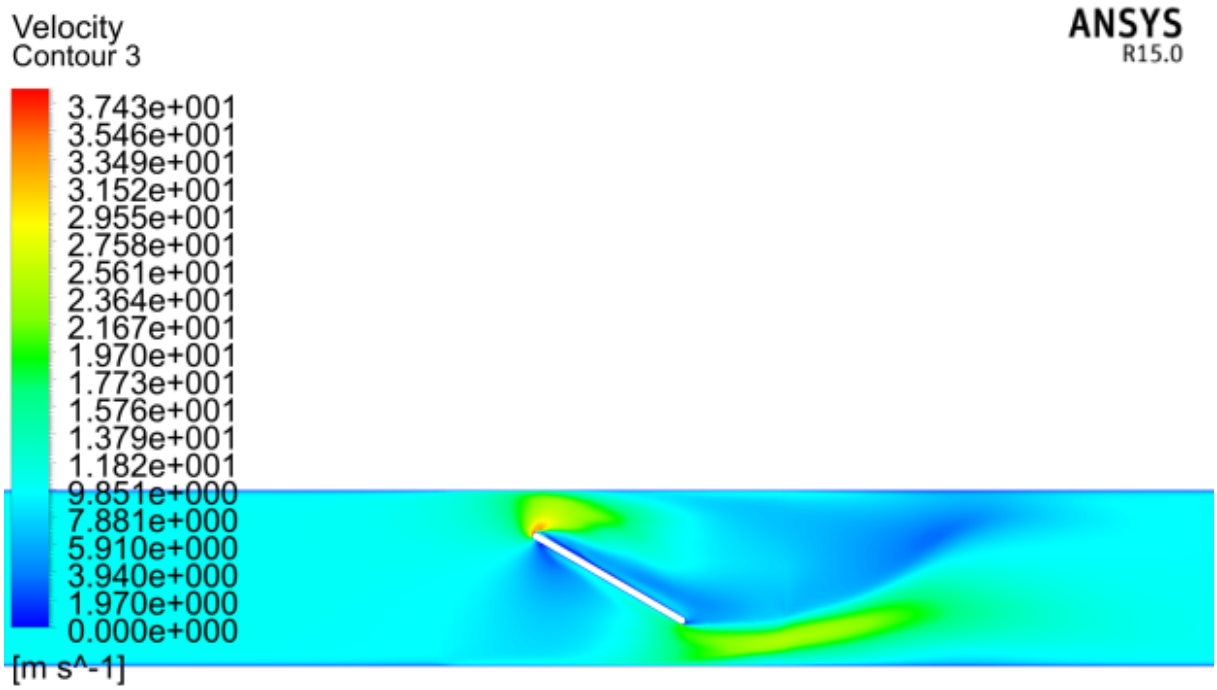


Fig C.3: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 30 degree open case.

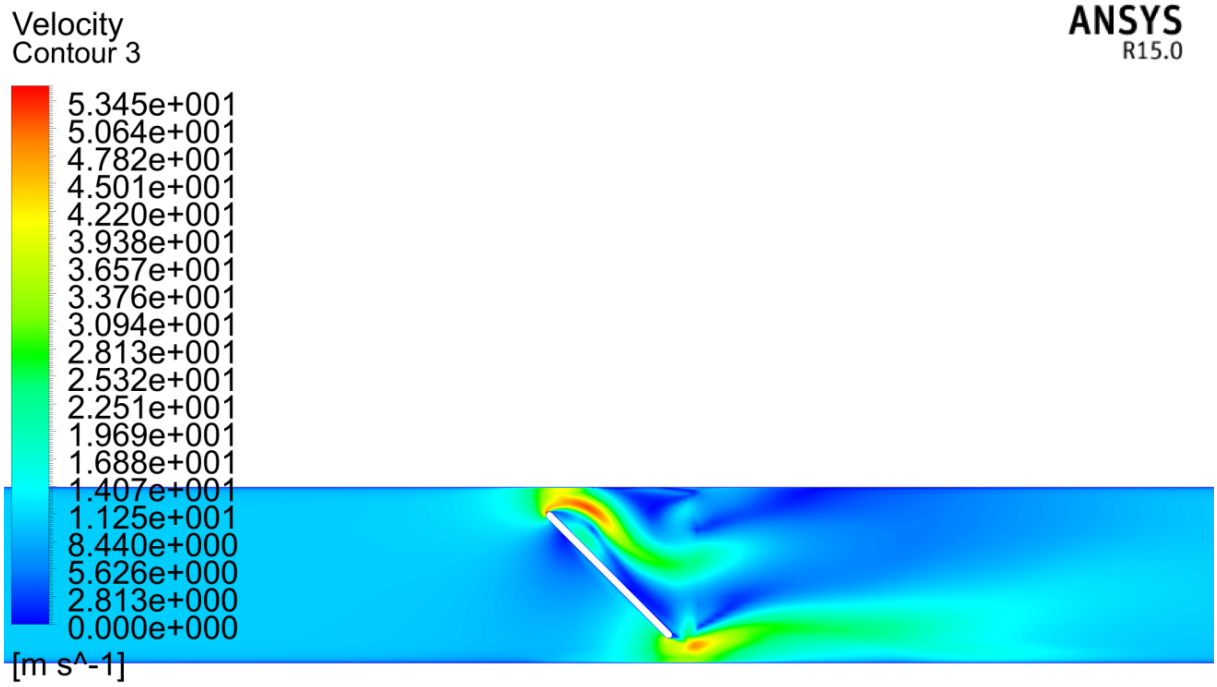


Fig C.4: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 45 degree open case.

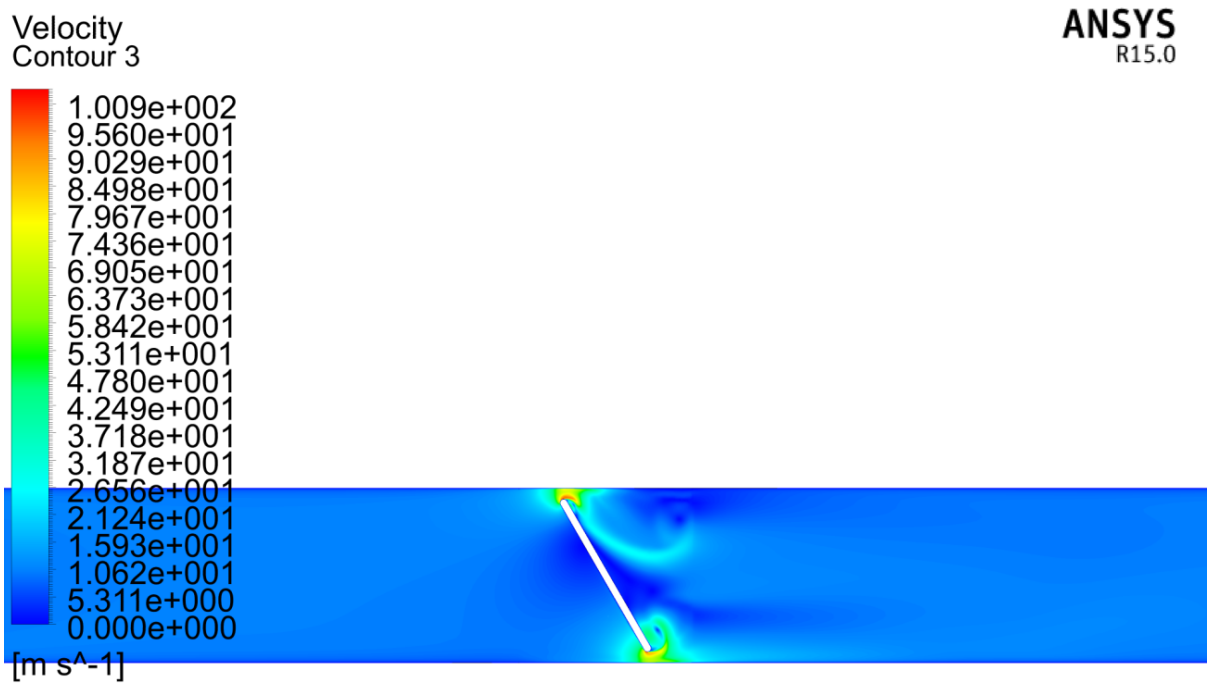


Fig C.5: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 60 degree open case.

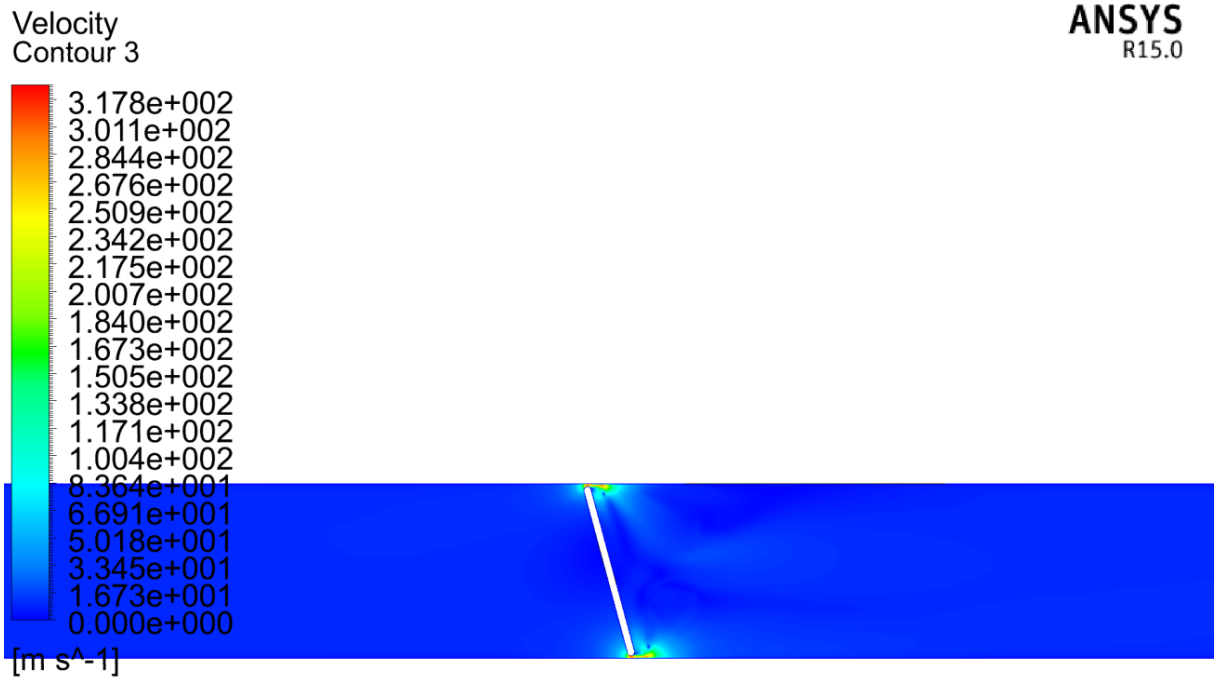


Fig C.6: Detailed View of Velocity contours across the entire fluid domain of a Butterfly Valve for 75 degree open case.

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Ball Valve

The following are the velocity contours generated for the Ball Valve at different valve opening (in percentage)

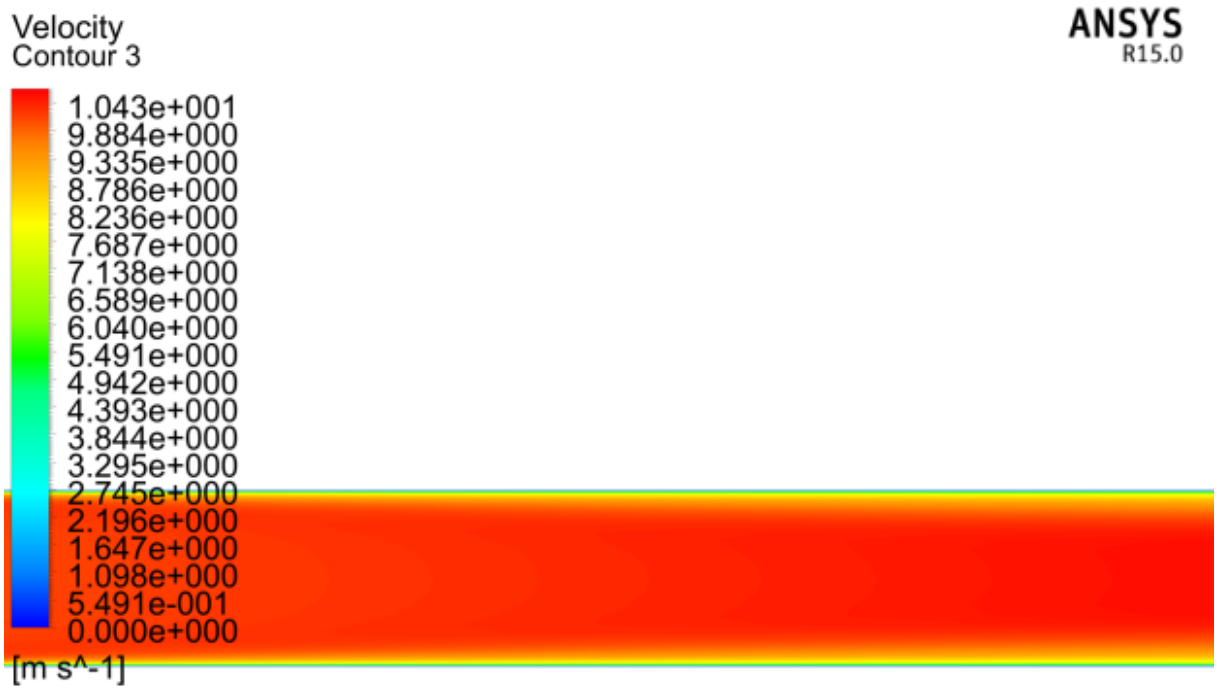


Fig C.7: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 0 percentage open case.

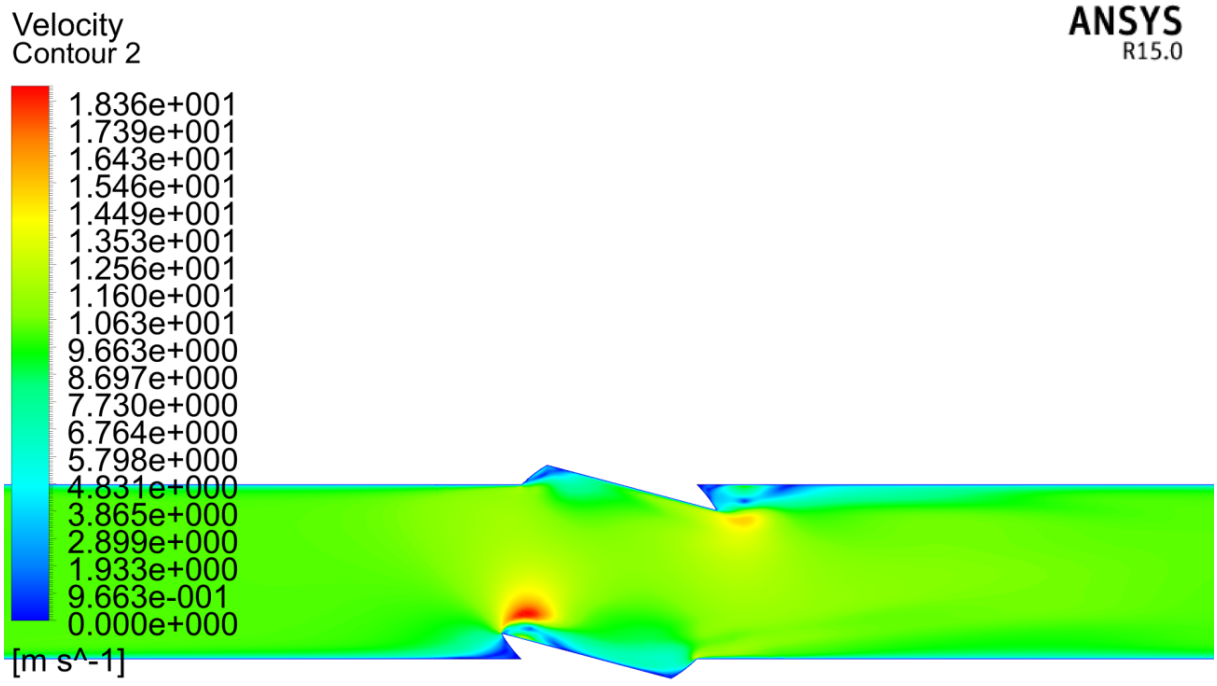


Fig C.8: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 14.64 percentage open case.

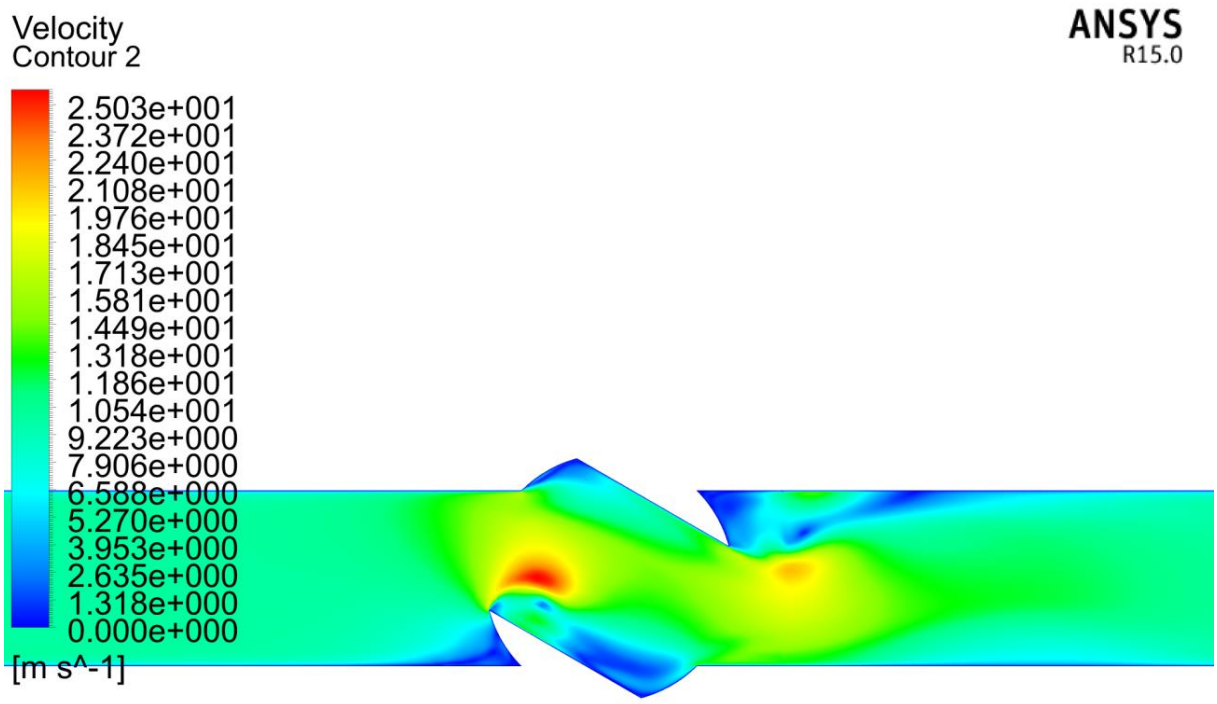


Fig C.9: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 31.7 percentage open case.

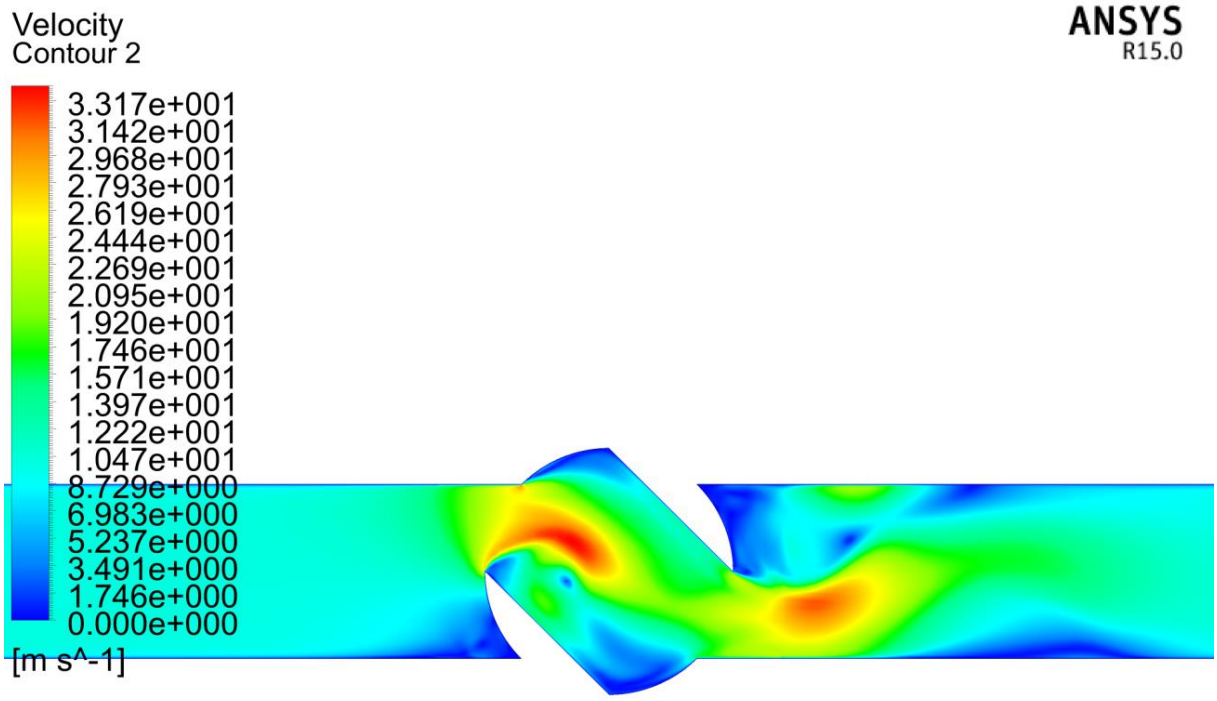


Fig C.10: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 50 percentage open case.

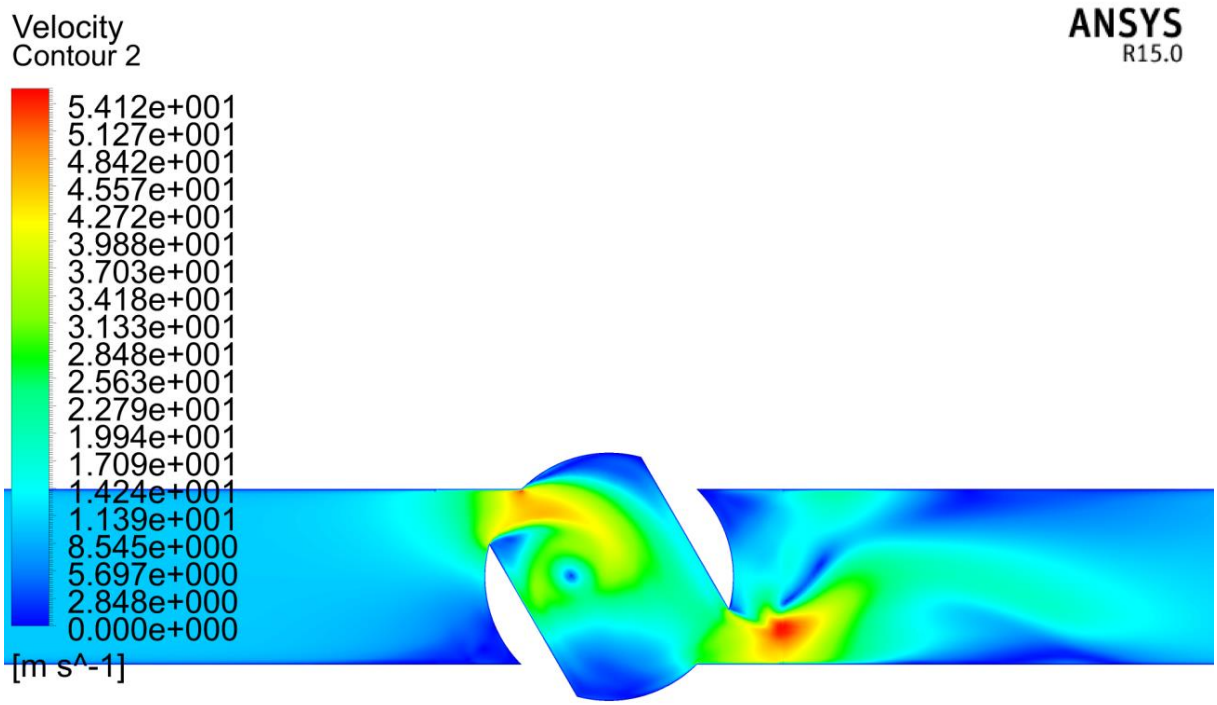


Fig C.11: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 68.3 percentage open case.

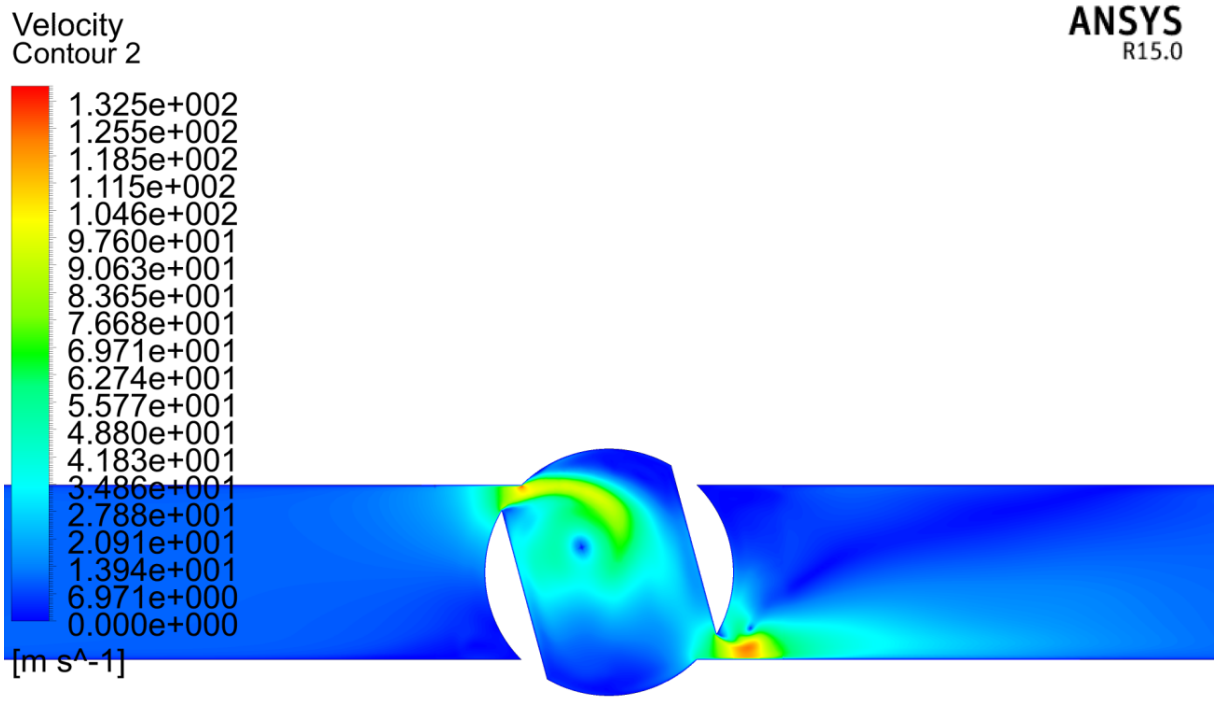


Fig C.12: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 85.36 percentage open case.

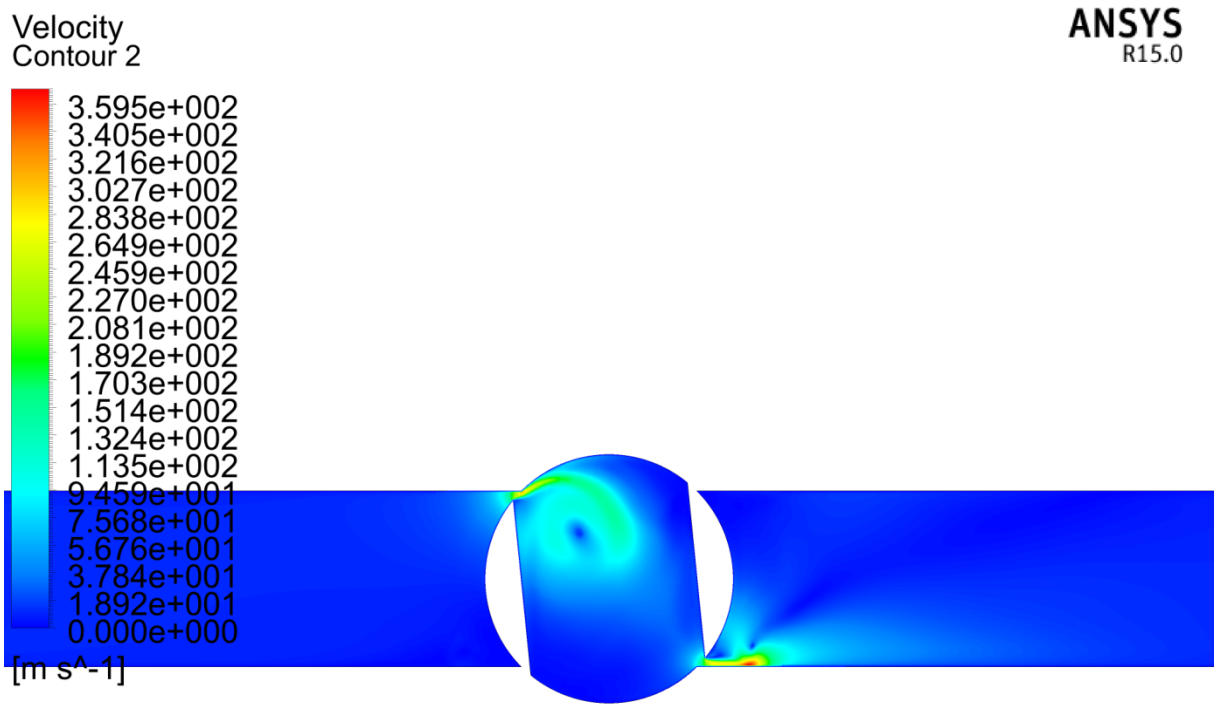


Fig C.13: Detailed View of Velocity contours across the entire fluid domain of a Ball Valve for 96.72 percentage open case.

GATE VALVE

The following are the velocity contours generated for the Gate Valve at different valve opening (in percentage)

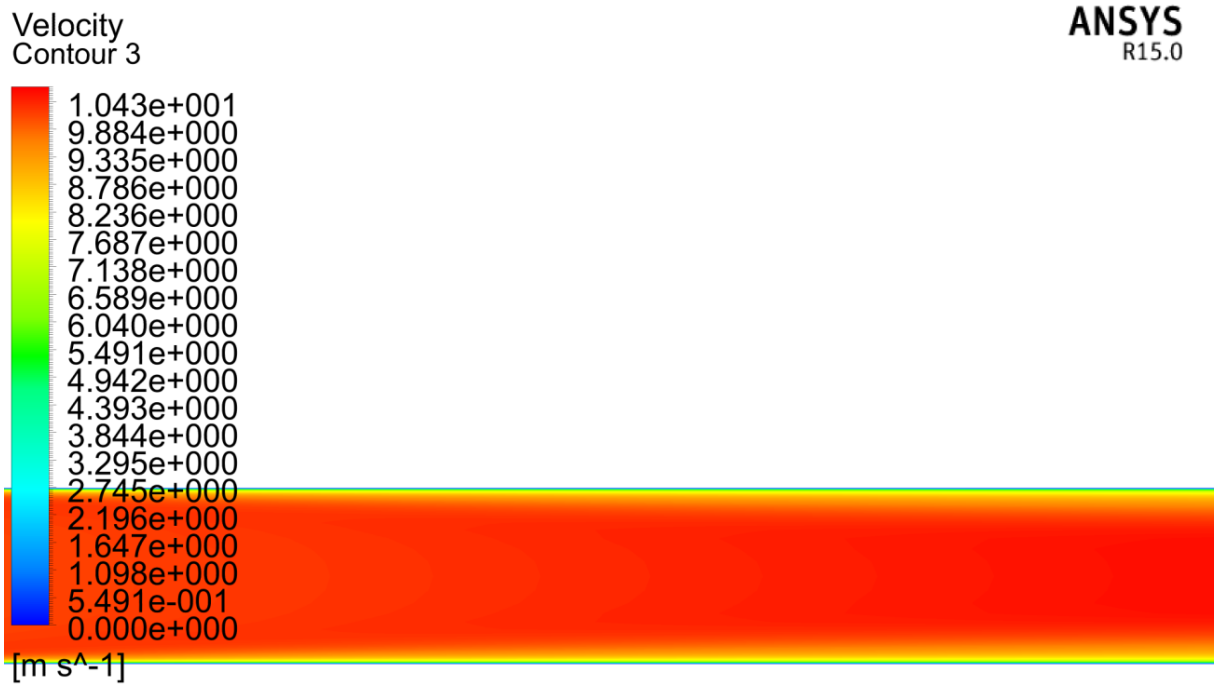


Fig C.14: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 0 percentage open case.

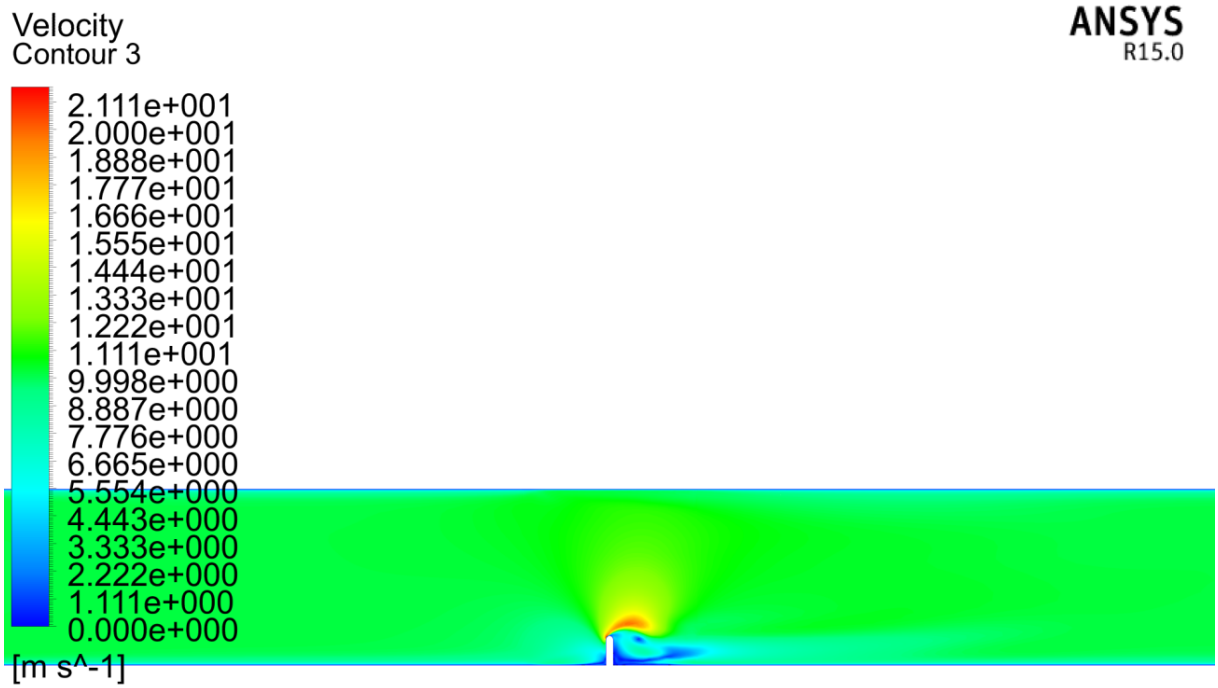


Fig C.15: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 16.67 percentage open case.

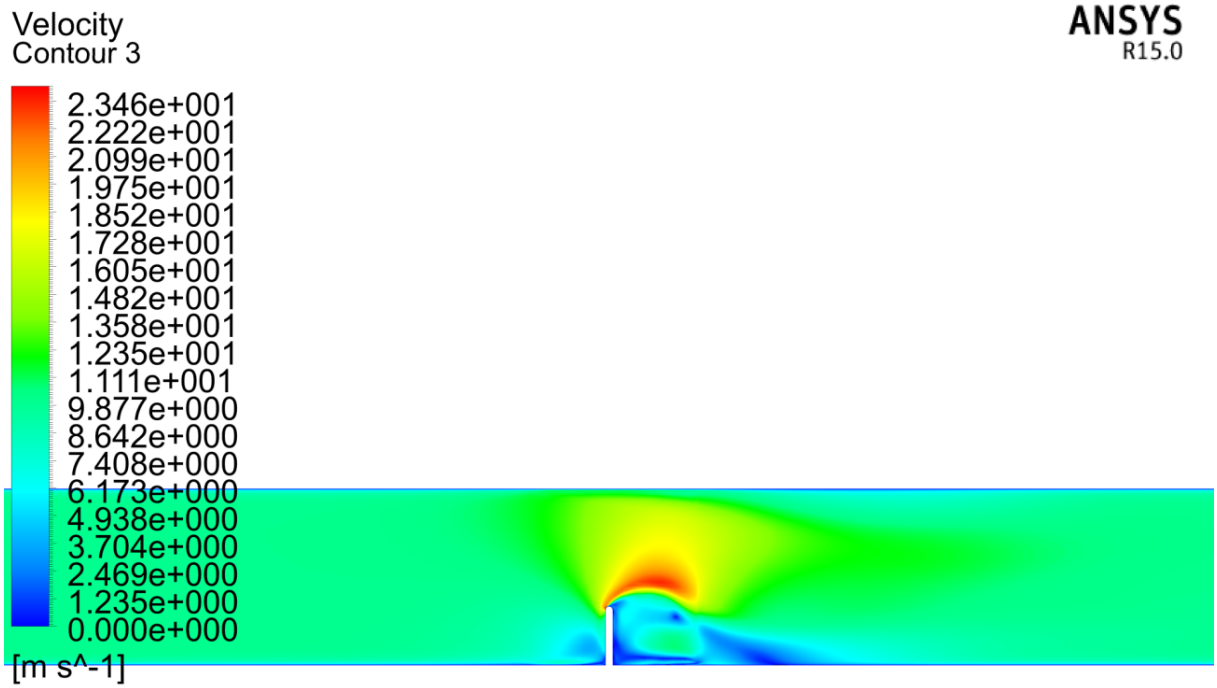


Fig C.16: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 33.34 percentage open case.

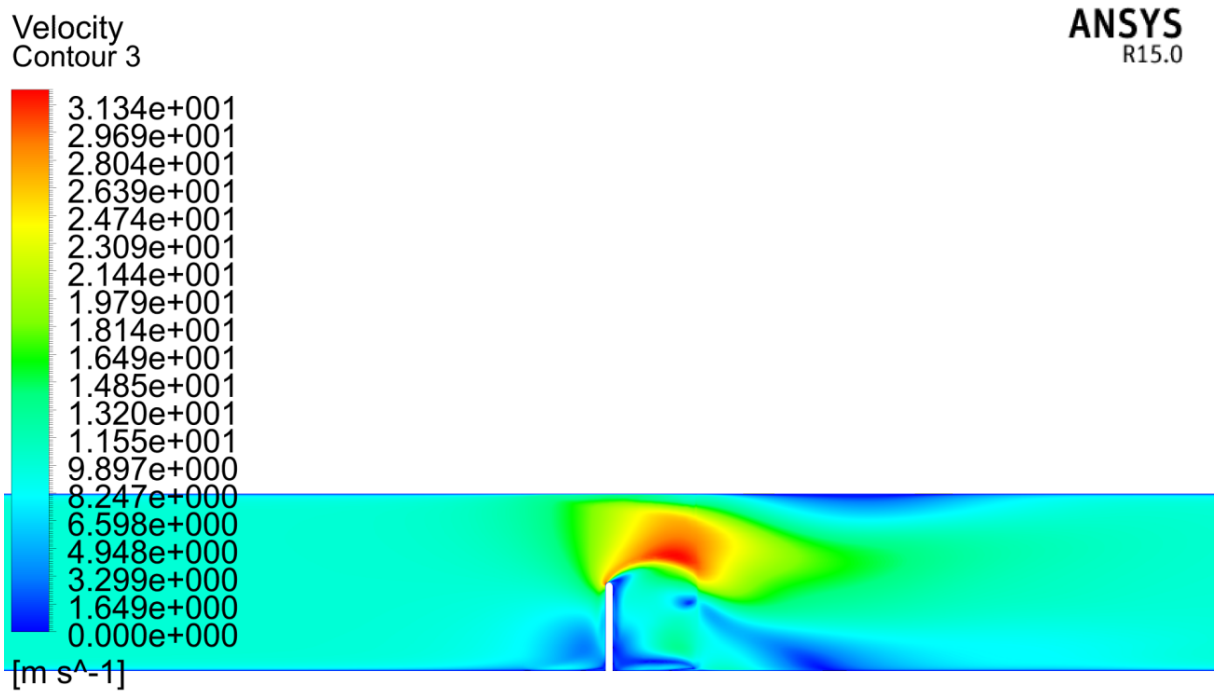


Fig C.17: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 50 percentage open case.

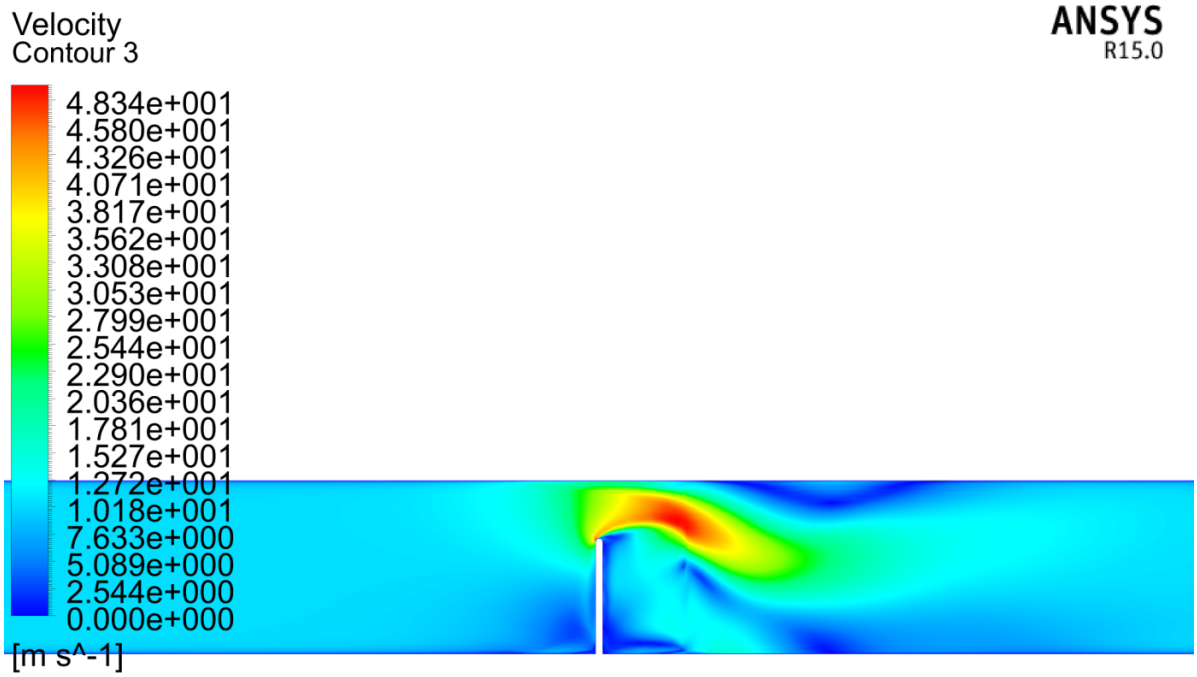


Fig C.18: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 66.67 percentage open case.

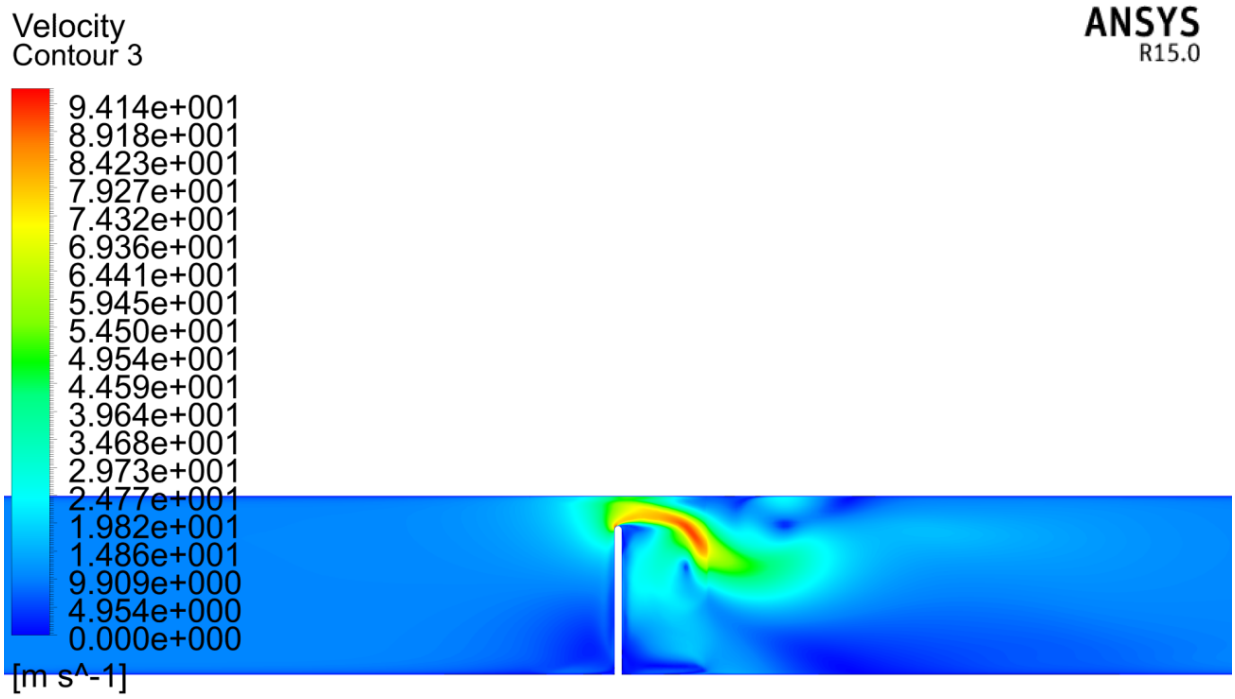


Fig C.19: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 83.34 percentage open case.

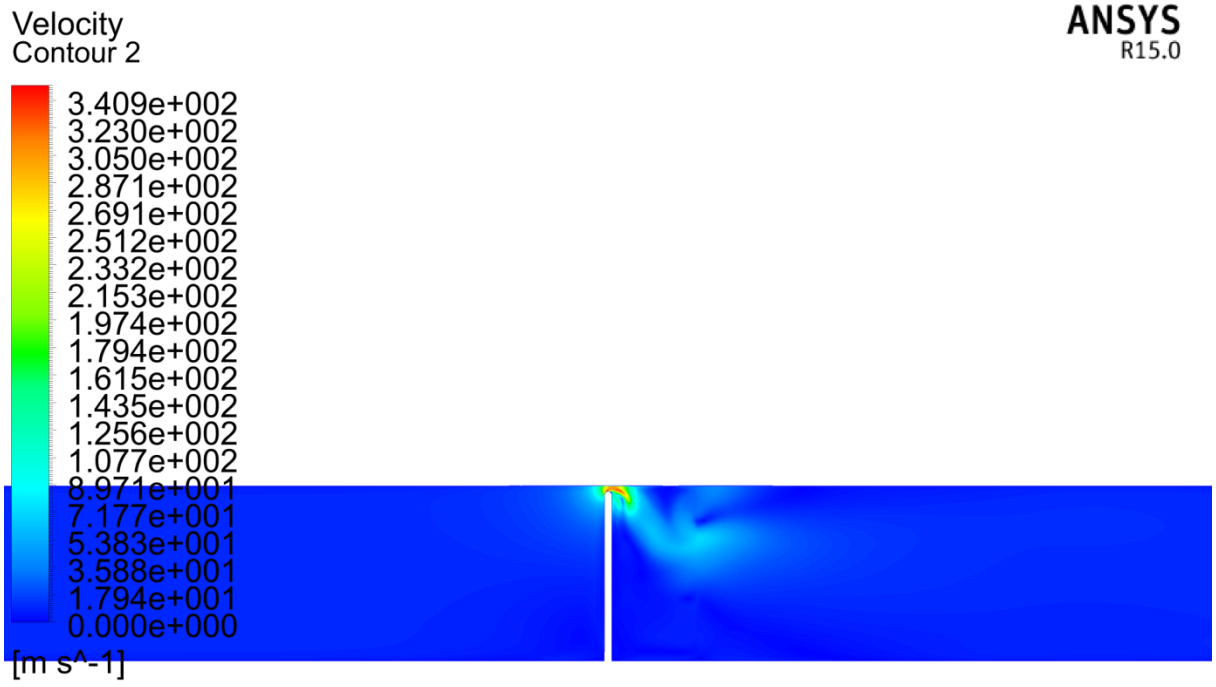


Fig C.20: Detailed View of Velocity contours across the entire fluid domain of a Gate Valve for 96.72 percentage open case.

PRESSURE CONTOURS

BUTTERFLY VALVE

The following are the Relative Pressure (Gauge) contours generated for the Butterfly Valve at different valve opening (in degrees)



Fig C.21: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 0 degree open case.

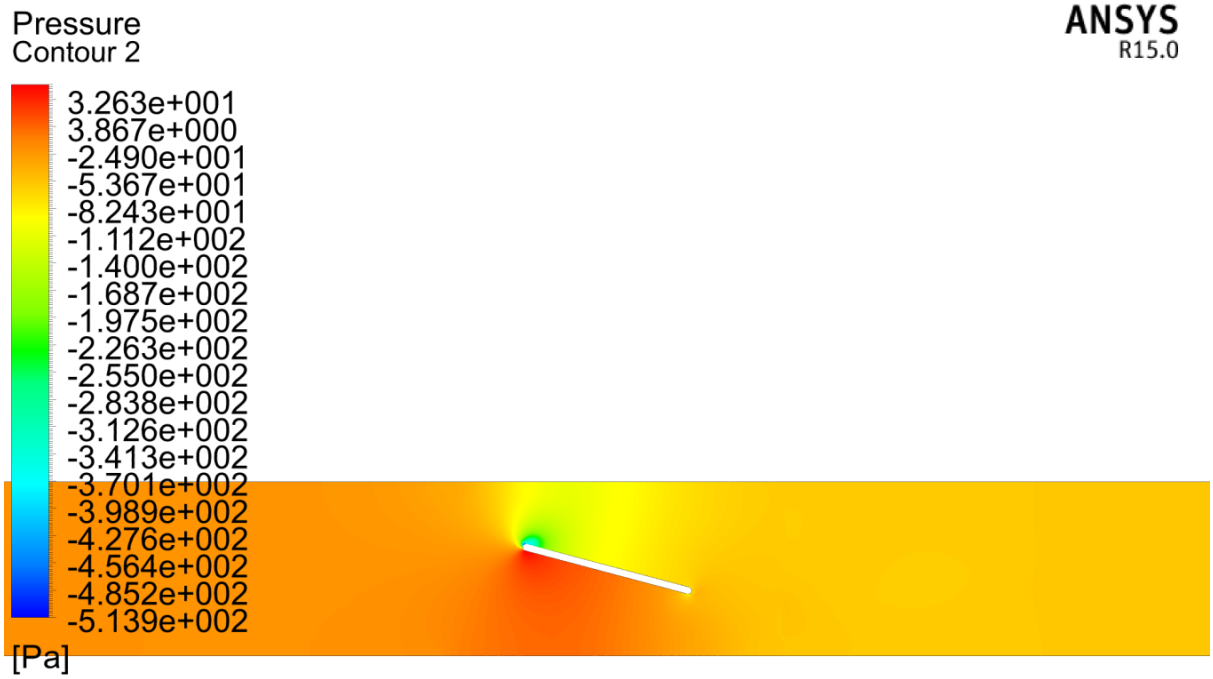


Fig C.22: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 15 degree open case.



Fig C.23: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 30 degree open case.

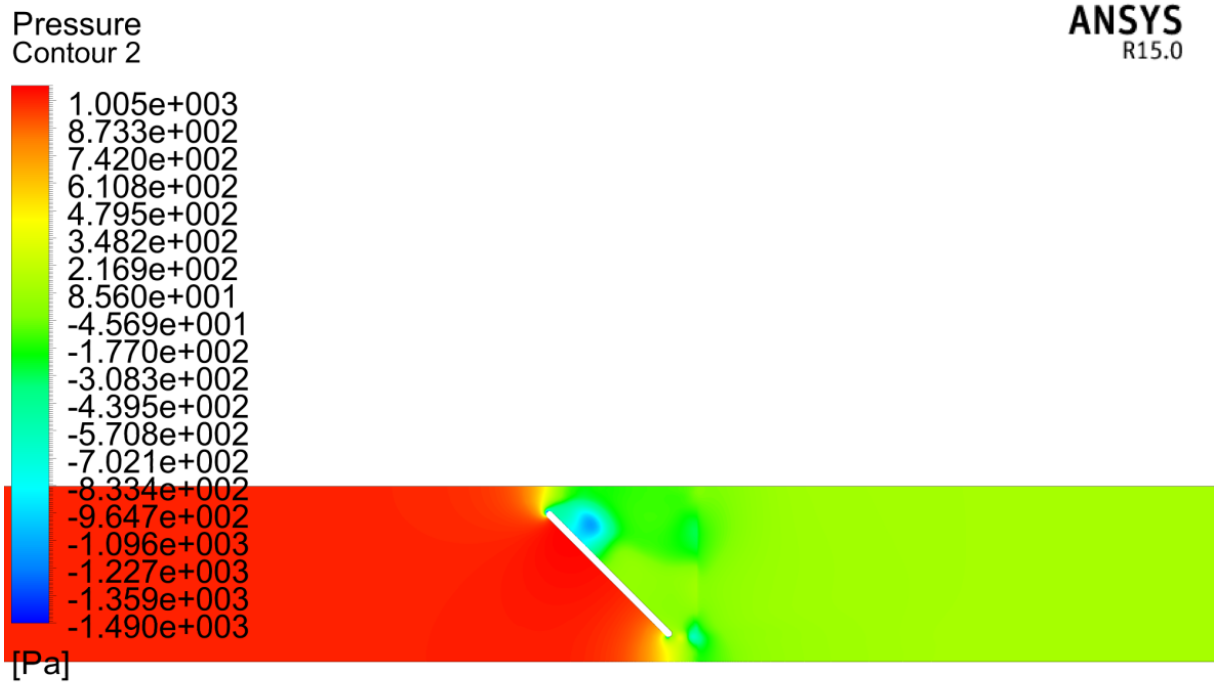


Fig C.24: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 45 degree open case.

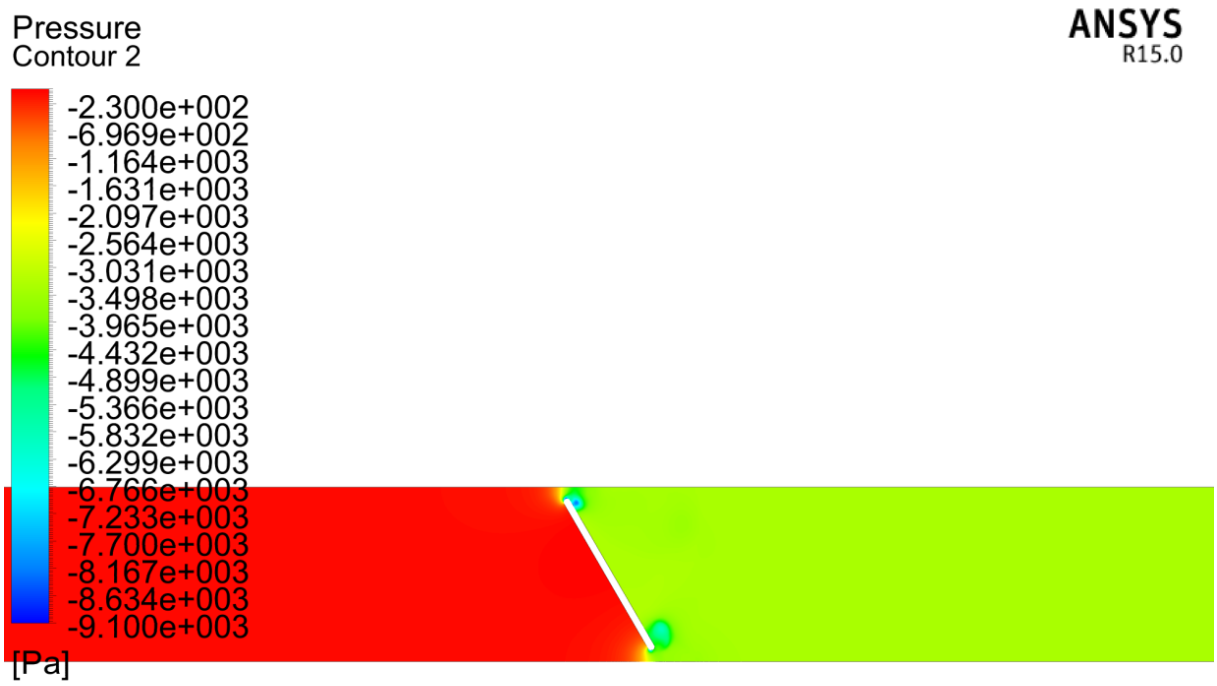


Fig C.25: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 60 degree open case.

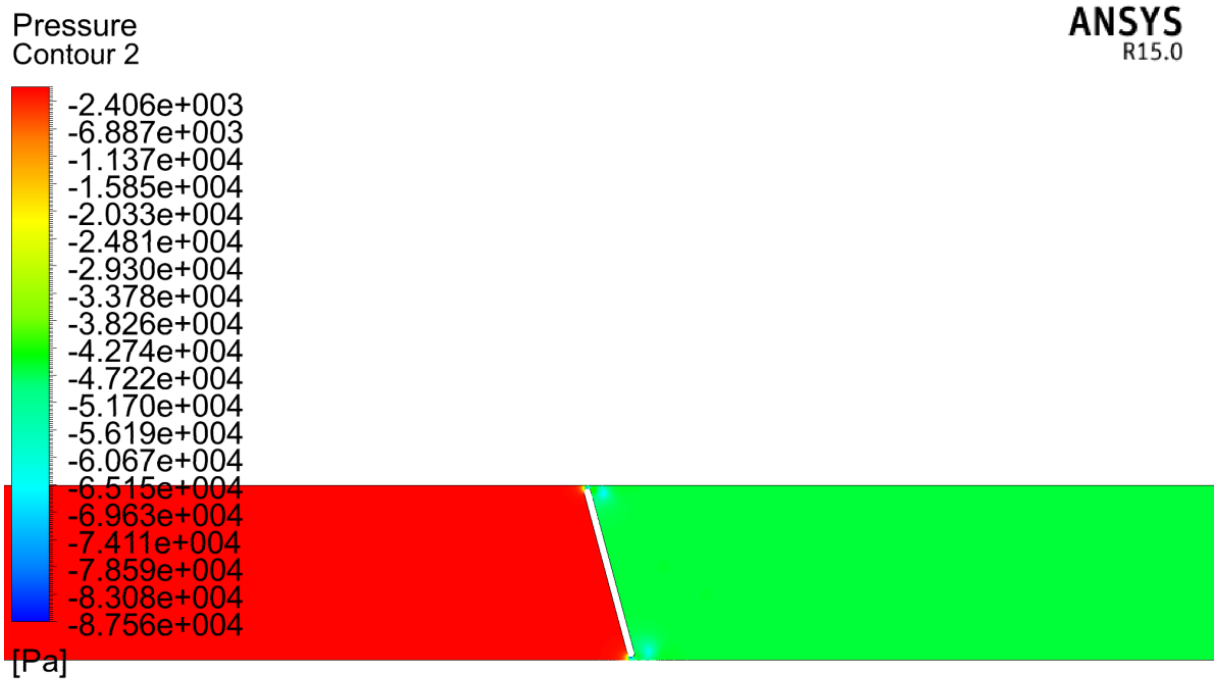


Fig C.26: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Butterfly Valve for 75 degree open case.

BALL VALVE

The following are the Relative Pressure (Gauge) contours generated for the Ball Valve at different valve opening (in percentage).



Fig C.27: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 0 percentage open case.

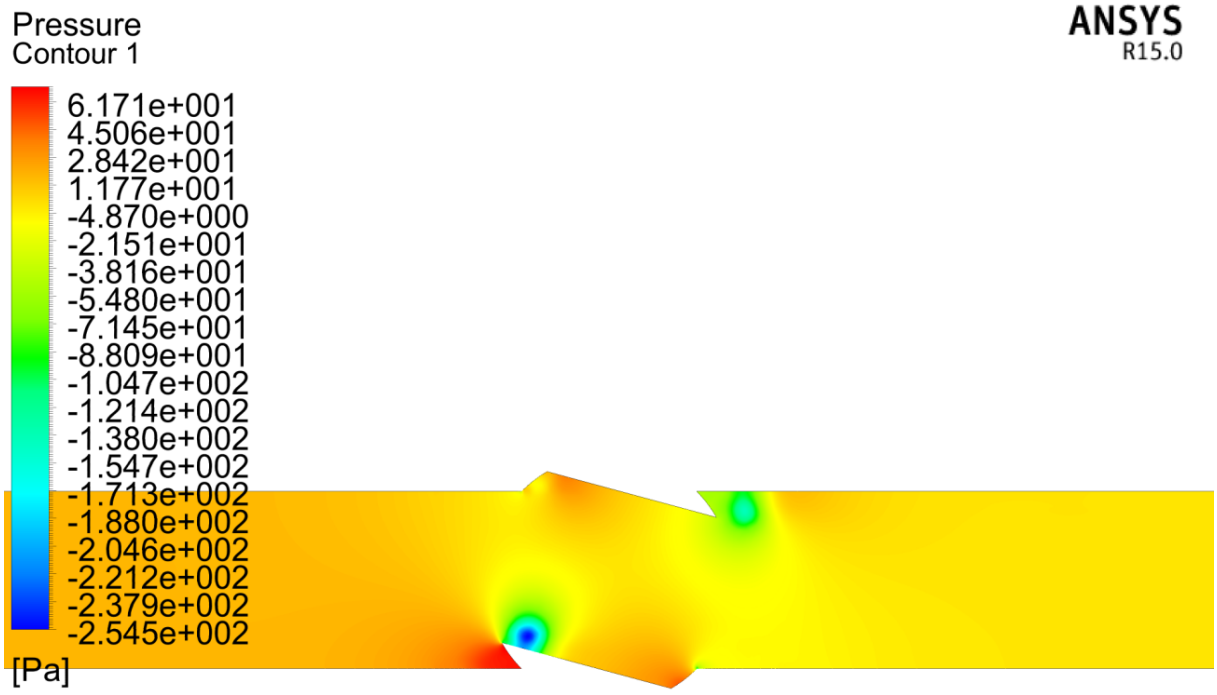


Fig C.28: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 14.64 percentage open case.

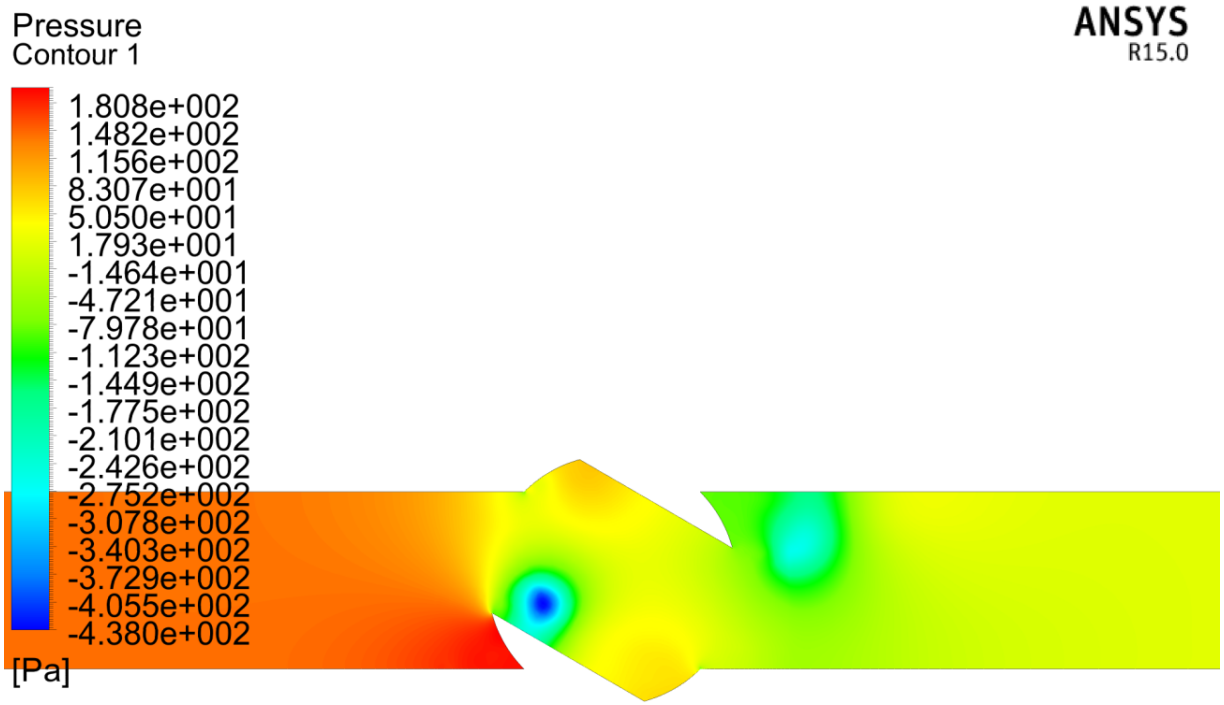


Fig C.29: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 31.7 percentage open case.

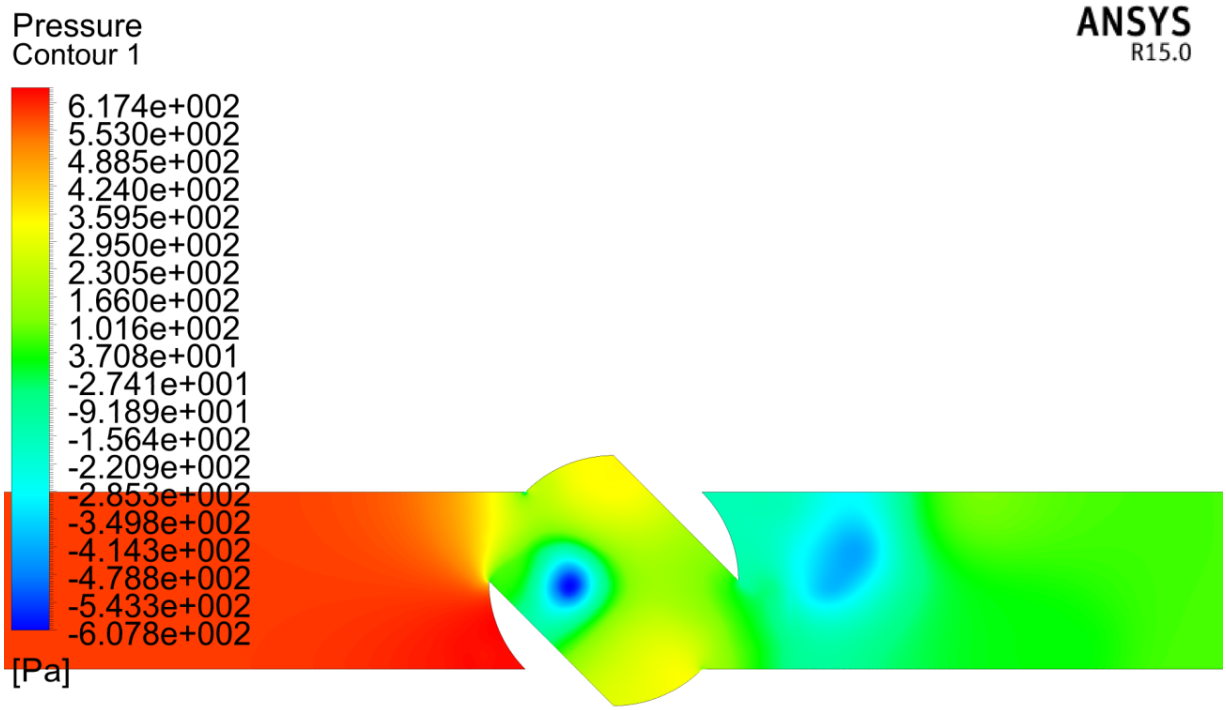


Fig C.30: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 50 percentage open case.

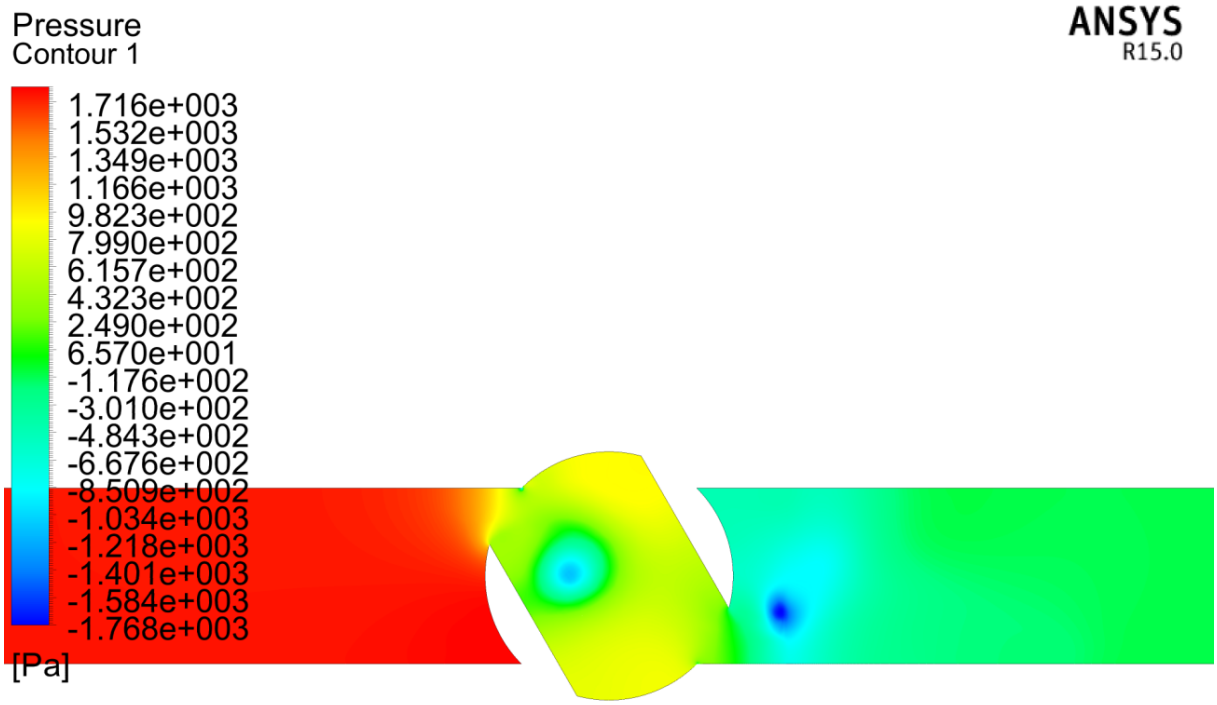


Fig C.31: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 68.3 percentage open case.

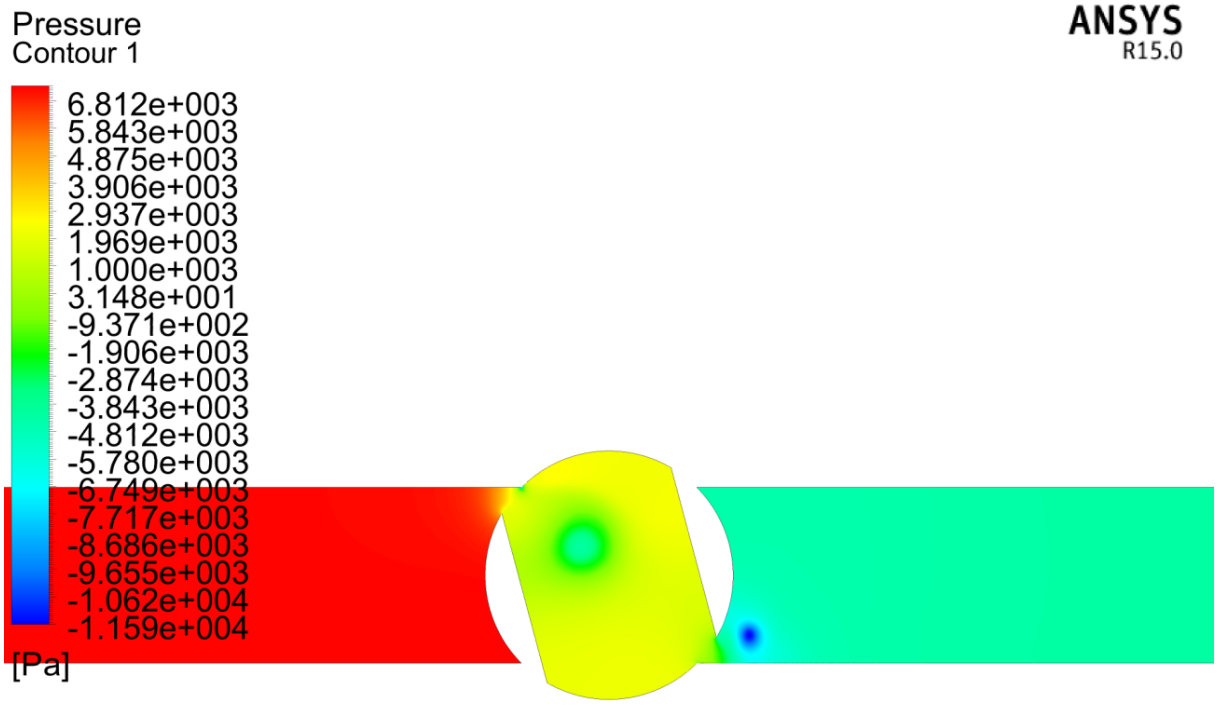


Fig C.32: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 85.36 percentage open case.

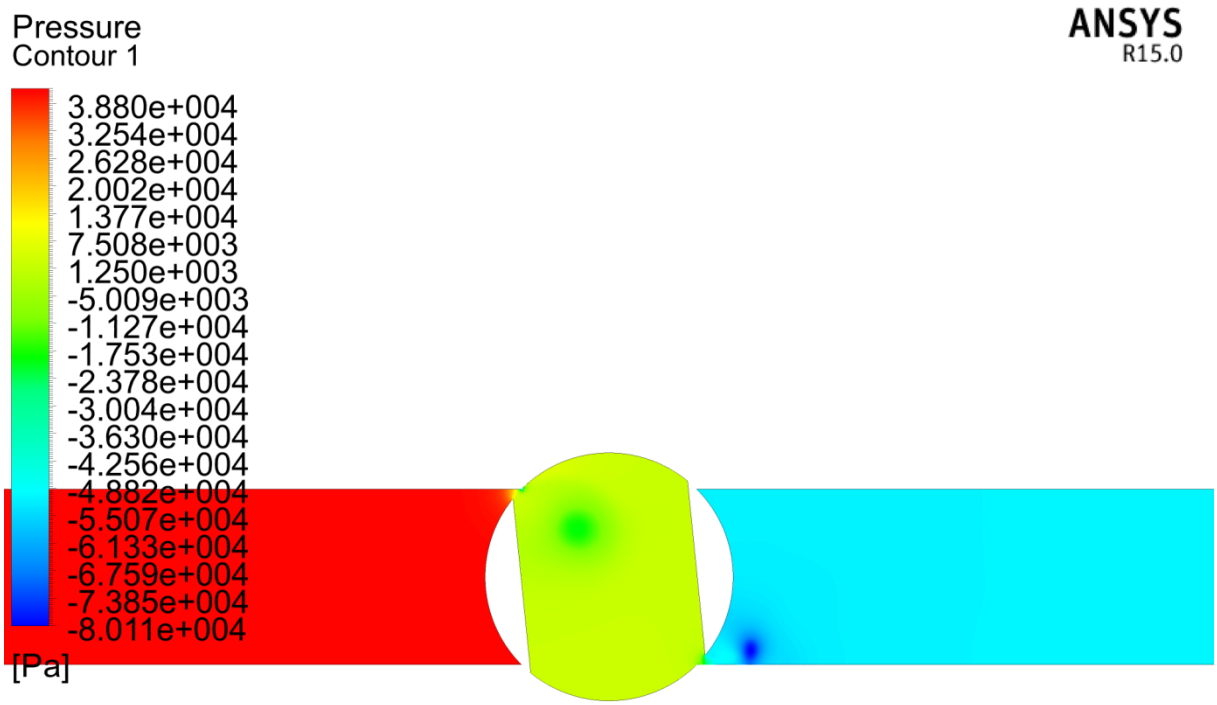


Fig C.33: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Ball Valve for 96.72 percentage open case.

GATE VALVE

The following are the Relative Pressure contours generated for the Gate Valve at different valve opening (in percentage)



Fig C.34: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 0 percentage open case.

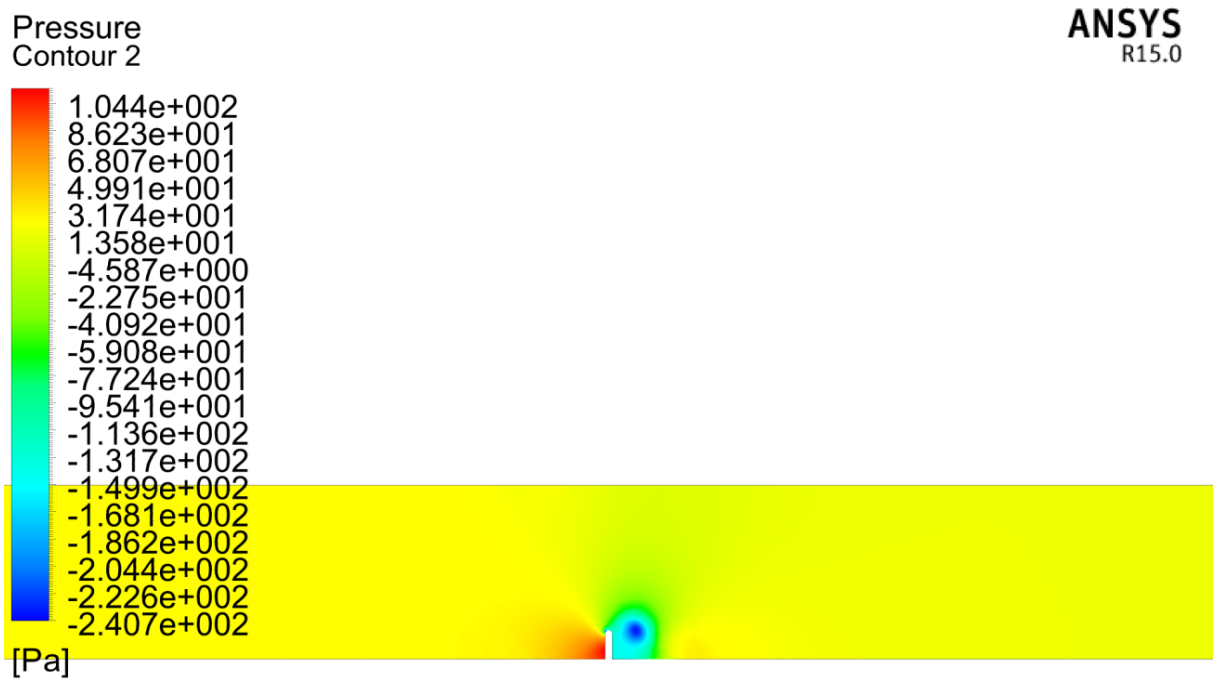


Fig C.35: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 16.67 percentage open case.

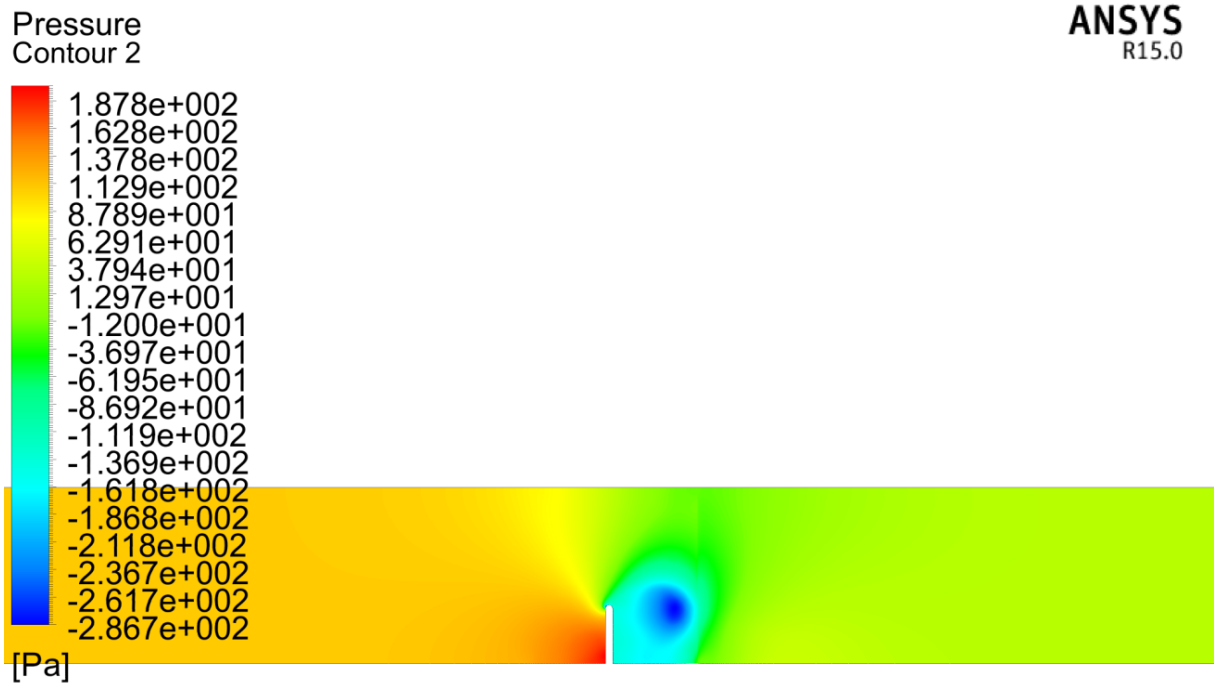


Fig C.36: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 33.34 percentage open case.

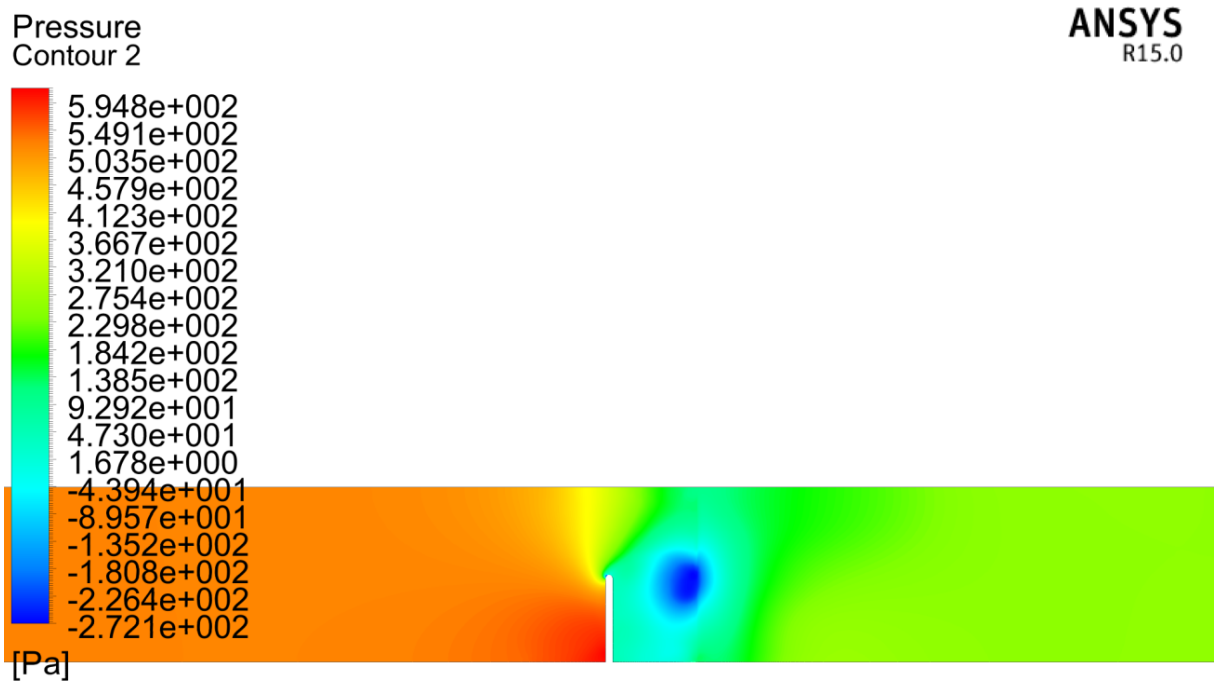


Fig C.37: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 50 percentage open case.

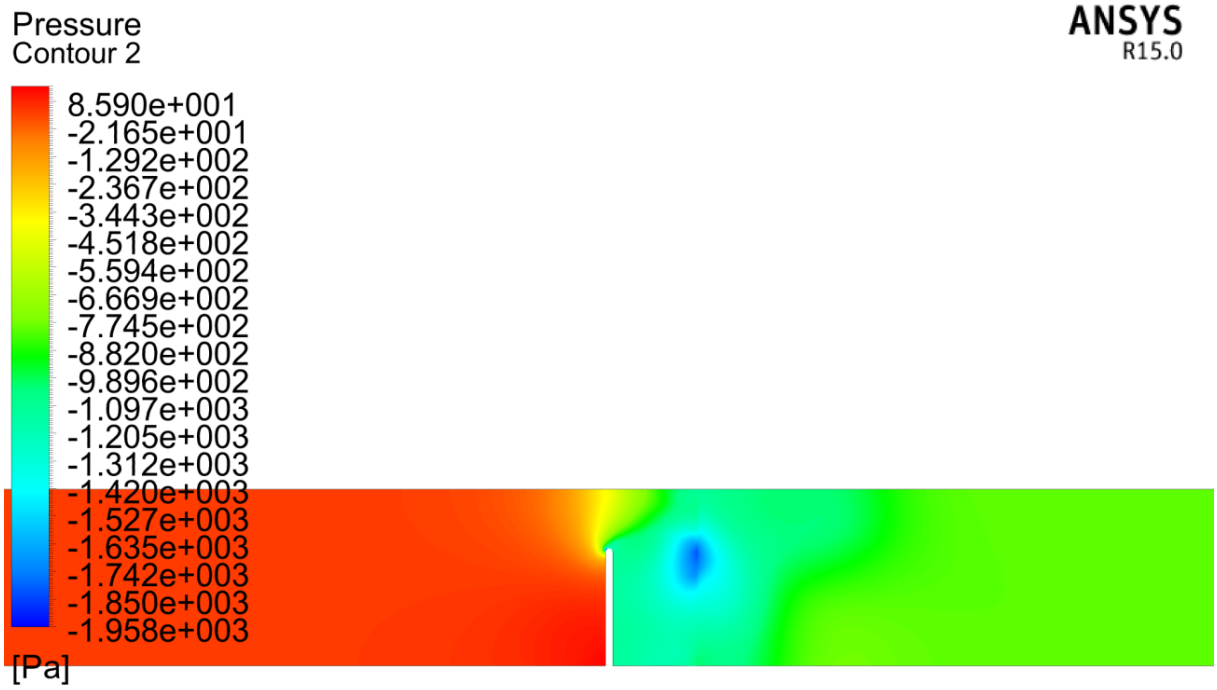


Fig C.38: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 66.67 percentage open case.

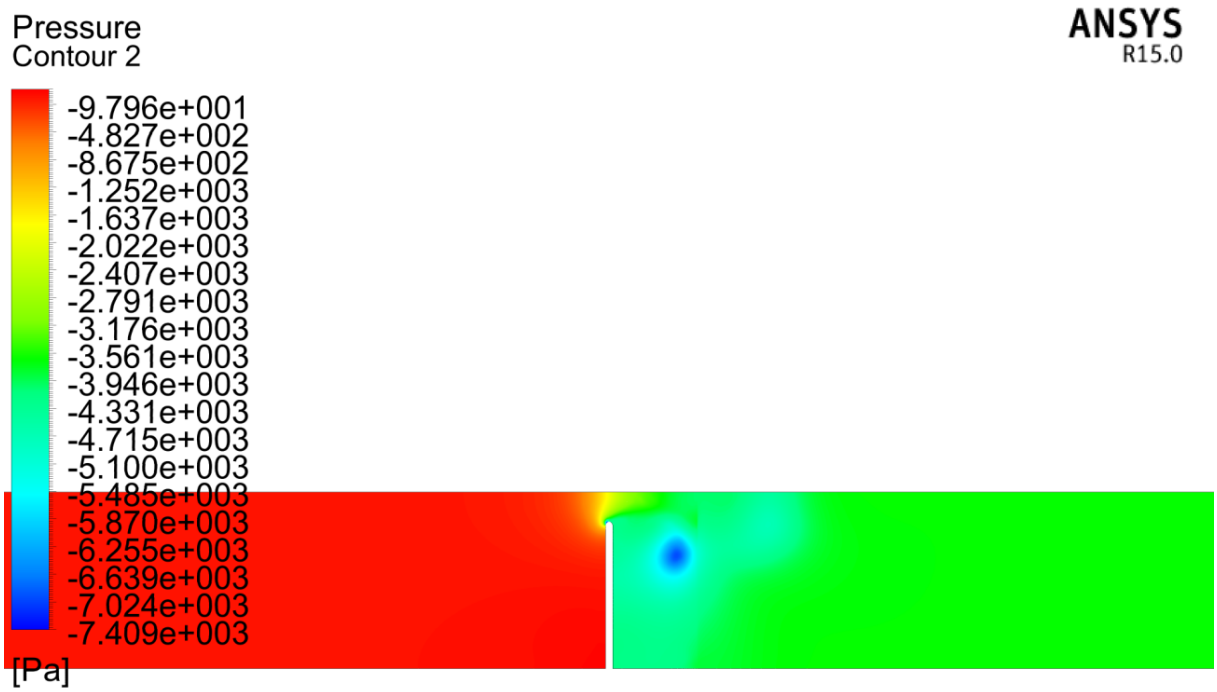


Fig C.39: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 83.34 percentage open case.

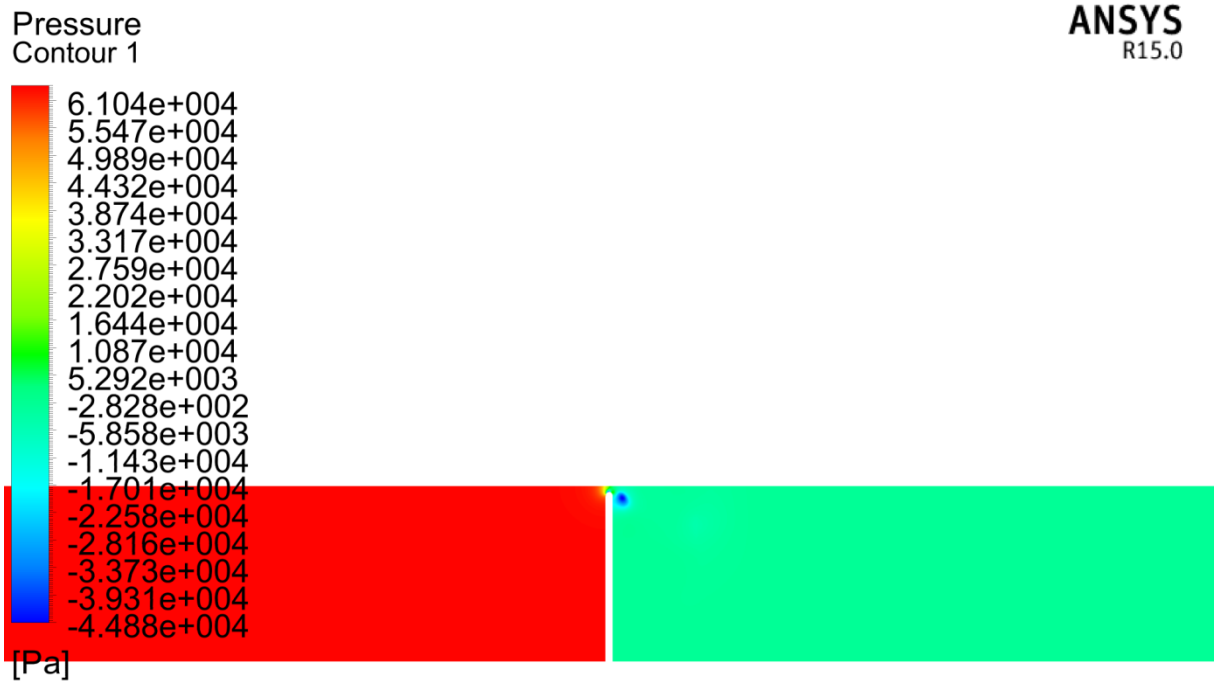


Fig C.40: Detailed View of relative (Gauge) Static Pressure contours across the entire fluid domain of a Gate Valve for 96.72 percentage open case.

Appendix D

ANSYS FLUENT 15.0 Result Tabulation

This Appendix consists of the point values of various parameters which were obtained from ANSYS FLUENT 15.0 solution plots. The point values are imported from the nodal points. Since we used a refined mesh with edge sizing on the Inlet and Outlet Boundaries on all the valve meshes, the numbers of nodal points at the boundaries are fifty one (51) each. The following parameters are tabulated for each valve at different throttle positions.

- **Nodal Points (m):** These are the y coordinates of the mesh nodes (vertices). Range of this is from -0.025 m to 0.025 m.
- **Outlet Velocity (m/s):** These values are the velocity magnitude at the outlet of the valve.
- **Inlet (Pa, gauge)**
    - **Static Pressure:** these values give the relative (gauge) Static Pressures, also used to describe the pressure head at inlet of the valve.
    - **Total Pressure:** these values give the summation of the stagnation (Static) and impact (dynamic) pressures at the inlet of the valve.
- **Outlet (Pa, gauge)**
    - **Static Pressure:** these values give the relative (gauge) Static Pressures, also used to describe the back pressure at outlet of the valve.
    - **Total Pressure:** these values give the summation of the stagnation (Static) and impact (dynamic) pressures at the outlet of the valve.
- **Pressure Difference (Pa, gauge)**
    - **Static:**
    - **Dynamic:**
    - **Total:** these values give the pressure head difference of the summation of stagnation (Static) and impact (dynamic) pressures, which is the total pressure at the outlet of the valve.

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2K14/ME/072

Butterfly Valve

Table D.1: Butterfly Valve throttled at 0 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	36.7371	90.1461	-3.42245	-3.03113	40.15955	53.01768	93.17723
-0.02495	1.57955	34.4489	91.9497	-3.42548	-1.45014	37.87438	55.52546	93.39984
-0.02488	3.31942	30.8116	92.9619	-3.43127	3.79264	34.24287	54.92639	89.16926
-0.02481	4.96274	28.1322	89.8288	-3.4315	11.9922	31.5637	46.2729	77.8366
-0.02472	6.27813	25.8548	87.3095	-3.42278	20.90342	29.27758	37.1285	66.40608
-0.02461	7.24681	24.1006	85.4493	-3.40625	28.85925	27.50685	29.0832	56.59005
-0.02447	7.96729	22.649	83.9535	-3.37774	35.55976	26.02674	22.367	48.39374
-0.02432	8.52348	21.4601	82.7392	-3.33489	41.19891	24.79499	16.7453	41.54029
-0.02413	8.96695	20.4668	81.7334	-3.27245	45.99975	23.73925	11.9944	35.73365
-0.0239	9.32736	19.6402	80.8992	-3.18457	50.11833	22.82477	7.9561	30.78087
-0.02363	9.62142	18.9478	80.2028	-3.05989	53.65061	22.00769	4.5445	26.55219
-0.0233	9.85825	18.3672	79.6199	-2.89259	56.63981	21.25979	1.7203	22.98009
-0.0229	10.0419	17.8763	79.1277	-2.67006	59.09804	20.54636	-0.5167	20.02966
-0.02243	10.1741	17.4586	78.7094	-2.37264	61.03016	19.83124	-2.152	17.67924
-0.02186	10.2566	17.1005	78.3509	-2.01473	62.41897	19.11523	-3.1833	15.93193
-0.02118	10.292	16.7926	78.0428	-1.54525	63.33355	18.33785	-3.6286	14.70925
-0.02037	10.2915	16.5286	77.7786	-0.97762	63.89498	17.50622	-3.6226	13.88362
-0.01939	10.2689	16.2988	77.5488	-0.36713	64.22097	16.66593	-3.3381	13.32783
-0.01821	10.2361	16.0926	77.3426	0.277837	64.45434	15.81476	-2.9265	12.88826
-0.0168	10.2033	15.9094	77.1594	0.921555	64.68786	14.98785	-2.5163	12.47155
-0.01511	10.1717	15.7479	76.9979	1.575	64.9459	14.1729	-2.1209	12.052
-0.01308	10.1417	15.6082	76.8582	2.16987	65.16757	13.43833	-1.7477	11.69063
-0.01064	10.1159	15.489	76.739	2.63228	65.31088	12.85672	-1.4286	11.42812
-0.00772	10.0973	15.3963	76.6463	2.96282	65.41092	12.43348	-1.1981	11.23538
-0.00421	10.0866	15.3314	76.5814	3.17738	65.49268	12.15402	-1.0653	11.08872
-3.47E-18	10.0834	15.3036	76.5536	3.25472	65.53092	12.04888	-1.0262	11.02268
0.004211	10.0879	15.3315	76.5815	3.17002	65.50162	12.16148	-1.0816	11.07988
0.00772	10.0989	15.3963	76.6463	2.95913	65.42633	12.43717	-1.2172	11.21997
0.010644	10.1181	15.489	76.739	2.62606	65.33126	12.86294	-1.4552	11.40774
0.013081	10.1447	15.6084	76.8584	2.15588	65.19188	13.45252	-1.786	11.66652
0.015112	10.176	15.7481	76.9981	1.5484	64.9734	14.1997	-2.175	12.0247
0.016804	10.2087	15.9095	77.1595	0.882465	64.71527	15.02704	-2.5828	12.44424
0.018214	10.2416	16.0927	77.3427	0.22658	64.47248	15.86612	-2.9959	12.87022
0.019389	10.2729	16.2989	77.5489	-0.42197	64.21713	16.72087	-3.3891	13.33177
0.020368	10.2922	16.5287	77.7787	-1.02857	63.85303	17.55727	-3.6316	13.92567
0.021184	10.2882	16.7928	78.043	-1.59239	63.23921	18.38519	-3.5814	14.80379
0.021865	10.2476	17.1007	78.3511	-2.05138	62.26942	19.15208	-3.0704	16.08168
0.022431	10.1608	17.4588	78.7096	-2.40102	60.83618	19.85982	-1.9864	17.87342
0.022904	10.026	17.8764	79.1278	-2.69567	58.87663	20.57207	-0.3209	20.25117
0.023297	9.84089	18.3672	79.6199	-2.9147	56.4083	21.2819	1.9297	23.2116
0.023625	9.60369	18.9479	80.2029	-3.08142	53.42028	22.02932	4.7533	26.78262
0.023898	9.30991	19.6402	80.8992	-3.2041	49.8996	22.8443	8.1553	30.9996
0.024126	8.95025	20.4667	81.7333	-3.29078	45.79812	23.75748	12.1777	35.93518
0.024316	8.50784	21.46	82.7391	-3.35204	41.01836	24.81204	16.9087	41.72074
0.024474	7.95293	22.6487	83.9533	-3.39392	35.40328	26.04262	22.5074	48.55002
0.024606	7.23393	24.1001	85.4489	-3.4217	28.7291	27.5218	29.198	56.7198
0.024716	6.26703	25.8543	87.3091	-3.43764	20.80256	29.29194	37.2146	66.50654
0.024807	4.95416	28.1314	89.8281	-3.44593	11.92427	31.57733	46.3265	77.90383
0.024884	3.31437	30.8104	92.9601	-3.44542	3.75589	34.25582	54.94839	89.20421
0.024947	1.57781	34.4457	91.9405	-3.43954	-1.46903	37.88524	55.52429	93.40953
0.025	0	36.732	90.1305	-3.4365	-3.04564	40.1685	53.00764	93.17614

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2K14/ME/072

Table D.2: Butterfly Valve throttled at 15 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	6.08242	59.41852	-57.8142	0.414575	63.89662	52.92153	116.8181
-0.02495	1.62656	3.76273	61.21683	-57.8129	2.09544	61.57563	55.35866	116.9343
-0.02488	3.41547	0.0760175	62.23432	-57.8102	7.64449	57.88622	54.51381	112.4
-0.02481	5.09294	-2.63357	59.08673	-57.8043	16.2353	55.17073	45.485	100.6557
-0.02472	6.42063	-4.94253	56.52347	-57.7973	25.435	52.85477	36.031	88.88577
-0.02461	7.38852	-6.72785	54.62845	-57.7948	33.5349	51.06695	27.8214	78.88835
-0.02447	8.10607	-8.20118	53.10852	-57.7911	40.3034	49.58992	21.0063	70.59622
-0.02432	8.6601	-9.40513	51.87737	-57.768	45.9714	48.36287	15.3111	63.67397
-0.02413	9.10221	-10.4063	50.8623	-57.7217	50.7691	47.3154	10.4995	57.8149
-0.0239	9.46176	-11.2362	50.024	-57.6479	54.8496	46.4117	6.4106	52.8223
-0.02363	9.75403	-11.929	49.3267	-57.53	58.284	45.601	2.9717	48.5727
-0.0233	9.98594	-12.5092	48.7439	-57.3558	61.084	44.8466	0.1691	45.0157
-0.0229	10.1584	-12.9994	48.2523	-57.0955	63.2082	44.0961	-1.9565	42.1396
-0.02243	10.2705	-13.4166	47.8343	-56.7412	64.6094	43.3246	-3.3585	39.9661
-0.02186	10.3236	-13.7745	47.476	-56.2691	65.2779	42.4946	-4.0274	38.4672
-0.02118	10.3284	-14.0822	47.1681	-55.6767	65.3384	41.5945	-4.0881	37.5064
-0.02037	10.3028	-14.3458	46.9043	-55.0281	65.016	40.6823	-3.7659	36.9164
-0.01939	10.2618	-14.5746	46.6754	-54.3574	64.4987	39.7828	-3.2487	36.5341
-0.01821	10.2187	-14.7793	46.4707	-53.6996	63.9586	38.9203	-2.7086	36.2117
-0.0168	10.18	-14.9606	46.2894	-53.0742	63.4756	38.1136	-2.2256	35.888
-0.01511	10.1453	-15.1196	46.1304	-52.4422	63.0427	37.3226	-1.7927	35.5299
-0.01308	10.1155	-15.2567	45.9933	-51.8799	62.6727	36.6232	-1.4227	35.2005
-0.01064	10.0925	-15.3733	45.8767	-51.474	62.3882	36.1007	-1.1382	34.9625
-0.00772	10.0768	-15.4636	45.7864	-51.1946	62.1947	35.731	-0.9447	34.7863
-0.00421	10.0676	-15.5266	45.7234	-51.0299	62.0814	35.5033	-0.8314	34.6719
-3.47E-18	10.0635	-15.5536	45.6964	-50.9916	62.0307	35.438	-0.7807	34.6573
0.004211	10.0662	-15.5267	45.7233	-51.079	62.064	35.5523	-0.814	34.7383
0.00772	10.0758	-15.4638	45.7862	-51.2614	62.1824	35.7976	-0.9324	34.8652
0.010644	10.0926	-15.3735	45.8765	-51.5409	62.3902	36.1674	-1.1402	35.0272
0.013081	10.1166	-15.257	45.993	-51.9447	62.6872	36.6877	-1.4372	35.2505
0.015112	10.1475	-15.1199	46.1301	-52.503	63.0703	37.3831	-1.8203	35.5628
0.016804	10.1834	-14.9609	46.2891	-53.1209	63.5169	38.16	-2.2669	35.8931
0.018214	10.2228	-14.7796	46.4704	-53.7291	64.0097	38.9495	-2.7597	36.1898
0.019389	10.2659	-14.575	46.675	-54.3805	64.5515	39.8055	-3.3015	36.504
0.020368	10.3058	-14.3462	46.9039	-55.0482	65.0532	40.702	-3.8031	36.8989
0.021184	10.3287	-14.0826	47.1676	-55.6949	65.3431	41.6123	-4.0929	37.5194
0.021865	10.3204	-13.775	47.4755	-56.2838	65.2376	42.5088	-3.9871	38.5217
0.022431	10.2633	-13.4172	47.8337	-56.7529	64.5192	43.3357	-3.2683	40.0674
0.022904	10.148	-13	48.2517	-57.1056	63.0793	44.1056	-1.8276	42.278
0.023297	9.9738	-12.5098	48.7433	-57.3629	60.9356	44.8531	0.3175	45.1706
0.023625	9.74141	-11.9297	49.326	-57.5352	58.1334	45.6055	3.1223	48.7278
0.023898	9.44964	-11.237	50.0233	-57.6521	54.7092	46.4151	6.5511	52.9662
0.024126	9.09119	-10.4071	50.8616	-57.7248	50.6461	47.3177	10.6226	57.9403
0.024316	8.6505	-9.40598	51.87662	-57.7706	45.8694	48.36462	15.4132	63.77782
0.024474	8.09802	-8.20198	53.10772	-57.793	40.2232	49.59102	21.0865	70.67752
0.024606	7.38196	-6.72853	54.62797	-57.7962	33.4752	51.06767	27.8813	78.94897
0.024716	6.41551	-4.94298	56.52332	-57.7986	25.3942	52.85562	36.0721	88.92772
0.024807	5.08946	-2.63384	59.08696	-57.8054	16.2128	55.17156	45.508	100.6796
0.024884	3.41401	0.0757779	62.23488	-57.8111	7.6372	57.88688	54.5219	112.4088
0.024947	1.62657	3.76222	61.21622	-57.8139	2.09496	61.57612	55.35904	116.9352
0.025	0	6.08162	59.41702	-57.8152	-3.04564	63.89682	52.9204	116.8172

Joe Joseph
2K14/ME/072

Table D.3: Butterfly Valve throttled at 30 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	-8.02382	45.31228	-201.319	-200.904	193.2952	52.92106	246.2162
-0.02495	1.62746	-10.3436	47.1106	-201.317	-199.219	190.9734	55.35644	246.3298
-0.02488	3.41726	-14.0304	48.1281	-201.314	-193.662	187.2836	54.5061	241.7897
-0.02481	5.09531	-16.74	44.9803	-201.308	-185.058	184.568	45.47	230.038
-0.02472	6.42332	-19.049	42.417	-201.301	-175.845	182.252	36.0098	218.2618
-0.02461	7.39134	-20.8344	40.5219	-201.298	-167.738	180.4636	27.7958	208.2594
-0.02447	8.10892	-22.3077	39.002	-201.294	-160.962	178.9863	20.978	199.9643
-0.02432	8.66288	-23.5116	37.7709	-201.27	-155.269	177.7584	15.2817	193.0401
-0.02413	9.10478	-24.5128	36.7559	-201.224	-150.426	176.7112	10.4709	187.1821
-0.0239	9.46396	-25.3426	35.9177	-201.149	-146.274	175.8064	6.3853	182.1917
-0.02363	9.7557	-26.0354	35.2203	-201.031	-142.727	174.9956	2.9518	177.9474
-0.0233	9.98692	-26.6155	34.6376	-200.856	-139.76	174.2405	0.1572	174.3977
-0.0229	10.1585	-27.1057	34.146	-200.596	-137.386	173.4903	-1.9588	171.5315
-0.02243	10.2699	-27.5229	33.728	-200.242	-135.641	172.7191	-3.3504	169.3687
-0.02186	10.3223	-27.8807	33.3698	-199.774	-134.513	171.8933	-4.011	167.8823
-0.02118	10.3268	-28.1883	33.062	-199.187	-133.869	170.9987	-4.0679	166.9308
-0.02037	10.3011	-28.4519	32.7982	-198.544	-133.549	170.0921	-3.7446	166.3475
-0.01939	10.2603	-28.6806	32.5694	-197.88	-133.399	169.1994	-3.2306	165.9688
-0.01821	10.2177	-28.8852	32.3648	-197.221	-133.275	168.3358	-2.6964	165.6394
-0.0168	10.1799	-29.0664	32.1836	-196.589	-133.115	167.5226	-2.224	165.2986
-0.01511	10.1461	-29.2254	32.0246	-195.959	-132.906	166.7336	-1.8029	164.9307
-0.01308	10.1167	-29.3624	31.8876	-195.396	-132.708	166.0336	-1.4382	164.5954
-0.01064	10.0932	-29.4786	31.7714	-194.978	-132.58	165.4994	-1.1476	164.3518
-0.00772	10.0765	-29.5686	31.6814	-194.693	-132.502	165.1244	-0.9408	164.1836
-0.00421	10.0666	-29.6316	31.6184	-194.529	-132.461	164.8974	-0.8181	164.0793
-3.47E-18	10.0634	-29.6596	31.5904	-194.497	-132.468	164.8374	-0.7786	164.0588
0.004211	10.0666	-29.6345	31.6155	-194.582	-132.513	164.9475	-0.8188	164.1287
0.00772	10.0759	-29.5731	31.6769	-194.763	-132.58	165.1899	-0.933	164.2569
0.010644	10.0926	-29.4834	31.7666	-195.05	-132.66	165.5666	-1.1398	164.4268
0.013081	10.1167	-29.367	31.883	-195.459	-132.772	166.092	-1.4374	164.6546
0.015112	10.1474	-29.23	32.02	-196.018	-132.949	166.788	-1.8193	164.9687
0.016804	10.1831	-29.0712	32.1788	-196.637	-133.124	167.5658	-2.2632	165.3026
0.018214	10.2223	-28.8901	32.3599	-197.25	-133.246	168.3599	-2.754	165.6059
0.019389	10.2654	-28.6856	32.5644	-197.903	-133.358	169.2174	-3.2948	165.9226
0.020368	10.3053	-28.4569	32.7932	-198.572	-133.525	170.1151	-3.7972	166.3179
0.021184	10.3284	-28.1934	33.0568	-199.22	-133.881	171.0266	-4.089	166.9376
0.021865	10.3203	-27.8858	33.3647	-199.81	-134.573	171.9242	-3.9862	167.938
0.022431	10.2636	-27.528	33.7229	-200.281	-135.758	172.753	-3.2722	169.4808
0.022904	10.1487	-27.1109	34.1408	-200.636	-137.547	173.5251	-1.8369	171.6882
0.023297	9.97499	-26.6208	34.6323	-200.895	-139.945	174.2742	0.3029	174.5771
0.023625	9.74306	-26.0408	35.2149	-201.069	-142.916	175.0282	3.1027	178.1309
0.023898	9.45167	-25.348	35.9123	-201.187	-146.454	175.839	6.5277	182.3667
0.024126	9.09349	-24.5182	36.7505	-201.261	-150.589	176.7428	10.5969	187.3397
0.024316	8.65295	-23.5171	37.7655	-201.307	-155.412	177.7899	15.3873	193.1772
0.024474	8.10051	-22.313	38.9968	-201.33	-161.082	179.017	21.0619	200.0789
0.024606	7.38442	-20.8395	40.517	-201.334	-167.837	180.4945	27.8591	208.3536
0.024716	6.41782	-19.0538	42.4125	-201.336	-175.924	182.2822	36.0539	218.3361
0.024807	5.09152	-16.7446	44.9764	-201.344	-185.118	184.5994	45.4953	230.0947
0.024884	3.41556	-14.0347	48.1245	-201.35	-193.706	187.3153	54.51517	241.8305
0.024947	1.62738	-10.348	47.1058	-201.352	-199.255	191.004	55.35679	246.3608
0.025	0	-8.02841	45.30669	-201.354	-200.939	193.3256	52.91966	246.2452

Joe Joseph
2K14/ME/072

Table D.4: Butterfly Valve throttled at 45 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	1034.48	1087.845	99.6621	100.0425	934.8179	52.984517	987.802417
-0.02495	1.56164	1032.16	1089.63	99.6635	101.5971	932.4965	55.53611	988.03261
-0.02488	3.29531	1028.47	1090.626	99.6687	106.7966	928.8013	55.02828	983.82958
-0.02481	4.94533	1025.76	1087.477	99.6803	115.0032	926.0797	46.3936	972.4733
-0.02472	6.26832	1023.45	1084.914	99.6954	123.9474	923.7546	37.2119	960.9665
-0.02461	7.24102	1021.67	1083.025	99.7121	131.9272	921.9579	29.1398	951.0977
-0.02447	7.96767	1020.19	1081.499	99.7325	138.6753	920.4575	22.3658	942.8233
-0.02432	8.53333	1018.99	1080.272	99.7604	144.3987	919.2296	16.6434	935.873
-0.02413	8.98779	1017.99	1079.258	99.8022	149.3049	918.1878	11.7653	929.9531
-0.0239	9.35864	1017.16	1078.42	99.8643	153.5262	917.2957	7.5978	924.8935
-0.02363	9.66063	1016.47	1077.725	99.9568	157.1309	916.5132	4.0812	920.5944
-0.0233	9.90114	1015.89	1077.143	100.087	160.1385	915.803	1.2013	917.0043
-0.0229	10.083	1015.4	1076.652	100.267	162.5419	915.133	-1.0234	914.1096
-0.02243	10.2073	1014.98	1076.231	100.518	164.3351	914.462	-2.5663	911.8957
-0.02186	10.2768	1014.62	1075.87	100.84	165.5281	913.78	-3.4377	910.3423
-0.02118	10.2999	1014.32	1075.57	101.262	166.2408	913.058	-3.7286	909.3294
-0.02037	10.2914	1014.05	1075.3	101.76	166.6312	912.29	-3.6211	908.6689
-0.01939	10.2658	1013.83	1075.08	102.293	166.8424	911.537	-3.2994	908.2376
-0.01821	10.2344	1013.62	1074.87	102.861	167.0163	910.759	-2.9053	907.8537
-0.0168	10.2051	1013.44	1074.69	103.438	167.227	910.002	-2.539	907.463
-0.01511	10.1772	1013.28	1074.53	104.029	167.4685	909.251	-2.1896	907.0614
-0.01308	10.1469	1013.14	1074.39	104.602	167.6644	908.538	-1.8124	906.7256
-0.01064	10.118	1013.03	1074.28	105.065	167.7696	907.965	-1.4546	906.5104
-0.00772	10.0964	1012.94	1074.19	105.393	167.8291	907.547	-1.1862	906.3608
-0.00421	10.0828	1012.88	1074.13	105.592	167.8608	907.288	-1.0189	906.2691
-3.47E-18	10.0769	1012.85	1074.1	105.656	167.8516	907.194	-0.9456	906.2484
0.004211	10.0797	1012.88	1074.13	105.591	167.8217	907.289	-0.9807	906.3083
0.00772	10.0906	1012.94	1074.19	105.416	167.7803	907.524	-1.1143	906.4097
0.010644	10.1088	1013.03	1074.28	105.134	167.724	907.896	-1.34	906.556
0.013081	10.1338	1013.14	1074.39	104.733	167.6331	908.407	-1.65	906.757
0.015112	10.1635	1013.28	1074.53	104.204	167.4739	909.076	-2.0198	907.0562
0.016804	10.1959	1013.44	1074.69	103.633	167.306	909.807	-2.4229	907.3841
0.018214	10.2305	1013.62	1074.87	103.071	167.1772	910.549	-2.8561	907.6929
0.019389	10.2667	1013.83	1075.08	102.482	167.0424	911.348	-3.3104	908.0376
0.020368	10.2951	1014.05	1075.3	101.91	166.828	912.14	-3.6679	908.4721
0.021184	10.3034	1014.32	1075.57	101.371	166.3936	912.949	-3.7723	909.1767
0.021865	10.2766	1014.62	1075.871	100.91	165.5951	913.71	-3.4346	910.2754
0.022431	10.1993	1014.98	1076.231	100.563	164.28	914.417	-2.4661	911.9509
0.022904	10.0658	1015.4	1076.652	100.296	162.3584	915.104	-0.8107	914.2933
0.023297	9.8755	1015.89	1077.143	100.105	159.8465	915.785	1.5115	917.2965
0.023625	9.62836	1016.47	1077.726	99.9741	156.7674	916.4959	4.4622	920.9581
0.023898	9.32242	1017.16	1078.42	99.883	153.1307	917.277	8.0122	925.2892
0.024126	8.95036	1017.99	1079.258	99.8253	148.9169	918.1647	12.1765	930.3412
0.024316	8.49712	1018.99	1080.272	99.7874	144.0476	919.2026	17.0215	936.2241
0.024474	7.93436	1020.19	1081.499	99.7622	138.3799	920.4278	22.691	943.1188
0.024606	7.2114	1021.67	1083.025	99.7435	131.6955	921.9265	29.403	951.3295
0.024716	6.24283	1023.45	1084.914	99.7278	123.783	923.7222	37.409	961.1312
0.024807	4.92524	1025.76	1087.477	99.7131	114.9117	926.0469	46.5185	972.5654
0.024884	3.28257	1028.47	1090.626	99.7016	106.7738	928.7684	55.0842	983.8526
0.024947	1.55636	1032.15	1089.615	99.6964	101.6164	932.4536	55.54534	987.99894
0.025	0	1034.48	1087.837	99.695	100.0733	934.785	52.978709	987.763709

Joe Joseph
2K14/ME/072

Table D.5: Butterfly Valve throttled at 60 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	-16.695	36.6725	-3411.19	-3410.81	3394.495	52.988296	3447.4833
-0.02495	1.55876	-19.0136	38.4577	-3411.18	-3409.25	3392.166	55.54501	3447.71141
-0.02488	3.28813	-22.6971	39.4575	-3411.18	-3404.08	3388.483	55.05852	3443.54142
-0.02481	4.93349	-25.404	36.3083	-3411.18	-3395.93	3385.776	46.4627	3432.2387
-0.02472	6.25699	-27.7096	33.7513	-3411.17	-3387	3383.46	37.2942	3420.7546
-0.02461	7.23456	-29.4909	31.8612	-3411.15	-3378.99	3381.659	29.193	3410.8521
-0.02447	7.96427	-30.9612	30.3451	-3411.13	-3372.22	3380.169	22.3965	3402.5653
-0.02432	8.52887	-32.1622	29.1178	-3411.09	-3366.5	3378.928	16.6888	3395.6166
-0.02413	8.97904	-33.1613	28.1056	-3411.04	-3361.63	3377.879	11.8611	3389.7398
-0.0239	9.34424	-33.9894	27.2697	-3410.97	-3357.47	3376.981	7.7627	3384.7433
-0.02363	9.64093	-34.6808	26.5741	-3410.87	-3353.93	3376.189	4.3141	3380.5033
-0.0233	9.87773	-35.2598	25.9928	-3410.73	-3350.96	3375.47	1.4848	3376.955
-0.0229	10.0585	-35.749	25.5024	-3410.54	-3348.57	3374.791	-0.7207	3374.0703
-0.02243	10.1849	-36.1653	25.0854	-3410.29	-3346.75	3374.125	-2.2867	3371.838
-0.02186	10.2595	-36.5224	24.728	-3409.97	-3345.5	3373.448	-3.2201	3370.2275
-0.02118	10.2882	-36.8295	24.4207	-3409.55	-3344.72	3372.721	-3.5809	3369.1396
-0.02037	10.2839	-37.0926	24.1574	-3409.05	-3344.27	3371.957	-3.5268	3368.4306
-0.01939	10.2605	-37.3211	23.9288	-3408.51	-3344.03	3371.189	-3.2325	3367.9564
-0.01821	10.229	-37.5254	23.7246	-3407.94	-3343.85	3370.415	-2.8376	3367.577
-0.0168	10.1989	-37.7063	23.5437	-3407.36	-3343.65	3369.654	-2.461	3367.1927
-0.01511	10.1707	-37.8652	23.3848	-3406.77	-3343.41	3368.905	-2.1093	3366.7955
-0.01308	10.1429	-38.0023	23.2477	-3406.21	-3343.2	3368.208	-1.7631	3366.4446
-0.01064	10.118	-38.119	23.131	-3405.76	-3343.06	3367.641	-1.4535	3366.1875
-0.00772	10.0991	-38.2096	23.0404	-3405.44	-3342.97	3367.23	-1.22	3366.0104
-0.00421	10.0872	-38.2737	22.9763	-3405.26	-3342.94	3366.986	-1.0723	3365.914
-3.47E-18	10.0834	-38.3021	22.9479	-3405.21	-3342.93	3366.908	-1.0264	3365.8815
0.004211	10.0889	-38.2769	22.9731	-3405.31	-3342.97	3367.033	-1.0941	3365.939
0.00772	10.1006	-38.2154	23.0346	-3405.51	-3343.02	3367.295	-1.238	3366.0566
0.010644	10.1187	-38.1257	23.1243	-3405.83	-3343.12	3367.704	-1.4623	3366.242
0.013081	10.143	-38.0094	23.2406	-3406.26	-3343.25	3368.251	-1.7643	3366.4863
0.015112	10.1717	-37.8724	23.3776	-3406.82	-3343.45	3368.948	-2.1221	3366.8255
0.016804	10.2029	-37.7134	23.5366	-3407.42	-3343.66	3369.707	-2.5112	3367.1954
0.018214	10.2358	-37.5323	23.7177	-3408.02	-3343.85	3370.488	-2.9226	3367.5651
0.019389	10.2691	-37.3278	23.9222	-3408.63	-3344.04	3371.302	-3.3404	3367.9618
0.020368	10.2928	-37.0993	24.1508	-3409.21	-3344.32	3372.111	-3.6396	3368.4711
0.021184	10.2953	-36.8357	24.4146	-3409.76	-3344.84	3372.924	-3.6705	3369.2538
0.021865	10.2619	-36.5282	24.7223	-3410.22	-3345.72	3373.692	-3.2497	3370.4421
0.022431	10.1794	-36.1706	25.0803	-3410.56	-3347.09	3374.389	-2.218	3372.1714
0.022904	10.0439	-35.7536	25.498	-3410.84	-3349.05	3375.086	-0.5409	3374.5455
0.023297	9.85347	-35.2637	25.9893	-3411.04	-3351.56	3375.776	1.7777	3377.554
0.023625	9.607	-34.684	26.5715	-3411.19	-3354.65	3376.506	4.7139	3381.2199
0.023898	9.3013	-33.9919	27.2679	-3411.3	-3358.29	3377.308	8.253	3385.5611
0.024126	8.92805	-33.1631	28.1047	-3411.37	-3362.52	3378.207	12.4203	3390.6272
0.024316	8.47142	-32.1636	29.1175	-3411.41	-3367.42	3379.246	17.2873	3396.5337
0.024474	7.90285	-30.9624	30.345	-3411.44	-3373.13	3380.478	22.994	3403.4716
0.024606	7.1732	-29.4925	31.8606	-3411.45	-3379.83	3381.958	29.7361	3411.6936
0.024716	6.20187	-27.7116	33.7499	-3411.46	-3387.72	3383.748	37.7187	3421.4671
0.024807	4.89062	-25.4064	36.3067	-3411.47	-3396.48	3386.064	46.7279	3432.7915
0.024884	3.26073	-22.7002	39.4555	-3411.47	-3404.49	3388.77	55.17833	3443.94813
0.024947	1.54671	-19.0185	38.4488	-3411.47	-3409.57	3392.452	55.5713	3448.0228
0.025	0	-16.7015	36.6578	-3411.47	-3411.1	3394.769	52.985408	3447.75391

Joe Joseph
2K14/ME/072

Table D.6: Butterfly Valve throttled at 75 degrees.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	-30.7961	22.5745	-45864.9	-45864.5	45834.1	52.99034	45887.09
-0.02495	1.5608	-33.1161	24.3566	-45864.9	-45863	45831.78	55.54145	45887.33
-0.02488	3.2924	-36.8014	25.3535	-45864.9	-45857.8	45828.1	55.04028	45883.14
-0.02481	4.9395	-39.5088	22.2052	-45864.8	-45849.5	45825.29	46.4277	45871.72
-0.02472	6.26171	-41.8151	19.647	-45864.8	-45840.6	45822.98	37.2603	45860.25
-0.02461	7.236	-43.5975	17.7558	-45864.8	-45832.6	45821.2	29.1823	45850.38
-0.02447	7.96369	-45.0687	16.2385	-45864.8	-45825.9	45819.73	22.4032	45842.13
-0.02432	8.52891	-46.2707	15.01	-45864.8	-45820.2	45818.53	16.6888	45835.22
-0.02413	8.98154	-47.2706	13.9968	-45864.7	-45815.3	45817.43	11.8337	45829.26
-0.0239	9.35	-48.0992	13.1602	-45864.6	-45811	45816.5	7.6967	45824.2
-0.02363	9.65041	-48.791	12.4642	-45864.6	-45807.5	45815.81	4.202	45820.01
-0.0233	9.89061	-49.3702	11.8825	-45864.4	-45804.5	45815.03	1.3288	45816.36
-0.0229	10.0739	-49.8596	11.3919	-45864.2	-45802	45814.34	-0.9101	45813.43
-0.02243	10.2007	-50.2761	10.9747	-45864	-45800.3	45813.72	-2.4842	45811.24
-0.02186	10.2734	-50.6333	10.6171	-45863.6	-45799	45812.97	-3.3953	45809.57
-0.02118	10.2993	-50.9403	10.3099	-45863.2	-45798.2	45812.26	-3.7213	45808.54
-0.02037	10.2918	-51.2033	10.0467	-45862.7	-45797.8	45811.5	-3.6273	45807.87
-0.01939	10.2654	-51.4317	9.8183	-45862.1	-45797.6	45810.67	-3.2943	45807.37
-0.01821	10.232	-51.6359	9.6141	-45861.5	-45797.4	45809.86	-2.8749	45806.99
-0.0168	10.201	-51.8168	9.4332	-45861	-45797.3	45809.18	-2.4868	45806.7
-0.01511	10.1722	-51.9755	9.2745	-45860.4	-45797	45808.42	-2.1272	45806.3
-0.01308	10.1426	-52.1122	9.1378	-45859.8	-45796.8	45807.69	-1.7599	45805.93
-0.01064	10.1143	-52.2285	9.0215	-45859.3	-45796.6	45807.07	-1.4083	45805.66
-0.00772	10.0952	-52.3187	8.9313	-45859	-45796.6	45806.68	-1.1722	45805.51
-0.00421	10.0835	-52.3816	8.8684	-45858.8	-45796.5	45806.42	-1.027	45805.39
-3.47E-18	10.0809	-52.4085	8.8415	-45858.8	-45796.6	45806.39	-0.9948	45805.4
0.004211	10.0862	-52.3816	8.8684	-45858.9	-45796.6	45806.52	-1.0607	45805.46
0.00772	10.0968	-52.319	8.931	-45859.1	-45796.7	45806.78	-1.192	45805.59
0.010644	10.1148	-52.2289	9.0211	-45859.4	-45796.7	45807.17	-1.4139	45805.76
0.013081	10.1396	-52.1125	9.1375	-45859.8	-45796.8	45807.69	-1.7227	45805.96
0.015112	10.1697	-51.9758	9.2742	-45860.4	-45797.1	45808.42	-2.0967	45806.33
0.016804	10.2013	-51.8171	9.4329	-45861	-45797.3	45809.18	-2.4912	45806.69
0.018214	10.2342	-51.6363	9.6137	-45861.6	-45797.4	45809.96	-2.9029	45807.06
0.019389	10.268	-51.4321	9.8179	-45862.2	-45797.6	45810.77	-3.3276	45807.44
0.020368	10.2928	-51.2039	10.0462	-45862.8	-45797.9	45811.6	-3.6392	45807.96
0.021184	10.2968	-50.9407	10.3095	-45863.3	-45798.4	45812.36	-3.6901	45808.67
0.021865	10.2657	-50.6335	10.617	-45863.8	-45799.3	45813.17	-3.2985	45809.87
0.022431	10.1856	-50.2762	10.9747	-45864.1	-45800.6	45813.82	-2.2953	45811.53
0.022904	10.0516	-49.8595	11.3921	-45864.4	-45802.5	45814.54	-0.6364	45813.9
0.023297	9.86254	-49.3698	11.8832	-45864.6	-45805	45815.23	1.6683	45816.9
0.023625	9.61731	-48.7903	12.4652	-45864.7	-45808	45815.91	4.5925	45820.5
0.023898	9.31287	-48.0982	13.1616	-45864.8	-45811.7	45816.7	8.1212	45824.82
0.024126	8.94145	-47.2693	13.9986	-45864.9	-45815.9	45817.63	12.274	45829.9
0.024316	8.48669	-46.2694	15.0119	-45864.9	-45820.7	45818.63	17.1292	45835.76
0.024474	7.92027	-45.0673	16.2406	-45864.9	-45826.4	45819.83	22.8261	45842.66
0.024606	7.19337	-43.5963	17.7576	-45865	-45833.2	45821.4	29.5601	45850.96
0.024716	6.22342	-41.8139	19.6488	-45865	-45841.1	45823.19	37.5559	45860.74
0.024807	4.90976	-39.5075	22.2074	-45865	-45849.9	45825.49	46.6126	45872.11
0.024884	3.27396	-36.8	25.3559	-45865	-45858	45828.2	55.12201	45883.32
0.024947	1.55294	-33.1155	24.3522	-45865	-45863.1	45831.88	55.55616	45887.44
0.025	0	-30.7964	22.5645	-45865	-45864.6	45834.2	52.98421	45887.19

Joe Joseph
2K14/ME/072

Ball Valve

Table D.7: Ball Valve throttled at 0 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	13.2006	25.7545	-3.98365	-3.83447	17.18425	12.40472	29.58897
-0.02495	0.984309	13.132	38.4116	-3.98363	-3.21316	17.11563	24.50913	41.62476
-0.02488	2.12824	12.9031	60.6623	-3.98362	-0.98299	16.88672	44.75857	61.64529
-0.02481	3.33689	12.5485	71.439	-3.98362	3.05296	16.53212	51.85392	68.38604
-0.02472	4.43888	12.1591	74.3725	-3.98365	8.23415	16.14275	49.9956	66.13835
-0.02461	5.33172	11.7594	74.372	-3.98374	13.51896	15.74314	45.1099	60.85304
-0.02447	6.03411	11.3306	73.8738	-3.98388	18.37512	15.31448	40.1842	55.49868
-0.02432	6.60008	10.8626	73.3046	-3.9841	22.7359	14.8467	35.722	50.5687
-0.02413	7.07043	10.3593	72.7058	-3.9844	26.6628	14.3437	31.6993	46.043
-0.0239	7.47224	9.83129	72.06179	-3.98477	30.23463	13.81606	28.0111	41.82716
-0.02363	7.82361	9.29188	71.37918	-3.98523	33.52147	13.27711	24.5806	37.85771
-0.0233	8.13693	8.75646	70.67716	-3.98576	36.58094	12.74222	21.354	34.09622
-0.0229	8.42089	8.23996	69.98696	-3.98636	39.45794	12.22632	18.3027	30.52902
-0.02243	8.68149	7.75532	69.34812	-3.98697	42.18553	11.74229	15.4203	27.16259
-0.02186	8.92185	7.31325	68.78855	-3.98757	44.77513	11.30082	12.7126	24.01342
-0.02118	9.14708	6.92276	68.31276	-3.988	47.2667	10.91076	10.1353	21.04606
-0.02037	9.37021	6.58852	67.91982	-3.9881	49.7977	10.57662	7.5455	18.12212
-0.01939	9.60196	6.30618	67.60378	-3.98779	52.49171	10.29397	4.8181	15.11207
-0.01821	9.84168	6.06616	67.34456	-3.98679	55.34801	10.05295	1.9436	11.99655
-0.0168	10.0826	5.86192	67.12852	-3.98439	58.28991	9.84631	-1.0077	8.83861
-0.01511	10.313	5.68913	66.94883	-3.98025	61.17135	9.66938	-3.8919	5.77748
-0.01308	10.5133	5.54388	66.79958	-3.97329	63.73061	9.51717	-6.4482	3.06897
-0.01064	10.6544	5.42422	66.67772	-3.96481	65.56519	9.38903	-8.2765	1.11253
-0.00772	10.7177	5.33132	66.58362	-3.9551	66.4026	9.28642	-9.1054	0.18102
-0.00421	10.7277	5.26863	66.52013	-3.94748	66.54162	9.21611	-9.2376	-0.02149
-3.47E-18	10.7261	5.24526	66.49636	-3.94556	66.52154	9.19082	-9.216	-0.02518
0.004211	10.7277	5.26863	66.52013	-3.94743	66.54157	9.21606	-9.2375	-0.02144
0.00772	10.7177	5.33132	66.58362	-3.955	66.4026	9.28632	-9.1053	0.18102
0.010644	10.6544	5.42421	66.67771	-3.96466	65.56494	9.38887	-8.2761	1.11277
0.013081	10.5132	5.54387	66.79957	-3.97312	63.73018	9.51699	-6.4476	3.06939
0.015112	10.3129	5.68912	66.94882	-3.98006	61.17064	9.66918	-3.891	5.77818
0.016804	10.0825	5.86192	67.12852	-3.98419	58.28891	9.84611	-1.0065	8.83961
0.018214	9.84154	6.06616	67.34456	-3.98658	55.34662	10.05274	1.9452	11.99794
0.019389	9.60179	6.30617	67.60377	-3.98758	52.49002	10.29375	4.82	15.11375
0.020368	9.37001	6.58852	67.91992	-3.98789	49.79561	10.57641	7.5479	18.12431
0.021184	9.14684	6.92276	68.31276	-3.98777	47.26423	10.91053	10.138	21.04853
0.021865	8.92159	7.31324	68.78854	-3.98734	44.77236	11.30058	12.7156	24.01618
0.022431	8.6812	7.75531	69.34811	-3.98675	42.18265	11.74206	15.4234	27.16546
0.022904	8.42059	8.23995	69.98695	-3.98613	39.45507	12.22608	18.3058	30.53188
0.023297	8.13661	8.75645	70.67715	-3.98554	36.57786	12.74199	21.3573	34.09929
0.023625	7.82327	9.29188	71.37928	-3.985	33.5185	13.27688	24.5839	37.86078
0.023898	7.47189	9.83128	72.06178	-3.98454	30.23166	13.81582	28.0143	41.83012
0.024126	7.07007	10.3593	72.7058	-3.98417	26.66003	14.34347	31.7023	46.04577
0.024316	6.59973	10.8626	73.3045	-3.98387	22.73333	14.84647	35.7247	50.57117
0.024474	6.03376	11.3306	73.8738	-3.98365	18.37285	15.31425	40.1867	55.50095
0.024606	5.33139	11.7594	74.372	-3.98351	13.51709	15.74291	45.112	60.85491
0.024716	4.43858	12.1591	74.3725	-3.98342	8.23268	16.14252	49.9973	66.13982
0.024807	3.33664	12.5485	71.439	-3.98339	3.05213	16.53189	51.85498	68.38687
0.024884	2.12806	12.9031	60.6623	-3.98338	-0.98324	16.88648	44.75906	61.64554
0.024947	0.984225	13.132	38.4116	-3.9834	-3.21306	17.1154	24.50926	41.62466
0.025	0	13.2006	25.7545	-3.98342	-3.83426	17.18402	12.40474	29.58876

Joe Joseph
2K14/ME/072

Table D.8: Ball Valve throttled at 14.64 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	42.8061	96.1361	-4.2889	-3.90782	47.095	52.94892	100.0439
-0.02495	1.56223	40.4965	97.9503	-4.28838	-2.35382	44.78488	55.51924	100.3041
-0.02488	3.29313	36.8243	98.9842	-4.28619	2.82981	41.11049	55.0439	96.15439
-0.02481	4.93633	34.122	95.8386	-4.27908	10.98572	38.40108	46.4518	84.85288
-0.02472	6.25325	31.8196	93.2834	-4.26857	19.86653	36.08817	37.3287	73.41687
-0.02461	7.22306	30.0401	91.3947	-4.25862	27.79698	34.29872	29.299	63.59772
-0.02447	7.94805	28.571	89.8793	-4.2437	34.5075	32.8147	22.5571	55.3718
-0.02432	8.51226	27.3703	88.6519	-4.21612	40.20198	31.58642	16.8635	48.44992
-0.02413	8.96567	26.371	87.6391	-4.17099	45.08851	30.54199	12.0086	42.55059
-0.0239	9.33644	25.5423	86.8023	-4.10267	49.30513	29.64497	7.8522	37.49717
-0.02363	9.63976	24.8501	86.1057	-3.99732	52.93018	28.84742	4.3281	33.17552
-0.0233	9.88337	24.2705	85.5236	-3.84956	55.98684	28.12006	1.4167	29.53676
-0.0229	10.0699	23.7808	85.0325	-3.63899	58.47361	27.41979	-0.8609	26.55889
-0.02243	10.2001	23.364	84.6149	-3.35054	60.37686	26.71454	-2.4765	24.23804
-0.02186	10.2754	23.0066	84.2571	-2.9818	61.688	25.9884	-3.4193	22.5691
-0.02118	10.3013	22.6994	83.9497	-2.49878	62.49812	25.19818	-3.7466	21.45158
-0.02037	10.2929	22.4361	83.6862	-1.93381	62.95659	24.36991	-3.6403	20.72961
-0.01939	10.2644	22.208	83.458	-1.33173	63.19987	23.53973	-3.2816	20.25813
-0.01821	10.2282	22.0038	83.2538	-0.71122	63.36688	22.71502	-2.8281	19.88692
-0.0168	10.1939	21.8226	83.0726	-0.11343	63.53557	21.93603	-2.399	19.53703
-0.01511	10.1618	21.6634	82.9134	0.487976	63.73668	21.17542	-1.9987	19.17672
-0.01308	10.1324	21.5269	82.7769	1.03245	63.91505	20.49445	-1.6326	18.86185
-0.01064	10.1079	21.4166	82.6666	1.43364	64.01264	19.98296	-1.329	18.65396
-0.00772	10.0901	21.336	82.586	1.72592	64.08462	19.61008	-1.1087	18.50138
-0.00421	10.0798	21.28	82.53	1.96954	64.20124	19.31046	-0.9817	18.32876
-3.47E-18	10.0773	21.2448	82.4948	2.15127	64.35197	19.09353	-0.9507	18.14283
0.004211	10.0844	21.2477	82.4977	2.16369	64.45159	19.08401	-1.0379	18.04611
0.00772	10.0978	21.2959	82.5459	1.97003	64.42453	19.32587	-1.2045	18.12137
0.010644	10.1184	21.3853	82.6353	1.60901	64.31791	19.77629	-1.4589	18.31739
0.013081	10.1457	21.5034	82.7534	1.11208	64.16048	20.39132	-1.7984	18.59292
0.015112	10.1768	21.642	82.892	0.503986	63.93969	21.13801	-2.1857	18.95231
0.016804	10.2078	21.802	83.052	-0.11465	63.70775	21.91665	-2.5724	19.34425
0.018214	10.2396	21.9831	83.2331	-0.70748	63.51282	22.69058	-2.9703	19.72028
0.019389	10.2716	22.187	83.437	-1.30168	63.32072	23.48868	-3.3724	20.11628
0.020368	10.2945	22.415	83.665	-1.86389	63.04701	24.27889	-3.6609	20.61799
0.021184	10.2975	22.6778	83.928	-2.38365	62.56485	25.06145	-3.6983	21.36315
0.021865	10.2673	22.9845	84.2349	-2.81479	61.75321	25.79929	-3.3176	22.48169
0.022431	10.1916	23.3413	84.5921	-3.14862	60.47268	26.48992	-2.3705	24.11942
0.022904	10.0649	23.7575	85.009	-3.41176	58.63884	27.16926	-0.7991	26.37016
0.023297	9.88445	24.2468	85.4996	-3.60322	56.24588	27.85002	1.4037	29.25372
0.023625	9.64881	24.826	86.0812	-3.74443	53.28937	28.57043	4.2214	32.79183
0.023898	9.35388	25.5179	86.7775	-3.84605	49.76055	29.36395	7.653	37.01695
0.024126	8.9909	26.3465	87.6142	-3.91665	45.61945	30.26315	11.7316	41.99475
0.024316	8.54352	27.346	88.6272	-3.96642	40.77748	31.31242	16.5373	47.84972
0.024474	7.98256	28.5471	89.8552	-4.00026	35.08734	32.54736	22.2205	54.76786
0.024606	7.25743	30.0165	91.3711	-4.02102	28.33988	34.03752	28.9937	63.03122
0.024716	6.28458	31.7962	93.2603	-4.03341	20.34369	35.82961	37.087	72.91661
0.024807	4.96247	34.0984	95.8155	-4.04437	11.38173	38.14277	46.291	84.43377
0.024884	3.31181	36.8002	98.9604	-4.05165	3.1445	40.85185	54.96405	95.8159
0.024947	1.57177	40.4711	97.9216	-4.05386	-2.09599	44.52496	55.49263	100.0176
0.025	0	42.7797	96.1038	-4.05437	-3.66828	46.83407	52.93801	99.77208

Joe Joseph
2K14/ME/072

Table D.9: Ball Valve throttled at 31.7 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	167.324	220.6439	3.97817	4.356857	163.3458	52.94121	216.287
-0.02495	1.55631	165.019	222.4676	3.97795	5.89732	161.0411	55.52923	216.5703
-0.02488	3.27795	161.354	223.5135	3.97767	11.02657	157.3763	55.1106	212.4869
-0.02481	4.91048	158.655	220.37	3.98006	19.08446	154.6749	46.6106	201.2855
-0.02472	6.22018	156.355	217.8178	3.98463	27.86583	152.3704	37.5816	189.952
-0.02461	7.18749	154.578	215.9315	3.98798	35.72938	150.59	29.6121	180.2021
-0.02447	7.91268	153.111	214.4184	3.99336	42.40126	149.1176	22.8995	172.0171
-0.02432	8.47787	151.911	213.1919	4.01275	48.07305	147.8983	17.2206	165.1189
-0.02413	8.93224	150.913	212.1807	4.05322	52.94632	146.8598	12.3746	159.2344
-0.0239	9.3043	150.084	211.3437	4.11886	57.15986	145.9651	8.2187	154.1838
-0.02363	9.60946	149.391	210.6464	4.22595	60.79655	145.1651	4.6848	149.8499
-0.0233	9.85588	148.811	210.0639	4.3801	63.8844	144.4309	1.7486	146.1795
-0.0229	10.0463	148.319	209.5706	4.60426	66.42706	143.7147	-0.5712	143.1435
-0.02243	10.182	147.901	209.1519	4.91504	68.41604	142.986	-2.2501	140.7359
-0.02186	10.2639	147.542	208.7925	5.30531	69.83171	142.2367	-3.2759	138.9608
-0.02118	10.296	147.232	208.4822	5.82166	70.75136	141.4103	-3.6795	137.7308
-0.02037	10.2917	146.966	208.2161	6.43345	71.30915	140.5326	-3.6256	136.907
-0.01939	10.2656	146.736	207.986	7.08457	71.63177	139.6514	-3.2972	136.3542
-0.01821	10.23	146.529	207.779	7.76081	71.86131	138.7682	-2.8505	135.9177
-0.0168	10.1954	146.34	207.59	8.42263	72.08933	137.9174	-2.4167	135.5007
-0.01511	10.1637	146.17	207.42	9.04952	72.32162	137.1205	-2.0221	135.0984
-0.01308	10.1356	146.025	207.275	9.58204	72.50434	136.443	-1.6723	134.7707
-0.01064	10.1121	145.899	207.149	9.98732	72.61842	135.9117	-1.3811	134.5306
-0.00772	10.095	145.835	207.085	10.2751	72.6945	135.5599	-1.1694	134.3905
-0.00421	10.085	145.95	207.1998	10.456	72.7511	135.494	-1.0453	134.4487
-3.47E-18	10.0823	146.186	207.4356	10.5221	72.7848	135.6639	-1.0131	134.6508
0.004211	10.0885	146.377	207.6268	10.4546	72.7937	135.9224	-1.0893	134.8331
0.00772	10.102	146.466	207.7161	10.2643	72.7699	136.2017	-1.2555	134.9462
0.010644	10.1224	146.491	207.7413	9.96384	72.72254	136.5272	-1.5084	135.0188
0.013081	10.1482	146.552	207.8022	9.55287	72.63137	136.9991	-1.8283	135.1708
0.015112	10.1748	146.67	207.92	9.02596	72.43636	137.644	-2.1604	135.4836
0.016804	10.2014	146.82	208.0699	8.43602	72.17802	138.384	-2.4921	135.8919
0.018214	10.2311	147.003	208.2529	7.82995	71.94335	139.1731	-2.8635	136.3096
0.019389	10.2631	147.212	208.4618	7.21074	71.72624	140.0013	-3.2657	136.7356
0.020368	10.2879	147.448	208.6979	6.6145	71.4416	140.8335	-3.5772	137.2563
0.021184	10.2938	147.718	208.9681	6.05461	70.95601	141.6634	-3.6513	138.0121
0.021865	10.2668	148.029	209.2793	5.58074	70.14234	142.4483	-3.3113	139.137
0.022431	10.1938	148.39	209.6406	5.21563	68.86413	143.1744	-2.3979	140.7765
0.022904	10.069	148.809	210.0603	4.92691	67.02821	143.8821	-0.85	143.0321
0.023297	9.88948	149.3	210.5525	4.71839	64.62839	144.5816	1.3425	145.9241
0.023625	9.65362	149.88	211.1349	4.56858	61.65938	145.3114	4.1641	149.4755
0.023898	9.3577	150.571	211.8301	4.46226	58.11276	146.1087	7.6086	153.7173
0.024126	8.99309	151.399	212.666	4.39089	53.95129	147.0081	11.7066	158.7147
0.024316	8.54361	152.398	213.6783	4.34182	49.08692	148.0562	16.5352	164.5914
0.024474	7.97992	153.598	214.905	4.31087	43.37327	149.2871	22.2446	171.5317
0.024606	7.2517	155.065	216.4185	4.29574	36.60644	150.7693	29.0428	179.8121
0.024716	6.27725	156.842	218.3051	4.28793	28.60873	152.5541	37.1423	189.6964
0.024807	4.95676	159.142	220.8579	4.28097	19.67077	154.861	46.3261	201.1871
0.024884	3.30905	161.841	224.0017	4.27749	11.4611	157.5635	54.97709	212.5406
0.024947	1.57069	165.505	222.9508	4.2774	6.23273	161.2276	55.49047	216.7181
0.025	0	167.809	221.1226	4.27758	4.663014	163.5314	52.92817	216.4596

Joe Joseph
2K14/ME/072

Table D.10: Ball Valve throttled at 50 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	619.262	672.5857	64.1802	64.5572	555.0818	52.9467	608.0285
-0.02495	1.55086	616.963	674.4147	64.1792	66.08414	552.7838	55.54676	608.33056
-0.02488	3.26252	613.305	675.4639	64.1748	71.15526	549.1302	55.17844	604.30864
-0.02481	4.88424	610.611	672.3217	64.1689	79.1118	546.4421	46.7678	593.2099
-0.02472	6.18923	608.316	669.7767	64.164	87.81	544.152	37.8147	581.9667
-0.02461	7.15899	606.543	667.8955	64.1603	95.6525	542.3827	29.8603	572.243
-0.02447	7.88874	605.079	666.3859	64.1619	102.3389	540.9171	23.1299	564.047
-0.02432	8.45755	603.882	665.1626	64.1814	108.0314	539.7006	17.4306	557.1312
-0.02413	8.91462	602.885	664.1525	64.2262	112.927	538.6588	12.5667	551.2255
-0.0239	9.28906	602.057	663.3166	64.3001	117.1678	537.7569	8.3919	546.1488
-0.02363	9.59657	601.366	662.6213	64.4207	120.8399	536.9453	4.8361	541.7814
-0.0233	9.84557	600.786	662.0389	64.5908	123.9709	536.1952	1.8728	538.068
-0.0229	10.0387	600.297	661.5486	64.8356	126.5643	535.4614	-0.4771	534.9843
-0.02243	10.177	599.88	661.1309	65.1662	128.6056	534.7138	-2.1885	532.5253
-0.02186	10.2615	599.523	660.7735	65.5722	130.0678	533.9508	-3.2451	530.7057
-0.02118	10.2955	599.216	660.4662	66.1063	131.0297	533.1097	-3.6732	529.4365
-0.02037	10.2927	598.953	660.2031	66.7401	131.6282	532.2129	-3.638	528.5749
-0.01939	10.2678	598.725	659.975	67.4231	131.9975	531.3019	-3.3244	527.9775
-0.01821	10.2332	598.521	659.771	68.1428	132.2831	530.3782	-2.8903	527.4879
-0.0168	10.1989	598.338	659.588	68.8439	132.5552	529.4941	-2.4613	527.0328
-0.01511	10.1667	598.18	659.43	69.486	132.7947	528.694	-2.0587	526.6353
-0.01308	10.1371	598.043	659.293	70.0108	132.9518	528.0322	-1.691	526.3412
-0.01064	10.113	597.913	659.163	70.3688	133.0104	527.5442	-1.3916	526.1526
-0.00772	10.0967	597.795	659.045	70.602	133.0417	527.193	-1.1897	526.0033
-0.00421	10.0878	597.737	658.987	70.7958	133.1261	526.9412	-1.0803	525.8609
-3.47E-18	10.0859	597.784	659.034	70.833	133.1403	526.951	-1.0573	525.8937
0.004211	10.0909	597.894	659.144	70.6677	133.036	527.2263	-1.1183	526.108
0.00772	10.1021	597.984	659.234	70.4458	132.9531	527.5382	-1.2573	526.2809
0.010644	10.1214	598.058	659.3081	70.1643	132.9104	527.8937	-1.496	526.3977
0.013081	10.1475	598.16	659.41	69.7869	132.8567	528.3731	-1.8198	526.5533
0.015112	10.176	598.298	659.548	69.32	132.7457	528.978	-2.1757	526.8023
0.016804	10.2034	598.456	659.706	68.7906	132.5579	529.6654	-2.5173	527.1481
0.018214	10.2326	598.636	659.8859	68.2178	132.35	530.4182	-2.8823	527.5359
0.019389	10.2644	598.84	660.0899	67.608	132.1394	531.232	-3.2815	527.9505
0.020368	10.2886	599.069	660.319	67.0094	131.8452	532.0596	-3.5858	528.4738
0.021184	10.2931	599.332	660.5821	66.4409	131.3337	532.8911	-3.6427	529.2484
0.021865	10.2638	599.638	660.8883	65.9586	130.4832	533.6794	-3.2743	530.4051
0.022431	10.1881	599.995	661.2456	65.5873	129.1643	534.4077	-2.3264	532.0813
0.022904	10.0609	600.411	661.6621	65.2884	127.2904	535.1226	-0.7509	534.3717
0.023297	9.87984	600.9	662.1522	65.0702	124.8635	535.8298	1.4589	537.2887
0.023625	9.64316	601.478	662.7324	64.9125	121.8796	536.5655	4.2873	540.8528
0.023898	9.34718	602.169	663.4273	64.7995	118.3294	537.3695	7.7284	545.0979
0.024126	8.98325	602.995	664.2609	64.7237	114.1757	538.2713	11.8139	550.0852
0.024316	8.53511	603.992	665.2707	64.6718	109.3278	539.3202	16.6227	555.9429
0.024474	7.97334	605.189	666.4939	64.6378	103.6355	540.5512	22.3072	562.8584
0.024606	7.24668	606.653	668.0037	64.6184	96.8843	542.0346	29.0848	571.1194
0.024716	6.27193	608.427	669.8869	64.6082	88.8887	543.8188	37.1794	580.9982
0.024807	4.95057	610.722	672.4332	64.6021	79.9546	546.1199	46.3587	592.4786
0.024884	3.30451	613.418	675.5781	64.6016	71.76466	548.8164	54.99704	603.81344
0.024947	1.56954	617.074	674.522	64.6044	66.55596	552.4696	55.49644	607.96604
0.025	0	619.373	672.6887	64.6055	64.99126	554.7675	52.929938	607.697438

Joe Joseph
2K14/ME/072

Table D11: Ball Valve throttled at 68.3 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	1783.14	1836.478	-99.6263	-99.2456	1882.766	52.957233	1935.72353
-0.02495	1.55631	1780.85	1838.31	-99.6286	-97.7112	1880.479	55.54293	1936.02153
-0.02488	3.26971	1777.2	1839.357	-99.6381	-92.6293	1876.838	55.14836	1931.98646
-0.02481	4.89115	1774.51	1836.214	-99.6523	-84.6682	1874.162	46.7202	1920.8825
-0.02472	6.20029	1772.22	1833.678	-99.6644	-75.9316	1871.884	37.725	1909.6094
-0.02461	7.17941	1770.45	1831.801	-99.6673	-67.9932	1870.117	29.6768	1899.7941
-0.02447	7.91688	1768.99	1830.296	-99.6531	-61.2027	1868.643	22.8555	1891.4986
-0.02432	8.48812	1767.8	1829.08	-99.6155	-55.4483	1867.416	17.1126	1884.5281
-0.02413	8.94294	1766.81	1828.077	-99.5509	-50.5408	1866.361	12.2568	1878.6177
-0.0239	9.31184	1765.98	1827.24	-99.4578	-46.3314	1865.438	8.1331	1873.5709
-0.02363	9.61174	1765.3	1826.555	-99.3243	-42.7274	1864.624	4.6585	1869.2828
-0.0233	9.85172	1764.73	1825.983	-99.1465	-39.6928	1863.877	1.7993	1865.6758
-0.0229	10.0356	1764.25	1825.502	-98.9094	-37.2187	1863.159	-0.4391	1862.7203
-0.02243	10.1658	1763.85	1825.101	-98.597	-35.298	1862.447	-2.0481	1860.3989
-0.02186	10.2451	1763.51	1824.761	-98.2197	-33.9301	1861.73	-3.039	1858.6907
-0.02118	10.2782	1763.22	1824.47	-97.7349	-33.0298	1860.955	-3.4547	1857.5002
-0.02037	10.2774	1762.98	1824.23	-97.1504	-32.4552	1860.13	-3.4451	1856.6853
-0.01939	10.2568	1762.77	1824.02	-96.5075	-32.0715	1859.278	-3.1859	1856.0916
-0.01821	10.2276	1762.58	1823.83	-95.8086	-31.7383	1858.389	-2.8201	1855.5685
-0.0168	10.1979	1762.45	1823.7	-95.087	-31.3886	1857.537	-2.4481	1855.0889
-0.01511	10.1686	1762.34	1823.59	-94.3549	-31.0215	1856.695	-2.0833	1854.6116
-0.01308	10.1412	1762.24	1823.49	-93.6254	-30.6328	1855.865	-1.7424	1854.123
-0.01064	10.1178	1762.21	1823.46	-92.9044	-30.2028	1855.114	-1.4516	1853.6628
-0.00772	10.0998	1762.08	1823.33	-92.3224	-29.8436	1854.402	-1.2292	1853.1732
-0.00421	10.0887	1761.47	1822.72	-92.1922	-29.8511	1853.662	-1.0914	1852.5708
-3.47E-18	10.0857	1760.38	1821.63	-92.6496	-30.345	1853.03	-1.0543	1851.9753
0.004211	10.0913	1759.51	1820.761	-93.2751	-30.902	1852.785	-1.1225	1851.6626
0.00772	10.103	1759.38	1820.63	-93.6202	-31.1017	1853	-1.2685	1851.7317
0.010644	10.123	1759.7	1820.949	-93.7559	-30.9893	1853.456	-1.5173	1851.9386
0.013081	10.1493	1760.01	1821.259	-93.8985	-30.8064	1853.909	-1.8427	1852.0658
0.015112	10.1778	1760.21	1821.46	-94.1852	-30.7374	1854.395	-2.1981	1852.1971
0.016804	10.2051	1760.39	1821.64	-94.6241	-30.8354	1855.014	-2.5388	1852.4753
0.018214	10.2343	1760.56	1821.81	-95.1611	-31.0076	1855.721	-2.9035	1852.8176
0.019389	10.2657	1760.74	1821.99	-95.764	-31.2156	1856.504	-3.2983	1853.2057
0.020368	10.2888	1760.95	1822.2	-96.3672	-31.5277	1857.317	-3.5893	1853.7279
0.021184	10.2917	1761.2	1822.45	-96.9461	-32.0701	1858.146	-3.6258	1854.5203
0.021865	10.2607	1761.49	1822.741	-97.4414	-32.9562	1858.931	-3.2347	1855.6967
0.022431	10.1831	1761.83	1823.081	-97.8227	-34.307	1859.653	-2.2648	1857.3879
0.022904	10.0549	1762.23	1823.482	-98.1334	-36.2051	1860.363	-0.6766	1859.6868
0.023297	9.87346	1762.7	1823.953	-98.3643	-38.6481	1861.064	1.5367	1862.601
0.023625	9.6366	1763.27	1824.525	-98.5323	-41.6426	1861.802	4.3653	1866.1676
0.023898	9.34063	1763.95	1825.209	-98.6554	-45.2004	1862.605	7.8037	1870.4091
0.024126	8.97677	1764.77	1826.036	-98.7383	-49.3577	1863.508	11.8855	1875.3938
0.024316	8.52866	1765.76	1827.038	-98.7952	-54.2066	1864.555	16.6896	1881.2448
0.024474	7.96671	1766.95	1828.253	-98.832	-59.8989	1865.782	22.3698	1888.1518
0.024606	7.23943	1768.4	1829.747	-98.8542	-66.6524	1867.254	29.1456	1896.3998
0.024716	6.26348	1770.17	1831.625	-98.8655	-74.6494	1869.036	37.2392	1906.2747
0.024807	4.94253	1772.46	1834.163	-98.8691	-83.5659	1871.329	46.4	1917.7291
0.024884	3.29974	1775.15	1837.308	-98.8648	-91.7239	1874.015	55.01664	1929.03144
0.024947	1.56846	1778.8	1836.257	-98.8586	-96.9104	1877.659	55.50853	1933.16713
0.025	0	1781.09	1834.421	-98.8563	-98.4703	1879.946	52.944815	1932.89112

Joe Joseph
2K14/ME/072

Table D.12: Ball Valve throttled at 85.36 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	7298.35	7351.688	-4182.81	-4182.42	11481.16	52.95086	11534.11
-0.02495	1.56823	7296.06	7353.52	-4182.81	-4180.86	11478.87	55.51375	11534.38
-0.02488	3.29438	7292.41	7354.566	-4182.82	-4175.7	11475.23	55.04106	11530.27
-0.02481	4.92979	7289.72	7351.422	-4182.83	-4167.61	11472.55	46.4792	11519.03
-0.02472	6.24898	7287.44	7348.897	-4182.84	-4158.73	11470.28	37.3506	11507.63
-0.02461	7.2277	7285.67	7347.021	-4182.83	-4150.73	11468.5	29.2521	11497.75
-0.02447	7.95556	7284.21	7345.516	-4182.8	-4143.98	11467.01	22.4814	11489.49
-0.02432	8.51561	7283.02	7344.299	-4182.76	-4138.31	11465.78	16.827	11482.61
-0.02413	8.96068	7282.02	7343.286	-4182.7	-4133.5	11464.72	12.0629	11476.78
-0.0239	9.32128	7281.2	7342.459	-4182.61	-4129.38	11463.81	8.0254	11471.84
-0.02363	9.61428	7280.51	7341.765	-4182.49	-4125.86	11463	4.6286	11467.63
-0.0233	9.84866	7279.93	7341.183	-4182.32	-4122.9	11462.25	1.8362	11464.09
-0.0229	10.0286	7279.45	7340.701	-4182.09	-4120.49	11461.54	-0.3527	11461.19
-0.02243	10.1566	7279.03	7340.281	-4181.79	-4118.6	11460.82	-1.9347	11458.89
-0.02186	10.2361	7278.68	7339.931	-4181.43	-4117.25	11460.11	-2.9259	11457.18
-0.02118	10.2711	7278.38	7339.63	-4180.96	-4116.34	11459.34	-3.3657	11455.97
-0.02037	10.2727	7278.12	7339.37	-4180.39	-4115.75	11458.51	-3.3857	11455.12
-0.01939	10.2541	7277.89	7339.14	-4179.74	-4115.34	11457.63	-3.1528	11454.48
-0.01821	10.2262	7277.69	7338.94	-4179.03	-4114.98	11456.72	-2.8028	11453.92
-0.0168	10.1972	7277.52	7338.77	-4178.33	-4114.64	11455.85	-2.44	11453.41
-0.01511	10.1682	7277.37	7338.62	-4177.71	-4114.38	11455.08	-2.0773	11453
-0.01308	10.1394	7277.23	7338.48	-4177.33	-4114.36	11454.56	-1.7197	11452.84
-0.01064	10.1167	7277.19	7338.44	-4177.07	-4114.38	11454.26	-1.4376	11452.82
-0.00772	10.1012	7277.23	7338.48	-4176.69	-4114.19	11453.92	-1.2463	11452.67
-0.00421	10.091	7277.16	7338.41	-4176.22	-4113.85	11453.38	-1.1199	11452.26
-3.47E-18	10.0953	7276.87	7338.12	-4176.14	-4113.72	11453.01	-1.173	11451.84
0.004211	10.1003	7276.55	7337.8	-4176.3	-4113.82	11452.85	-1.2347	11451.62
0.00772	10.1065	7276.51	7337.76	-4176.04	-4113.48	11452.55	-1.3113	11451.24
0.010644	10.1235	7276.7	7337.95	-4175.83	-4113.06	11452.53	-1.522	11451.01
0.013081	10.1457	7276.88	7338.13	-4176.04	-4112.99	11452.92	-1.7978	11451.12
0.015112	10.1711	7277.02	7338.27	-4176.57	-4113.21	11453.59	-2.1145	11451.48
0.016804	10.197	7277.19	7338.44	-4177.24	-4113.55	11454.43	-2.4366	11451.99
0.018214	10.2253	7277.36	7338.61	-4177.9	-4113.86	11455.26	-2.791	11452.47
0.019389	10.2559	7277.55	7338.8	-4178.56	-4114.13	11456.11	-3.1754	11452.93
0.020368	10.2783	7277.77	7339.02	-4179.19	-4114.48	11456.96	-3.4563	11453.5
0.021184	10.2804	7278.03	7339.28	-4179.78	-4115.05	11457.81	-3.4834	11454.33
0.021865	10.2486	7278.33	7339.58	-4180.28	-4115.95	11458.61	-3.0832	11455.53
0.022431	10.1704	7278.68	7339.931	-4180.66	-4117.3	11459.34	-2.1064	11457.23
0.022904	10.042	7279.09	7340.342	-4180.97	-4119.2	11460.06	-0.5175	11459.54
0.023297	9.86053	7279.58	7340.833	-4181.21	-4121.65	11460.79	1.6931	11462.48
0.023625	9.62373	7280.15	7341.405	-4181.38	-4124.64	11461.53	4.517	11466.05
0.023898	9.32784	7280.84	7342.099	-4181.5	-4128.19	11462.34	7.9501	11470.29
0.024126	8.96418	7281.66	7342.927	-4181.59	-4132.35	11463.25	12.0243	11475.27
0.024316	8.51644	7282.66	7343.939	-4181.65	-4137.19	11464.31	16.8181	11481.13
0.024474	7.95492	7283.85	7345.155	-4181.68	-4142.86	11465.53	22.4865	11488.02
0.024606	7.22794	7285.3	7346.648	-4181.71	-4149.61	11467.01	29.2484	11496.26
0.024716	6.25221	7287.07	7348.525	-4181.72	-4157.59	11468.79	37.325	11506.12
0.024807	4.93276	7289.35	7351.051	-4181.72	-4166.48	11471.07	46.4582	11517.53
0.024884	3.29337	7292.04	7354.198	-4181.72	-4174.61	11473.76	55.04511	11528.81
0.024947	1.56597	7295.69	7353.147	-4181.71	-4179.77	11477.4	55.51538	11532.92
0.025	0	7297.98	7351.31	-4181.7	-4181.31	11479.68	52.94433	11532.62

Joe Joseph
2K14/ME/072

Table D.13: Ball Valve throttled at 96.72 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	42141.2	42194.54	-51449.3	-51448.9	93590.5	52.95382	93643.45
-0.02495	1.56802	42138.9	42196.36	-51449.3	-51447.4	93588.2	55.51418	93643.71
-0.02488	3.29934	42135.3	42197.45	-51449.3	-51442.2	93584.6	55.01553	93639.62
-0.02481	4.9403	42132.6	42194.3	-51449.3	-51434	93581.9	46.4111	93628.31
-0.02472	6.25948	42130.3	42191.76	-51449.3	-51425.1	93579.6	37.2712	93616.87
-0.02461	7.23369	42128.6	42189.95	-51449.3	-51417.1	93577.9	29.1976	93607.1
-0.02447	7.95917	42127.1	42188.4	-51449.3	-51410.4	93576.4	22.4445	93598.84
-0.02432	8.52034	42125.9	42187.18	-51449.3	-51404.8	93575.2	16.7791	93591.98
-0.02413	8.9678	42124.9	42186.17	-51449.2	-51399.9	93574.1	11.9859	93586.09
-0.0239	9.33069	42124.1	42185.36	-51449.1	-51395.8	93573.2	7.9172	93581.12
-0.02363	9.62584	42123.4	42184.65	-51449	-51392.2	93572.4	4.4923	93576.89
-0.0233	9.86208	42122.8	42184.05	-51448.9	-51389.3	93571.7	1.6732	93573.37
-0.0229	10.0437	42122.3	42183.55	-51448.6	-51386.8	93570.9	-0.5421	93570.36
-0.02243	10.1724	42121.9	42183.15	-51448.4	-51385	93570.3	-2.1321	93568.17
-0.02186	10.2505	42121.5	42182.75	-51448.1	-51383.7	93569.6	-3.1066	93566.49
-0.02118	10.2827	42121.2	42182.45	-51447.6	-51382.8	93568.8	-3.5107	93565.29
-0.02037	10.2816	42121	42182.25	-51447.1	-51382.4	93568.1	-3.4966	93564.6
-0.01939	10.2602	42120.8	42182.05	-51446.5	-51382	93567.3	-3.229	93564.07
-0.01821	10.2299	42120.6	42181.85	-51445.9	-51381.8	93566.5	-2.8493	93563.65
-0.0168	10.1999	42120.4	42181.65	-51445.2	-51381.5	93565.6	-2.4731	93563.13
-0.01511	10.1711	42120.2	42181.45	-51444.5	-51381.1	93564.7	-2.1136	93562.59
-0.01308	10.142	42120.1	42181.35	-51443.8	-51380.8	93563.9	-1.7513	93562.15
-0.01064	10.1167	42120	42181.25	-51443.2	-51380.5	93563.2	-1.4382	93561.76
-0.00772	10.0993	42119.9	42181.15	-51442.6	-51380.1	93562.5	-1.2231	93561.28
-0.00421	10.0893	42119.8	42181.05	-51442.2	-51379.9	93562	-1.0977	93560.9
-3.47E-18	10.0859	42119.8	42181.05	-51442.2	-51379.9	93562	-1.0562	93560.94
0.004211	10.0894	42119.7	42180.95	-51442.5	-51380.1	93562.2	-1.1013	93561.1
0.00772	10.0986	42119.7	42180.95	-51442.8	-51380.3	93562.5	-1.2144	93561.29
0.010644	10.1193	42119.8	42181.05	-51443.1	-51380.4	93562.9	-1.4696	93561.43
0.013081	10.1492	42119.9	42181.15	-51443.4	-51380.3	93563.3	-1.8413	93561.46
0.015112	10.1805	42120	42181.25	-51443.9	-51380.4	93563.9	-2.232	93561.67
0.016804	10.2099	42120.2	42181.45	-51444.4	-51380.6	93564.6	-2.5985	93562
0.018214	10.2395	42120.4	42181.65	-51445	-51380.8	93565.4	-2.9696	93562.43
0.019389	10.2694	42120.6	42181.85	-51445.6	-51381	93566.2	-3.3445	93562.86
0.020368	10.2879	42120.8	42182.05	-51446.2	-51381.4	93567	-3.578	93563.42
0.021184	10.2847	42121.1	42182.35	-51446.7	-51381.9	93567.8	-3.537	93564.26
0.021865	10.2464	42121.4	42182.65	-51447.2	-51382.9	93568.6	-3.0564	93565.54
0.022431	10.1627	42121.7	42182.95	-51447.5	-51384.2	93569.2	-2.0104	93567.19
0.022904	10.0304	42122.1	42183.35	-51447.8	-51386.2	93569.9	-0.3748	93569.53
0.023297	9.84797	42122.6	42183.85	-51448	-51388.6	93570.6	1.8454	93572.45
0.023625	9.61172	42123.2	42184.45	-51448.2	-51391.6	93571.4	4.6566	93576.06
0.023898	9.31665	42123.9	42185.16	-51448.3	-51395.1	93572.2	8.0761	93580.28
0.024126	8.95449	42124.7	42185.97	-51448.4	-51399.3	93573.1	12.1315	93585.23
0.024316	8.50835	42125.7	42186.98	-51448.5	-51404.1	93574.2	16.9034	93591.1
0.024474	7.94899	42126.9	42188.2	-51448.5	-51409.7	93575.4	22.544	93597.94
0.024606	7.22476	42128.4	42189.75	-51448.5	-51416.4	93576.9	29.2786	93606.18
0.024716	6.25208	42130.1	42191.56	-51448.6	-51424.5	93578.7	37.3317	93616.03
0.024807	4.93576	42132.4	42194.1	-51448.6	-51433.3	93581	46.4452	93627.45
0.024884	3.29765	42135.1	42197.26	-51448.5	-51441.4	93583.6	55.02747	93638.63
0.024947	1.56835	42138.8	42196.26	-51448.5	-51446.6	93587.3	55.50976	93642.81
0.025	0	42141	42194.33	-51448.5	-51448.1	93589.5	52.94358	93642.44

Joe Joseph
2K14/ME/072

Gate Valve

Table D.14: Gate Valve throttled at 0 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	13.2006	25.7545	-3.98365	-3.83447	17.18425	12.40472	29.58897
-0.02495	0.984309	13.132	38.4116	-3.98363	-3.21316	17.11563	24.50913	41.62476
-0.02488	2.12824	12.9031	60.6623	-3.98362	-0.98299	16.88672	44.75857	61.64529
-0.02481	3.33689	12.5485	71.439	-3.98362	3.05296	16.53212	51.85392	68.38604
-0.02472	4.43888	12.1591	74.3725	-3.98365	8.23415	16.14275	49.9956	66.13835
-0.02461	5.33172	11.7594	74.372	-3.98374	13.51896	15.74314	45.1099	60.85304
-0.02447	6.03411	11.3306	73.8738	-3.98388	18.37512	15.31448	40.1842	55.49868
-0.02432	6.60008	10.8626	73.3046	-3.9841	22.7359	14.8467	35.722	50.5687
-0.02413	7.07043	10.3593	72.7058	-3.9844	26.6628	14.3437	31.6993	46.043
-0.0239	7.47224	9.83129	72.06179	-3.98477	30.23463	13.81606	28.0111	41.82716
-0.02363	7.82361	9.29188	71.37918	-3.98523	33.52147	13.27711	24.5806	37.85771
-0.0233	8.13693	8.75646	70.67716	-3.98576	36.58094	12.74222	21.354	34.09622
-0.0229	8.42089	8.23996	69.98696	-3.98636	39.45794	12.22632	18.3027	30.52902
-0.02243	8.68149	7.75532	69.34812	-3.98697	42.18553	11.74229	15.4203	27.16259
-0.02186	8.92185	7.31325	68.78855	-3.98757	44.77513	11.30082	12.7126	24.01342
-0.02118	9.14708	6.92276	68.31276	-3.988	47.2667	10.91076	10.1353	21.04606
-0.02037	9.37021	6.58852	67.91982	-3.9881	49.7977	10.57662	7.5455	18.12212
-0.01939	9.60196	6.30618	67.60378	-3.98779	52.49171	10.29397	4.8181	15.11207
-0.01821	9.84168	6.06616	67.34456	-3.98679	55.34801	10.05295	1.9436	11.99655
-0.0168	10.0826	5.86192	67.12852	-3.98439	58.28991	9.84631	-1.0077	8.83861
-0.01511	10.313	5.68913	66.94883	-3.98025	61.17135	9.66938	-3.8919	5.77748
-0.01308	10.5133	5.54388	66.79958	-3.97329	63.73061	9.51717	-6.4482	3.06897
-0.01064	10.6544	5.42422	66.67772	-3.96481	65.56519	9.38903	-8.2765	1.11253
-0.00772	10.7177	5.33132	66.58362	-3.9551	66.4026	9.28642	-9.1054	0.18102
-0.00421	10.7277	5.26863	66.52013	-3.94748	66.54162	9.21611	-9.2376	-0.02149
-3.47E-18	10.7261	5.24526	66.49636	-3.94556	66.52154	9.19082	-9.216	-0.02518
0.004211	10.7277	5.26863	66.52013	-3.94743	66.54157	9.21606	-9.2375	-0.02144
0.00772	10.7177	5.33132	66.58362	-3.955	66.4026	9.28632	-9.1053	0.18102
0.010644	10.6544	5.42421	66.67771	-3.96466	65.56494	9.38887	-8.2761	1.11277
0.013081	10.5132	5.54387	66.79957	-3.97312	63.73018	9.51699	-6.4476	3.06939
0.015112	10.3129	5.68912	66.94882	-3.98006	61.17064	9.66918	-3.891	5.77818
0.016804	10.0825	5.86192	67.12852	-3.98419	58.28891	9.84611	-1.0065	8.83961
0.018214	9.84154	6.06616	67.34456	-3.98658	55.34662	10.05274	1.9452	11.99794
0.019389	9.60179	6.30617	67.60377	-3.98758	52.49002	10.29375	4.82	15.11375
0.020368	9.37001	6.58852	67.91992	-3.98789	49.79561	10.57641	7.5479	18.12431
0.021184	9.14684	6.92276	68.31276	-3.98777	47.26423	10.91053	10.138	21.04853
0.021865	8.92159	7.31324	68.78854	-3.98734	44.77236	11.30058	12.7156	24.01618
0.022431	8.6812	7.75531	69.34811	-3.98675	42.18265	11.74206	15.4234	27.16546
0.022904	8.42059	8.23995	69.98695	-3.98613	39.45507	12.22608	18.3058	30.53188
0.023297	8.13661	8.75645	70.67715	-3.98554	36.57786	12.74199	21.3573	34.09929
0.023625	7.82327	9.29188	71.37928	-3.985	33.5185	13.27688	24.5839	37.86078
0.023898	7.47189	9.83128	72.06178	-3.98454	30.23166	13.81582	28.0143	41.83012
0.024126	7.07007	10.3593	72.7058	-3.98417	26.66003	14.34347	31.7023	46.04577
0.024316	6.59973	10.8626	73.3045	-3.98387	22.73333	14.84647	35.7247	50.57117
0.024474	6.03376	11.3306	73.8738	-3.98365	18.37285	15.31425	40.1867	55.50095
0.024606	5.33139	11.7594	74.372	-3.98351	13.51709	15.74291	45.112	60.85491
0.024716	4.43858	12.1591	74.3725	-3.98342	8.23268	16.14252	49.9973	66.13982
0.024807	3.33664	12.5485	71.439	-3.98339	3.05213	16.53189	51.85498	68.38687
0.024884	2.12806	12.9031	60.6623	-3.98338	-0.98324	16.88648	44.75906	61.64554
0.024947	0.984225	13.132	38.4116	-3.9834	-3.21306	17.1154	24.50926	41.62466
0.025	0	13.2006	25.7545	-3.98342	-3.83426	17.18402	12.40474	29.58876

Joe Joseph
2K14/ME/072

Table D.15: Gate Valve throttled at 16.67 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	52.4506	105.7995	9.59833	9.973666	42.85227	52.97356	95.82583
-0.02495	1.55181	50.1291	107.5906	9.60004	11.50965	40.52906	55.55189	96.08095
-0.02488	3.27775	46.4404	108.599	9.60696	16.66156	36.83344	55.104	91.93744
-0.02481	4.92591	43.7303	105.45	9.62074	24.82704	34.10956	46.5134	80.62296
-0.02472	6.25153	41.4212	102.8868	9.63963	33.76413	31.78157	37.3411	69.12267
-0.02461	7.2273	39.6359	100.992	9.66149	41.75559	29.97441	29.262	59.23641
-0.02447	7.95532	38.1626	99.4721	9.68477	48.50717	28.47783	22.4871	50.96493
-0.02432	8.52011	36.9586	98.2411	9.71184	54.21174	27.24676	16.7826	44.02936
-0.02413	8.97253	35.9575	97.2261	9.74804	59.08274	26.20946	11.9339	38.14336
-0.0239	9.34163	35.1277	96.388	9.79986	63.26686	25.32784	7.7933	33.12114
-0.02363	9.64333	34.4351	95.6909	9.87655	66.84615	24.55855	4.2862	28.84475
-0.0233	9.8854	33.8552	95.1083	9.98834	69.84924	23.86686	1.3922	25.25906
-0.0229	10.0705	33.3652	94.6169	10.1483	72.2688	23.2169	-0.8688	22.3481
-0.02243	10.1988	32.9481	94.1991	10.3809	74.0914	22.5672	-2.4595	20.1077
-0.02186	10.2719	32.5903	93.8408	10.6871	75.313	21.9032	-3.3754	18.5278
-0.02118	10.2971	32.2827	93.533	11.0976	76.0407	21.1851	-3.6928	17.4923
-0.02037	10.289	32.0191	93.2692	11.5867	76.4286	20.4324	-3.5918	16.8406
-0.01939	10.2629	31.7906	93.0406	12.1043	76.617	19.6863	-3.2627	16.4236
-0.01821	10.2299	31.5861	92.8361	12.6421	76.7409	18.944	-2.8488	16.0952
-0.0168	10.1984	31.4049	92.6549	13.1645	76.869	18.2404	-2.4545	15.7859
-0.01511	10.1694	31.2459	92.4959	13.6952	77.0378	17.5507	-2.0926	15.4581
-0.01308	10.1418	31.1086	92.3586	14.2096	77.2088	16.899	-1.7492	15.1498
-0.01064	10.117	30.9919	92.2419	14.6076	77.2997	16.3843	-1.4421	14.9422
-0.00772	10.098	30.9014	92.1514	14.8618	77.3187	16.0396	-1.2069	14.8327
-0.00421	10.0857	30.839	92.089	14.9724	77.2762	15.8666	-1.0538	14.8128
-3.47E-18	10.0806	30.8133	92.0633	14.9605	77.2017	15.8528	-0.9912	14.8616
0.004211	10.0834	30.8413	92.0913	14.8788	77.1542	15.9625	-1.0254	14.9371
0.00772	10.094	30.905	92.155	14.733	77.1397	16.172	-1.1567	15.0153
0.010644	10.1113	30.9954	92.2454	14.4968	77.1178	16.4986	-1.371	15.1276
0.013081	10.1341	31.1117	92.3617	14.1401	77.0442	16.9716	-1.6541	15.3175
0.015112	10.1603	31.2485	92.4985	13.6648	76.8945	17.5837	-1.9797	15.604
0.016804	10.1892	31.4073	92.6573	13.1544	76.7441	18.2529	-2.3397	15.9132
0.018214	10.2214	31.5885	92.8385	12.6469	76.6392	18.9416	-2.7423	16.1993
0.019389	10.2564	31.793	93.043	12.1119	76.5434	19.6811	-3.1815	16.4996
0.020368	10.2865	32.0217	93.2718	11.5838	76.3934	20.4379	-3.5595	16.8784
0.021184	10.2993	32.2852	93.5354	11.0801	76.0518	21.2051	-3.7215	17.4836
0.021865	10.2795	32.5927	93.8432	10.6464	75.3686	21.9463	-3.4717	18.4746
0.022431	10.2102	32.9504	94.2013	10.3215	74.1746	22.6289	-2.6022	20.0267
0.022904	10.083	33.3675	94.6192	10.0801	72.3543	23.2874	-1.0225	22.2649
0.023297	9.8971	33.8575	95.1106	9.91344	69.91624	23.94406	1.2503	25.19436
0.023625	9.65336	34.4376	95.6933	9.80192	66.89022	24.63568	4.1674	28.80308
0.023898	9.35021	35.1303	96.3906	9.72546	63.29076	25.40484	7.695	33.09984
0.024126	8.98016	35.9601	97.2287	9.67467	59.09327	26.28543	11.85	38.13543
0.024316	8.52709	36.9613	98.2438	9.6389	54.2117	27.3224	16.7097	44.0321
0.024474	7.96168	38.1654	99.4749	9.61169	48.49619	28.55371	22.425	50.97871
0.024606	7.233	39.6389	100.995	9.58815	41.73295	30.05075	29.2113	59.26205
0.024716	6.25643	41.4244	102.89	9.56583	33.72813	31.85857	37.3033	69.16187
0.024807	4.92962	43.7338	105.4536	9.54656	24.77586	34.18724	46.4905	80.67774
0.024884	3.27975	46.444	108.6026	9.53248	16.59617	36.91152	55.09491	92.00643
0.024947	1.55238	50.1331	107.5941	9.52534	11.43651	40.60776	55.54983	96.15759
0.025	0	52.4549	105.8031	9.52357	9.899086	42.93133	52.97268	95.90401

Joe Joseph
2K14/ME/072

Table D.16: Gate Valve throttled at 33.34 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	136.352	189.7064	21.9834	22.35747	114.3686	52.98033	167.3489
-0.02495	1.5491	134.03	191.4941	21.985	23.88791	112.045	55.56119	167.6062
-0.02488	3.27197	130.341	192.4985	21.9916	29.02133	108.3494	55.12777	163.4772
-0.02481	4.91734	127.631	189.3495	22.0048	37.1584	105.6262	46.5649	152.1911
-0.02472	6.24091	125.322	186.7869	22.0227	46.0653	103.2993	37.4223	140.7216
-0.02461	7.21531	123.537	184.8926	22.0433	54.0311	101.4937	29.3678	130.8615
-0.02447	7.94278	122.064	183.3732	22.0653	60.7655	99.9987	22.609	122.6077
-0.02432	8.50794	120.86	182.1422	22.0911	66.4642	98.7689	16.9091	115.678
-0.02413	8.96142	119.859	181.1274	22.1267	71.3394	97.7323	12.0557	109.788
-0.0239	9.33186	119.029	180.2891	22.1782	75.5336	96.8508	7.9047	104.7555
-0.02363	9.63489	118.337	179.5927	22.2558	79.1259	96.0812	4.3856	100.4668
-0.0233	9.87833	117.757	179.0101	22.3681	82.1436	95.3889	1.4776	96.8665
-0.0229	10.0649	117.267	178.5187	22.5294	84.581	94.7376	-0.7999	93.9377
-0.02243	10.195	116.85	178.1009	22.7626	86.4256	94.0874	-2.4121	91.6753
-0.02186	10.2701	116.492	177.7425	23.0688	87.6727	93.4232	-3.3534	90.0698
-0.02118	10.297	116.185	177.4353	23.4786	88.4205	92.7064	-3.6916	89.0148
-0.02037	10.29	115.921	177.1711	23.9678	88.8218	91.9532	-3.6039	88.3493
-0.01939	10.2645	115.693	176.943	24.4861	89.0186	91.2069	-3.2825	87.9244
-0.01821	10.2319	115.488	176.738	25.0226	89.1462	90.4654	-2.8736	87.5918
-0.0168	10.2011	115.307	176.557	25.5443	89.2821	89.7627	-2.4878	87.2749
-0.01511	10.1731	115.148	176.398	26.079	89.4685	89.069	-2.1395	86.9295
-0.01308	10.1465	115.011	176.261	26.6101	89.6685	88.4009	-1.8084	86.5925
-0.01064	10.1222	114.894	176.144	27.0744	89.8307	87.8196	-1.5063	86.3133
-0.00772	10.1027	114.803	176.053	27.4791	89.9931	87.3239	-1.264	86.0599
-0.00421	10.0895	114.738	175.988	27.8265	90.1778	86.9115	-1.1013	85.8102
-3.47E-18	10.0833	114.711	175.961	28.0036	90.2786	86.7074	-1.025	85.6824
0.004211	10.0848	114.74	175.99	27.8921	90.1859	86.8479	-1.0438	85.8041
0.00772	10.094	114.804	176.054	27.5629	89.9696	87.2411	-1.1567	86.0844
0.010644	10.1103	114.896	176.146	27.1444	89.7535	87.7516	-1.3591	86.3925
0.013081	10.1323	115.012	176.262	26.6934	89.5745	88.3186	-1.6311	86.6875
0.015112	10.158	115.149	176.399	26.1916	89.3925	88.9574	-1.9509	87.0065
0.016804	10.1868	115.308	176.558	25.6725	89.2317	89.6355	-2.3092	87.3263
0.018214	10.2191	115.489	176.739	25.1616	89.1251	90.3274	-2.7135	87.6139
0.019389	10.2544	115.694	176.944	24.6227	89.0284	91.0713	-3.1557	87.9156
0.020368	10.2843	115.923	177.173	24.0902	88.8724	91.8328	-3.5322	88.3006
0.021184	10.2963	116.186	177.4362	23.5854	88.5194	92.6006	-3.6838	88.9168
0.021865	10.2752	116.493	177.7435	23.1501	87.8179	93.3429	-3.4173	89.9256
0.022431	10.2037	116.851	178.1018	22.8232	86.5957	94.0278	-2.5217	91.5061
0.022904	10.0741	117.268	178.5196	22.5802	84.7445	94.6878	-0.9127	93.7751
0.023297	9.88565	117.758	179.011	22.4101	82.2743	95.3479	1.3888	96.7367
0.023625	9.63898	118.338	179.5936	22.2978	79.2164	96.0402	4.337	100.3772
0.023898	9.3328	119.031	180.2911	22.2207	75.5871	96.8103	7.8937	104.704
0.024126	8.96021	119.86	181.1284	22.1712	71.3708	97.6888	12.0688	109.7576
0.024316	8.50581	120.862	182.1443	22.1369	66.4878	98.7251	16.9314	115.6565
0.024474	7.94046	122.066	183.3753	22.1114	60.7891	99.9546	22.6316	122.5862
0.024606	7.21304	123.539	184.8949	22.0893	54.057	101.4497	29.3882	130.8379
0.024716	6.23878	125.324	186.7893	22.0682	46.0945	103.2558	37.439	140.6948
0.024807	4.91536	127.633	189.3524	22.0497	37.1913	105.5833	46.5778	152.1611
0.024884	3.27012	130.343	192.5015	22.036	29.05824	108.307	55.13626	163.4433
0.024947	1.54788	134.031	191.4923	22.0292	23.92927	112.0018	55.56123	167.563
0.025	0	136.353	189.7015	22.0276	22.40097	114.3254	52.97513	167.3005

Joe Joseph
2K14/ME/072

Table D.17: Gate Valve throttled at 50 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	552.61	605.965	246.903	247.2762	305.707	52.981847	358.688847
-0.02495	1.5471	550.288	607.7524	246.905	248.803	303.383	55.56645	358.94945
-0.02488	3.26746	546.6	608.7574	246.911	253.9212	299.689	55.14722	354.83622
-0.02481	4.91022	543.89	605.6081	246.924	262.0336	296.966	46.6085	343.5745
-0.02472	6.23173	541.582	603.0466	246.941	270.9129	294.641	37.4927	332.1337
-0.02461	7.20477	539.797	601.1524	246.961	278.8556	292.836	29.4608	322.2968
-0.02447	7.93183	538.324	599.6329	246.982	285.5758	291.342	22.7151	314.0571
-0.02432	8.49755	537.12	598.402	247.008	291.273	290.112	17.017	307.129
-0.02413	8.95198	536.119	597.3873	247.044	296.1534	289.075	12.1589	301.2339
-0.0239	9.32337	535.289	596.549	247.097	300.3555	288.192	8.0015	296.1935
-0.02363	9.62731	534.597	595.8526	247.177	303.9577	287.42	4.4749	291.8949
-0.0233	9.87176	534.017	595.27	247.292	306.9881	286.725	1.5569	288.2819
-0.0229	10.0596	533.527	594.7787	247.457	309.4426	286.07	-0.7339	285.3361
-0.02243	10.1911	533.11	594.3609	247.695	311.3103	285.415	-2.3644	283.0506
-0.02186	10.2681	532.752	594.0025	248.006	312.5845	284.746	-3.328	281.418
-0.02118	10.2965	532.445	593.6953	248.421	313.3567	284.024	-3.6854	280.3386
-0.02037	10.2904	532.181	593.4311	248.918	313.7773	283.263	-3.6092	279.6538
-0.01939	10.2652	531.953	593.203	249.447	313.9895	282.506	-3.2925	279.2135
-0.01821	10.2326	531.748	592.998	249.996	314.1288	281.752	-2.8828	278.8692
-0.0168	10.2017	531.567	592.817	250.532	314.2774	281.035	-2.4954	278.5396
-0.01511	10.1736	531.408	592.658	251.081	314.4764	280.327	-2.1454	278.1816
-0.01308	10.1468	531.271	592.521	251.612	314.6735	279.659	-1.8115	277.8475
-0.01064	10.1221	531.154	592.404	252.015	314.7705	279.139	-1.5055	277.6335
-0.00772	10.1026	531.064	592.314	252.236	314.7487	278.828	-1.2627	277.5653
-0.00421	10.0903	531.001	592.251	252.209	314.5699	278.792	-1.1109	277.6811
-3.47E-18	10.0846	530.974	592.224	251.973	314.264	279.001	-1.041	277.96
0.004211	10.0863	531.001	592.251	251.674	313.9859	279.327	-1.0619	278.2651
0.00772	10.0958	531.064	592.3139	251.391	313.8198	279.673	-1.1789	278.4941
0.010644	10.1119	531.155	592.405	251.123	313.7517	280.032	-1.3787	278.6533
0.013081	10.1342	531.271	592.521	250.793	313.6983	280.478	-1.6553	278.8227
0.015112	10.1601	531.408	592.658	250.348	313.5749	281.06	-1.9769	279.0831
0.016804	10.1889	531.567	592.817	249.839	313.4246	281.728	-2.3356	279.3924
0.018214	10.2213	531.748	592.998	249.307	313.2984	282.441	-2.7414	279.6996
0.019389	10.2567	531.953	593.203	248.747	313.182	283.206	-3.185	280.021
0.020368	10.2864	532.181	593.431	248.194	313.0027	283.987	-3.5587	280.4283
0.021184	10.2977	532.445	593.6952	247.672	312.6228	284.773	-3.7006	281.0724
0.021865	10.2752	532.752	594.0024	247.224	311.8921	285.528	-3.4177	282.1103
0.022431	10.2019	533.109	594.3598	246.889	310.6384	286.22	-2.4986	283.7214
0.022904	10.0701	533.526	594.7775	246.639	308.7548	286.887	-0.8643	286.0227
0.023297	9.87949	534.016	595.2688	246.464	306.2539	287.552	1.4629	289.0149
0.023625	9.63039	534.596	595.8513	246.349	303.1665	288.247	4.4378	292.6848
0.023898	9.32158	535.289	596.5488	246.27	299.5085	289.019	8.0213	297.0403
0.024126	8.94631	536.118	597.3862	246.221	295.2686	289.897	12.2206	302.1176
0.024316	8.48978	537.12	598.402	246.189	290.3733	290.931	17.0977	308.0287
0.024474	7.92357	538.323	599.6321	246.166	284.6796	292.157	22.7955	314.9525
0.024606	7.19671	539.797	601.1526	246.146	277.9694	293.651	29.5322	323.1832
0.024716	6.2241	541.582	603.047	246.126	270.0395	295.456	37.5515	333.0075
0.024807	4.90336	543.89	605.6089	246.109	261.177	297.781	46.6509	344.4319
0.024884	3.26199	546.6	608.7583	246.096	253.0834	300.504	55.17094	355.67494
0.024947	1.54406	550.288	607.75	246.09	247.9807	304.198	55.57132	359.76932
0.025	0	552.609	605.9589	246.088	246.4595	306.521	52.978352	359.499352

Joe Joseph
2K14/ME/072

Table D18: Gate Valve throttled at 66.67 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	75.8438	129.1999	-806.678	-806.307	882.5218	52.985005	935.506805
-0.02495	1.54277	73.5227	130.9878	-806.677	-804.79	880.1997	55.57777	935.77747
-0.02488	3.25839	69.8348	131.9919	-806.671	-799.7	876.5058	55.18568	931.69148
-0.02481	4.89697	67.1253	128.8429	-806.659	-791.631	873.7843	46.6892	920.4735
-0.02472	6.21556	64.8167	126.281	-806.642	-782.794	871.4587	37.6164	909.0751
-0.02461	7.18724	63.0321	124.3872	-806.624	-774.884	869.6561	29.6153	899.2714
-0.02447	7.91426	61.559	122.8677	-806.604	-768.181	868.163	22.8853	891.0483
-0.02432	8.48065	60.3553	121.637	-806.578	-762.489	866.9333	17.1923	884.1256
-0.02413	8.93588	59.3543	120.6224	-806.542	-757.609	865.8963	12.3351	878.2314
-0.0239	9.30814	58.5246	119.7845	-806.487	-753.402	865.0116	8.1752	873.1868
-0.02363	9.61309	57.8319	119.0874	-806.404	-749.791	864.2359	4.6423	868.8782
-0.0233	9.85879	57.2517	118.5047	-806.286	-746.747	863.5377	1.7136	865.2513
-0.0229	10.0481	56.7613	118.0129	-806.115	-744.271	862.8763	-0.5928	862.2835
-0.02243	10.1815	56.3437	117.5946	-805.872	-742.377	862.2157	-2.2446	859.9711
-0.02186	10.2606	55.9858	117.2363	-805.558	-741.073	861.5438	-3.2341	858.3097
-0.02118	10.2908	55.6778	116.9281	-805.137	-740.273	860.8148	-3.6135	857.2013
-0.02037	10.2858	55.414	116.6641	-804.629	-739.828	860.043	-3.5514	856.4916
-0.01939	10.2611	55.1856	116.4356	-804.091	-739.601	859.2766	-3.2398	856.0368
-0.01821	10.2282	54.9822	116.2322	-803.531	-739.454	858.5132	-2.827	855.6862
-0.0168	10.1968	54.7968	116.0468	-802.991	-739.307	857.7878	-2.4341	855.3537
-0.01511	10.1683	54.6335	115.8835	-802.452	-739.123	857.0855	-2.0792	855.0063
-0.01308	10.1413	54.4973	115.7473	-801.954	-738.961	856.4513	-1.7432	854.7081
-0.01064	10.1169	54.3805	115.6305	-801.576	-738.886	855.9565	-1.4401	854.5164
-0.00772	10.098	54.279	115.529	-801.305	-738.848	855.584	-1.2068	854.3772
-0.00421	10.0863	54.2011	115.4511	-801.127	-738.815	855.3281	-1.0617	854.2664
-3.47E-18	10.0834	54.1986	115.4486	-801.076	-738.8	855.2746	-1.026	854.2486
0.004211	10.0905	54.2428	115.4929	-801.17	-738.806	855.4128	-1.1141	854.2987
0.00772	10.104	54.293	115.543	-801.399	-738.869	855.692	-1.2803	854.4117
0.010644	10.122	54.3792	115.6292	-801.734	-738.98	856.1132	-1.5037	854.6095
0.013081	10.144	54.4901	115.7401	-802.149	-739.123	856.6391	-1.7764	854.8627
0.015112	10.1686	54.6194	115.8694	-802.643	-739.31	857.2624	-2.0833	855.1791
0.016804	10.1959	54.7718	116.0218	-803.177	-739.503	857.9488	-2.4237	855.5251
0.018214	10.2271	54.9489	116.1989	-803.727	-739.663	858.6759	-2.8139	855.862
0.019389	10.2618	55.1499	116.3999	-804.294	-739.795	859.4439	-3.2495	856.1944
0.020368	10.2914	55.3755	116.6255	-804.851	-739.98	860.2265	-3.6212	856.6053
0.021184	10.3025	55.6359	116.8861	-805.372	-740.36	861.0079	-3.7617	857.2462
0.021865	10.2801	55.9409	117.1913	-805.82	-741.09	861.7609	-3.4792	858.2817
0.022431	10.2069	56.2963	117.5471	-806.158	-742.346	862.4543	-2.5615	859.8928
0.022904	10.0749	56.7114	117.9628	-806.411	-744.236	863.1224	-0.9232	862.1992
0.023297	9.88337	57.1997	118.4524	-806.591	-746.754	863.7907	1.4159	865.2066
0.023625	9.63281	57.7782	119.0334	-806.71	-749.864	864.4882	4.409	868.8972
0.023898	9.32211	58.4697	119.7293	-806.79	-753.545	865.2597	8.0148	873.2745
0.024126	8.94471	59.2987	120.5666	-806.839	-757.809	866.1377	12.2376	878.3753
0.024316	8.48614	60.2994	121.5811	-806.87	-762.723	867.1694	17.1349	884.3043
0.024474	7.91857	61.5029	122.8117	-806.891	-768.426	868.3939	22.8435	891.2374
0.024606	7.19149	62.9757	124.331	-806.909	-775.132	869.8847	29.578	899.4627
0.024716	6.21976	64.7604	126.2251	-806.927	-783.047	871.6874	37.5847	909.2721
0.024807	4.90053	67.0687	128.7872	-806.943	-791.893	874.0117	46.6683	920.68
0.024884	3.26061	69.7778	131.9361	-806.955	-799.974	876.7328	55.17714	931.90994
0.024947	1.54359	73.465	130.9273	-806.961	-805.072	880.426	55.57283	935.99883
0.025	0	75.7856	129.1356	-806.963	-806.592	882.7486	52.978612	935.727212

Joe Joseph
2K14/ME/072

Table D.19: Gate Valve throttled at 83.34 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	38.2713	91.6275	-3644.27	-3643.9	3682.541	52.98555	3735.527
-0.02495	1.54173	35.9506	93.4157	-3644.27	-3642.39	3680.221	55.58038	3735.801
-0.02488	3.25595	32.2634	94.4202	-3644.26	-3637.3	3676.523	55.19598	3731.719
-0.02481	4.89301	29.5543	91.2714	-3644.25	-3629.25	3673.804	46.7131	3720.517
-0.02472	6.21061	27.2461	88.7101	-3644.24	-3620.43	3671.486	37.6539	3709.14
-0.02461	7.18247	25.4618	86.8165	-3644.22	-3612.52	3669.682	29.6567	3699.339
-0.02447	7.91051	23.989	85.2974	-3644.2	-3605.81	3668.189	22.9211	3691.11
-0.02432	8.4781	22.7857	84.0672	-3644.17	-3600.11	3666.956	17.2185	3684.174
-0.02413	8.93447	21.785	83.0529	-3644.14	-3595.22	3665.925	12.3502	3678.275
-0.0239	9.3078	20.9557	82.2155	-3644.08	-3591	3665.036	8.1789	3673.215
-0.02363	9.61386	20.2633	81.5187	-3643.99	-3587.37	3664.253	4.6331	3668.886
-0.0233	9.86065	19.6837	80.9366	-3643.87	-3584.31	3663.554	1.6909	3665.245
-0.0229	10.051	19.1939	80.4455	-3643.7	-3581.82	3662.894	-0.6287	3662.265
-0.02243	10.1855	18.777	80.0278	-3643.46	-3579.91	3662.237	-2.2944	3659.943
-0.02186	10.2656	18.4194	79.6699	-3643.14	-3578.59	3661.559	-3.2967	3658.263
-0.02118	10.2966	18.112	79.3622	-3642.72	-3577.78	3660.832	-3.6876	3657.144
-0.02037	10.2926	17.8486	79.0987	-3642.21	-3577.32	3660.059	-3.6365	3656.422
-0.01939	10.2687	17.62	78.87	-3641.68	-3577.09	3659.3	-3.3364	3655.964
-0.01821	10.2365	17.4156	78.6656	-3641.11	-3576.93	3658.526	-2.9318	3655.594
-0.0168	10.2061	17.2344	78.4844	-3640.57	-3576.77	3657.804	-2.5513	3655.253
-0.01511	10.1778	17.0754	78.3254	-3639.98	-3576.53	3657.055	-2.1973	3654.858
-0.01308	10.1512	16.9383	78.1883	-3639.29	-3576.17	3656.228	-1.8658	3654.363
-0.01064	10.1269	16.8215	78.0715	-3638.78	-3575.97	3655.602	-1.565	3654.037
-0.00772	10.1053	16.7307	77.9807	-3638.5	-3575.95	3655.231	-1.2962	3653.935
-0.00421	10.0923	16.6676	77.9176	-3638.27	-3575.88	3654.938	-1.1356	3653.802
-3.47E-18	10.0856	16.641	77.891	-3637.69	-3575.39	3654.331	-1.0533	3653.278
0.004211	10.0862	16.6686	77.9186	-3637.39	-3575.08	3654.059	-1.0605	3652.998
0.00772	10.0958	16.7317	77.9817	-3637.76	-3575.33	3654.492	-1.179	3653.313
0.010644	10.1144	16.8217	78.0717	-3638.08	-3575.42	3654.902	-1.4098	3653.492
0.013081	10.1375	16.9381	78.1881	-3638.28	-3575.33	3655.218	-1.6958	3653.522
0.015112	10.1636	17.0751	78.3251	-3638.61	-3575.34	3655.685	-2.0205	3653.665
0.016804	10.1912	17.2339	78.4839	-3639.08	-3575.47	3656.314	-2.3646	3653.949
0.018214	10.2215	17.4151	78.6651	-3639.62	-3575.63	3657.035	-2.7432	3654.292
0.019389	10.2549	17.6196	78.8696	-3640.19	-3575.78	3657.81	-3.1627	3654.647
0.020368	10.2821	17.8482	79.0982	-3640.73	-3575.98	3658.578	-3.505	3655.073
0.021184	10.2911	18.1115	79.3617	-3641.24	-3576.37	3659.352	-3.6182	3655.733
0.021865	10.2665	18.4187	79.6692	-3641.67	-3577.11	3660.089	-3.3074	3656.781
0.022431	10.1921	18.7761	80.0269	-3641.99	-3578.36	3660.766	-2.376	3658.39
0.022904	10.0607	19.1928	80.4443	-3642.23	-3580.23	3661.423	-0.7479	3660.675
0.023297	9.87095	19.6823	80.9351	-3642.4	-3582.71	3662.082	1.5664	3663.649
0.023625	9.62238	20.2617	81.5169	-3642.52	-3585.8	3662.782	4.5322	3667.314
0.023898	9.31267	20.9537	82.2132	-3642.6	-3589.46	3663.554	8.1226	3671.676
0.024126	8.93451	21.7829	83.0506	-3642.65	-3593.73	3664.433	12.3489	3676.782
0.024316	8.47374	22.7838	84.0651	-3642.69	-3598.67	3665.474	17.2629	3682.737
0.024474	7.90389	23.9875	85.2959	-3642.71	-3604.39	3666.698	22.985	3689.683
0.024606	7.17584	25.4605	86.8155	-3642.72	-3611.08	3668.181	29.7154	3697.896
0.024716	6.20495	27.245	88.7095	-3642.74	-3618.97	3669.985	37.6978	3707.683
0.024807	4.88843	29.5533	91.2715	-3642.76	-3627.78	3672.313	46.7421	3719.055
0.024884	3.25249	32.2623	94.4211	-3642.77	-3635.82	3675.032	55.21239	3730.245
0.024947	1.53978	35.9492	93.4124	-3642.77	-3640.89	3678.719	55.58308	3734.302
0.025	0	38.2696	91.6207	-3642.77	-3642.4	3681.04	52.98151	3734.021

Joe Joseph
2K14/ME/072

Table D.20: Gate Valve throttled at 96.72 per cent.

Nodal Points	Outlet Velocity	Inlet		Outlet		Pressure difference		
		Static Pressure	Total Pressure	Static Pressure	Total Pressure	Static Pressure	Dynamic Pressure	Total Pressure
-0.025	0	63978.3	64031.66	68.3986	68.76856	63909.9	52.98524	63962.89
-0.02495	1.54039	63976	64033.47	68.3999	70.2814	63907.6	55.5841	63963.18
-0.02488	3.25319	63972.3	64034.46	68.4052	75.35424	63903.89	55.21216	63959.11
-0.02481	4.88899	63969.6	64031.32	68.4162	83.3956	63901.18	46.7402	63947.92
-0.02472	6.20584	63967.3	64028.76	68.4309	92.2046	63898.87	37.6889	63936.56
-0.02461	7.17765	63965.5	64026.85	68.4473	100.103	63897.05	29.6991	63926.75
-0.02447	7.90598	63964.1	64025.41	68.4661	106.8096	63895.63	22.9646	63918.6
-0.02432	8.47378	63962.9	64024.18	68.4906	112.5089	63894.41	17.2611	63911.67
-0.02413	8.93019	63961.9	64023.17	68.5277	117.3986	63893.37	12.3948	63905.77
-0.0239	9.30344	63961	64022.26	68.5827	121.6139	63892.42	8.2277	63900.65
-0.02363	9.60922	63960.3	64021.56	68.6673	125.235	63891.63	4.6889	63896.32
-0.0233	9.85572	63959.7	64020.95	68.788	128.2903	63890.91	1.752	63892.66
-0.0229	10.0458	63959.3	64020.55	68.9604	130.7766	63890.34	-0.5658	63889.77
-0.02243	10.1801	63958.8	64020.05	69.2068	132.6848	63889.59	-2.2278	63887.37
-0.02186	10.2603	63958.5	64019.75	69.5219	134.0025	63888.98	-3.2306	63885.75
-0.02118	10.2914	63958.2	64019.45	69.9464	134.8185	63888.25	-3.6217	63884.63
-0.02037	10.2874	63957.9	64019.15	70.4561	135.2779	63887.44	-3.5713	63883.87
-0.01939	10.2634	63957.7	64018.95	70.9999	135.5197	63886.7	-3.2686	63883.43
-0.01821	10.2315	63957.5	64018.75	71.5586	135.677	63885.94	-2.8678	63883.07
-0.0168	10.2007	63957.3	64018.55	72.1059	135.8393	63885.19	-2.4846	63882.71
-0.01511	10.1727	63957.1	64018.35	72.6515	136.0357	63884.45	-2.1333	63882.32
-0.01308	10.1457	63957	64018.25	73.1667	136.2152	63883.83	-1.7965	63882.04
-0.01064	10.1218	63956.9	64018.15	73.5604	136.3112	63883.34	-1.4997	63881.84
-0.00772	10.1035	63956.8	64018.05	73.8249	136.3497	63882.98	-1.2743	63881.7
-0.00421	10.0937	63956.8	64018.05	73.9868	136.39	63882.81	-1.1528	63881.66
-3.47E-18	10.0864	63956.7	64017.95	74.1093	136.4228	63882.59	-1.0636	63881.53
0.004211	10.0863	63956.7	64017.95	74.0924	136.4038	63882.61	-1.0612	63881.55
0.00772	10.0985	63956.8	64018.05	73.8885	136.3511	63882.91	-1.2122	63881.7
0.010644	10.116	63956.9	64018.15	73.5889	136.2683	63883.31	-1.4279	63881.88
0.013081	10.14	63957	64018.25	73.1688	136.1461	63883.83	-1.7264	63882.1
0.015112	10.1664	63957.1	64018.35	72.6466	135.9516	63884.45	-2.0549	63882.4
0.016804	10.1948	63957.3	64018.55	72.0806	135.7406	63885.22	-2.4104	63882.81
0.018214	10.2257	63957.4	64018.65	71.5222	135.5678	63885.88	-2.7963	63883.08
0.019389	10.2588	63957.6	64018.85	70.9514	135.4126	63886.65	-3.2111	63883.44
0.020368	10.2856	63957.9	64019.15	70.406	135.2051	63887.49	-3.55	63883.94
0.021184	10.2942	63958.1	64019.35	69.8945	134.8013	63888.21	-3.6572	63884.55
0.021865	10.269	63958.5	64019.75	69.4645	134.055	63889.04	-3.3402	63885.7
0.022431	10.1952	63958.8	64020.05	69.1438	132.8095	63889.66	-2.4154	63887.24
0.022904	10.0655	63959.2	64020.45	68.8968	130.9553	63890.3	-0.8084	63889.49
0.023297	9.8781	63959.7	64020.95	68.7236	128.4963	63890.98	1.4818	63892.46
0.023625	9.63268	63960.3	64021.56	68.6024	125.4466	63891.7	4.4125	63896.11
0.023898	9.32665	63961	64022.26	68.5186	121.8147	63892.48	7.9636	63900.45
0.024126	8.95247	63961.8	64023.07	68.4627	117.5778	63893.34	12.1536	63905.49
0.024316	8.49469	63962.8	64024.08	68.4255	112.6613	63894.37	17.0472	63911.42
0.024474	7.92545	63964	64025.31	68.4001	106.9326	63895.6	22.778	63918.38
0.024606	7.19561	63965.5	64026.86	68.3807	100.1949	63897.12	29.5446	63926.66
0.024716	6.22204	63967.3	64028.77	68.3634	92.2611	63898.94	37.5697	63936.51
0.024807	4.90235	63969.6	64031.32	68.348	83.4092	63901.25	46.6603	63947.91
0.024884	3.26203	63972.3	64034.46	68.3364	75.32357	63903.96	55.16963	63959.13
0.024947	1.54428	63976	64033.46	68.3308	70.22198	63907.67	55.56952	63963.24
0.025	0	63978.3	64031.65	68.3295	68.70121	63909.97	52.98149	63962.95

Joe Joseph
2K14/ME/072