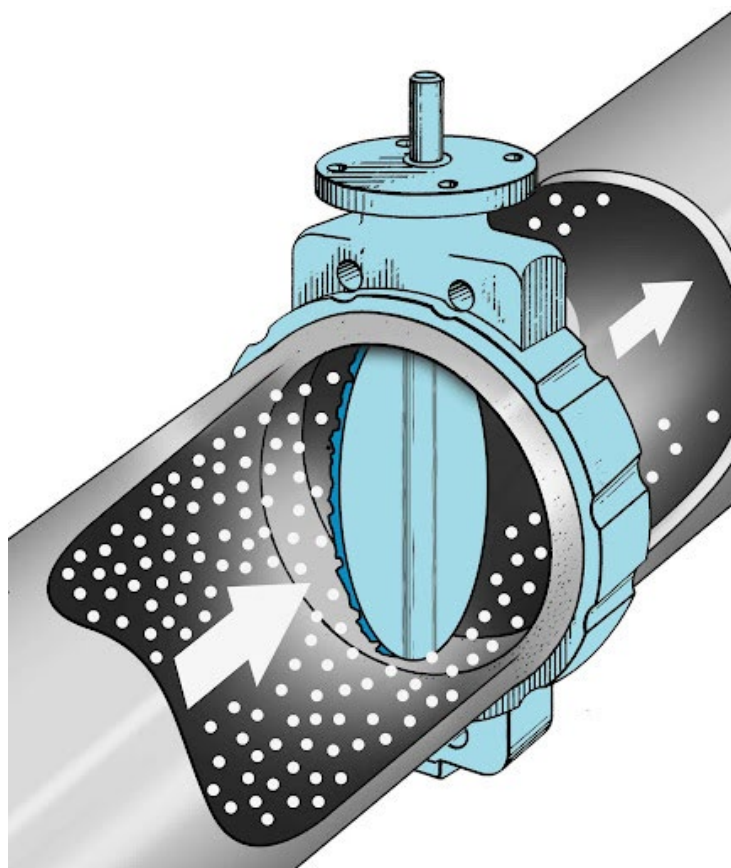




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[UWTSD. 2021.]

Structural & Fluid Analysis



[SIMSCALE. 2021.]

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1) INTRODUCTION

Throughout the second semester of university within Trinity Saint David the second-year full students and fifth-year part students have been discussing fluid flow during Structural & Fluid Analysis topic. The class has been tasked to carry out a theoretical situation where they must build upon the knowledge gained throughout the year where a butterfly valve is to be installed into a pipeline that forms the outlet at the base of a storage tank. The tank has been stated to be 5 metres tall containing petroleum at atmospheric pressure.

The class have tasked to complete several tasks such as explaining Reynolds number, discuss boundary flow on the valve and the valves material, implications of the chosen material. The other tasks that the class of engineering students have been tasked with is for them to discuss modelling techniques used to simulate fluid flow and how an experiment could be carried out within a laboratory.

The following report will demonstrate the results found by one of the engineering students tasked with the above information.

2) REYNOLDS NUMBER

Reynolds number is a dimensionless number used within engineering to determine the viscosity of the flow or in simpler terms as the flow pattern of a fluid. Reynolds number was discovered by Osborne Reynolds in 1883 where he carried out an experiment using dyed water and clear water in a glass tube to predict fluid flow. This was done by releasing the dye in the middle of the “cross-sectional area of the clear water to visualize the movement of fluid”. [Werner Sölken. 2021.]

Reynolds number therefore is used to calculate ratios to determine whether the flow is laminar or turbulent. When a fluid is calculated with a laminar flow it indicated that the flowing fluid has a path of least resistance, whereas when it has a turbulent flow it shows there's some resistance with the internal forces (pipe or tube). The image below displays the differences in flows passing over an object in a visual representation,

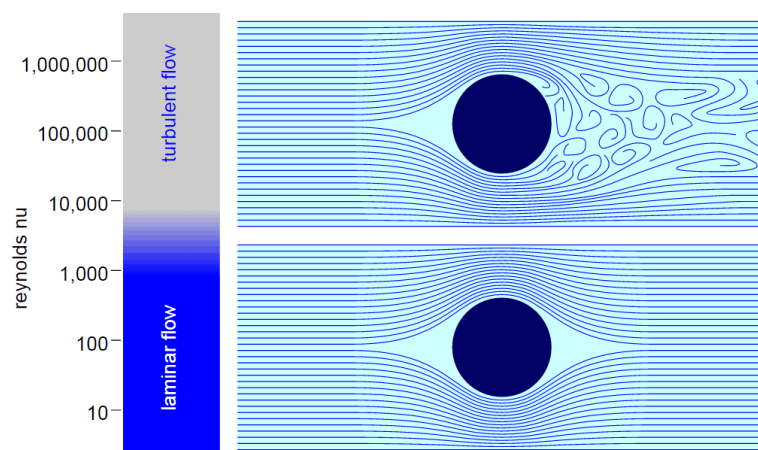


Figure 1 A visual representation of the two main fluid flows from Reynolds Number (Laminar and Turbulent) where flow direction is shown. [Nuclear Power. 2021.]

The bottom diagram in figure 1, demonstrates the visual representation of what laminar flow is. Whereas the top diagram above laminar flow in figure 1 shows a

different result meaning this is turbulent flow. However, without carrying out the experiment the theoretical outcome can be calculated using an equation.

$$Re = \frac{\rho \cdot V \cdot L}{\mu} \text{ or } Re = \frac{V \cdot L}{\nu}$$

Re = Reynolds number

ρ = Density

V = Velocity

L = Length

μ = Bulk viscosity

ν = Kinematic viscosity

Figure 2 A image containing Reynolds Number equation with the definition of the mathematical notation. [Paul Mueller

Company Engineering Staff. 2018]

When carrying out the equation displayed in figure 2 to determine the flow of the liquid, the results will give a unitless number. The result will show one of three results; if the result is equal or less than 2300 it is presumed the fluid has a laminar flow, if it's greater than 2300 to approximately 4,000 it will be in its transitional flow where it would have aspects of both laminar flow and turbulent flow. If the number exceeded 4,000 then the flow of fluid would be turbulent flow.

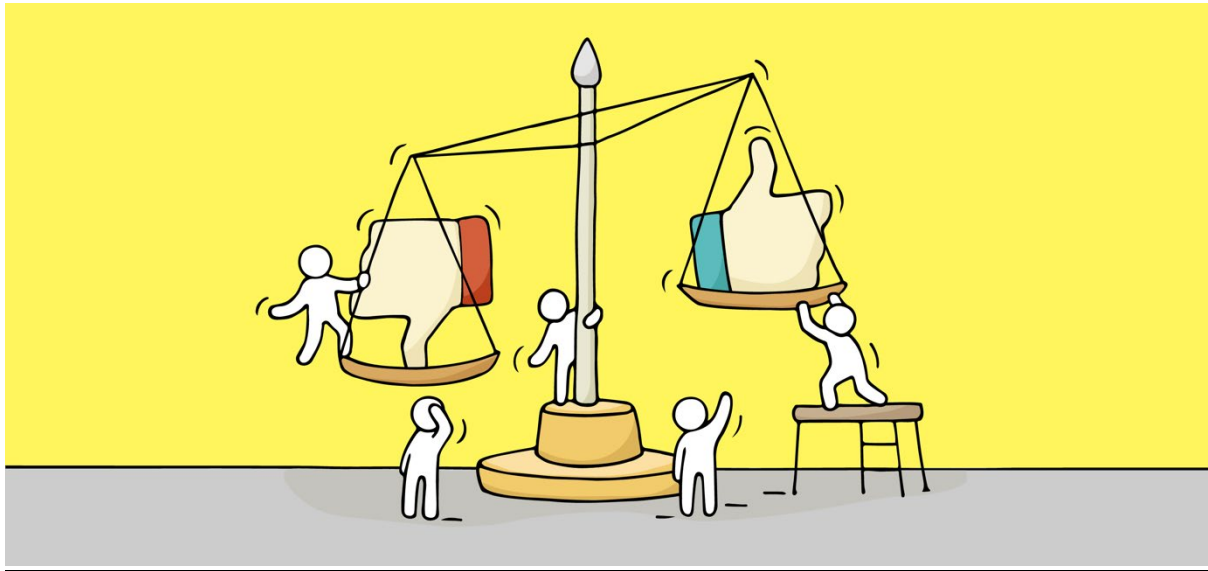
Different fluids would result in different results and have different fluid flows.

However, results have shown that laminar flow tends to occur with fluids with low velocity and small diameter pipes. It's also worth mentioning "Shear stress in laminar flow depends only on the viscosity of the fluid and independent of the density."

[Mechanical Booster. 2016] Whereas its almost the opposite with turbulent flow as

"Shear stress in the turbulent flow depends upon the density of the fluid" [Mechanical

Booster. 2016]. Turbulent is also likely to occur in larger pipes and where the velocity is high.



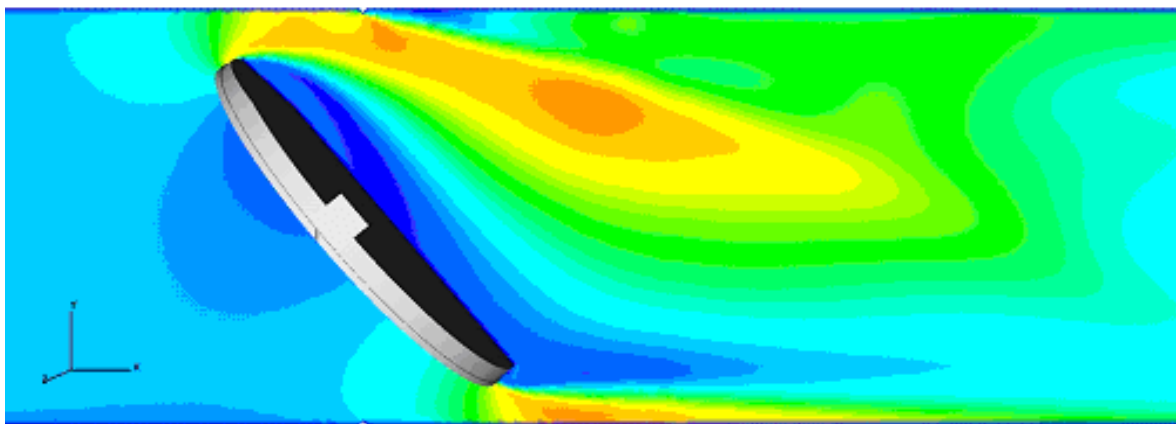
[Astro Exhibitions. 2021]

Knowing the Reynolds number is important as the desired outcome could not be the optimal solution required for the task at hand. Whether its theoretical or practical application. Both laminar and turbulent have their uses within the industry. Therefore, an advantage of having a laminar flow would be that the flow would allow low flow rates to be measured. Another advantage would be due to the linear relationships of both pressure and flow rate. The relationship between both will make it easier to see if a problem accrues.

Laminar flow is relatively quiet in comparison to turbulent. A disadvantage of having a laminar flow would be that its heavily dependent on the fluid's velocity. Therefore, if there was a fault with the pipeline the optimal flow required for a pump or machine would cause a greater strain on the equipment. The flow is also affected by temperature, the result of this means temperature compensation is required resulting

in additional costs. Another factor would be if there's a desired heat required for the machinery to run additional heat or insulation would be required.

Laminar flow is highly efficient when there's a single entry and exit; however, it becomes less effective when 2 or more joints are introduced causing the flow to become turbulent at the fork of the joining. [Industrial Automation, PLC Programming, scada & Pid Control Systems. 2017]



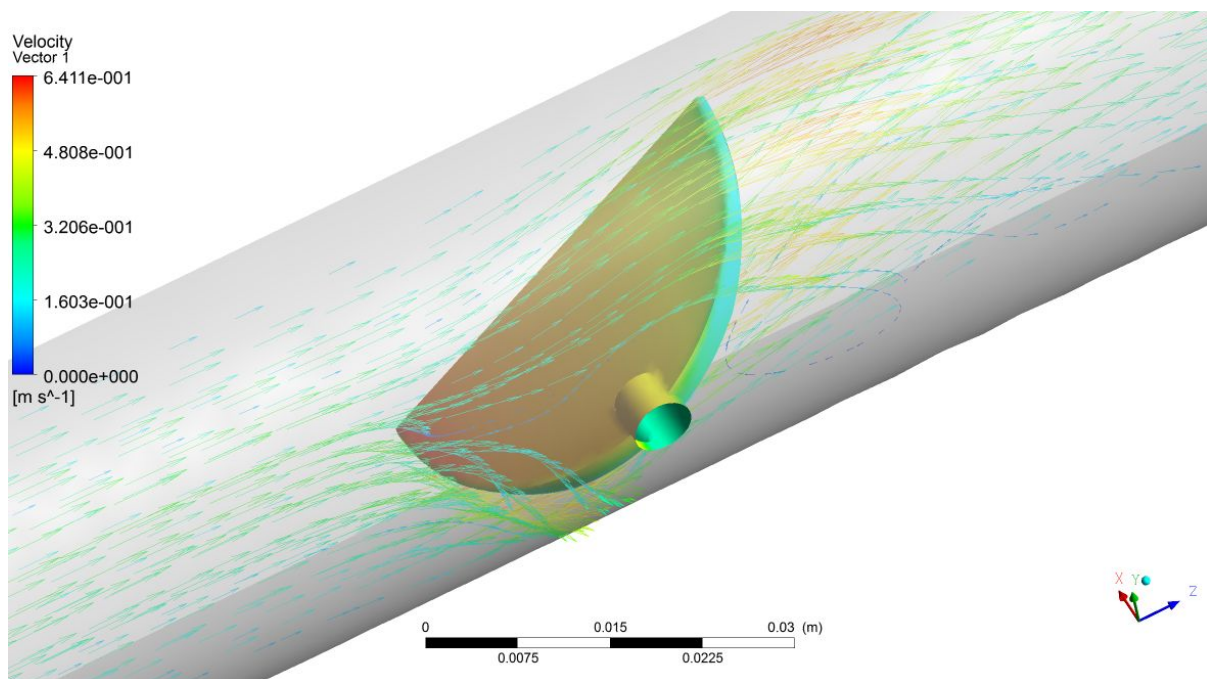
[ResearchGate, 2004]

However, the opposite can almost be said for turbulent flow. Turbulent flow causes more resistance when passing through the pipe which results in more noise being created; this can be seen as an advantage or disadvantage as increased noise would affect the climate noise pollution, effect the cetaceans living in the surrounding area and personnel working on site. As stated by the CDC (Centers for Disease Control and Prevention) which is an American government informational website states "Noise above 70 dB over a prolonged period of time may start to damage your hearing.

Loud noise above 120 dB can cause immediate harm to your ears." [Centers for Disease Control and Prevention, 2019] Meaning sound insulation must be installed if

it exceeds 70 db on a regular basis and Personnel Protective Equipment to be worn at all time when working in the area. The benefit of having increased noise due to turbulent would be if a problem occurred there would be greater change of the problem being heard due to the volume being decreased in decibel (dp). Whereas laminar draws heat from the climate, turbulent is slightly different as it “accelerates heat conduction and thermal mixing” (Philosophy-questions.com, 2021) In simpler terms due to its frictions within the tubes.

Laminar flow is highly efficient when there's a single entry and exit; however, turbulent flow is the best and most effective flow to have when 2 or more joints are introduced causing the flow to become a communitive turbulent flow at the fork of the joining. Turbulent flow is the preferred flow to be used within engineering applications.



[FetchCFD, 2016]

Prior to the fluid reaching the butterfly valve it is speculated that the flow passing through the pipe has a laminar flow prior to reaching the valve. Once the fluid

reaches the valve plate which is set at 90° , which means the valve is fully open. Therefore, the fluid will pass through the valve relatively unaffected and should remain at its initial state of flow. However, it speculated the flow to change as the valve closes and the surface area increases of the plate connected to the valve.

The result of the valve closing would cause the flow of fluid to transfer from the speculated laminar flow to turbulent flow created as the fluid leaves the valve. The same result would be cause when reopening to allow the fluid to flow. The flow would remain turbulent and gradually transfer back to its original flow after a duration of time. The ideal flow required would be a turbulent as most of the engineering industry works under a turbulent flow rate.

3) BOUNDARY FLOW

- What is boundary flow
- BF effects of the valve plate and rivets.
- Why has it been designed in such a way
- Talk about cost and implications of design.

Boundary flow is a thin surface layer residing on a body where viscous is present.

Viscous occurs on the internal of a pipe, whereas inviscid occurs on the outer side of the pipe. Boundary flow is also communally known as boundary layer. "The fluid in the boundary layer is subjected to shearing forces. A range of velocities exists across the boundary layer from maximum to zero, provided the fluid is in contact with the surface." ... "The flow in such boundary layers is generally laminar at the leading or upstream portion and turbulent in the trailing or downstream portion."

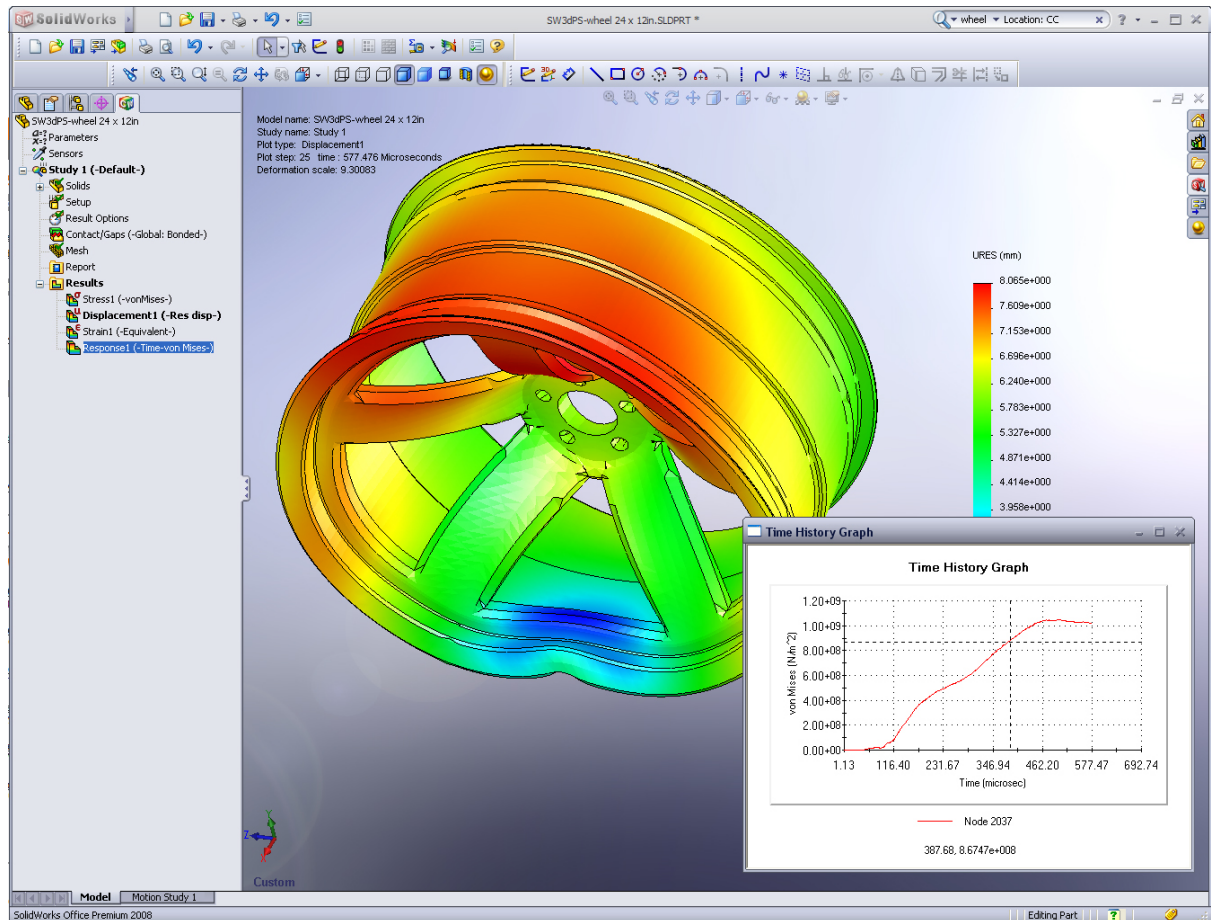
[<https://www.britannica.com/science/boundary-layer>]

4) BUTTERFLY VALVE MANUFACTURING

- What is glass fibre reinforced plastic?
- Advantages and disadvantages
- Research on how old the valve design is, material and manufacturing by relating it to historical, current, and future designs.
- Include standards and practices relevant to designs.

The speculative butterfly valves

5) MODELLING TECHNIQUES



[\[https://blogs.solidworks.com/solidworksblog/2014/04/what-do-people-mean-when-they-talk-about-cad-embedded-simulation.html\]](https://blogs.solidworks.com/solidworksblog/2014/04/what-do-people-mean-when-they-talk-about-cad-embedded-simulation.html)

When carrying out the theoretical experiments, modelling techniques are most cost-effective way to carry out a visual representation backed up by mathematics without carrying out a real experiment. There are plenty of highly recognised modelling technique packages used already with in the industry such as AutoCAD Inventor, Solidworks, fusion 360 and many more. The software packages can be free, however the more perfectional packages tend to lean towards a paid subscription as little as £60 a year up to £2000 and more. There are also options where the package is bought out right, but this is beginning to die out of the industry.

Prior to manufacturing the results from the simulation report, the engineer would be required to build up the frame what the desired experiment is trying to obtain. Therefore, in terms of gaining fluid flow results the engineer would begin by modelling the pipe in which the fluid would travel through giving the model the correct specification. This would include material, length of tube and any other measurements.

Once the tubing has been modelled the engineer would then import the proposed component that the experiment is designed around. It then would be structured in a way where the simulation layout is the way the actual experiment would be carried out. Once the layout has been set the engineer would go through the process setting up the relevant data and layers to carry out the experiment and gain the relevant results. The simulation package would then correlate data and manufacture a report with analysis, charts, and other various import information.

There are many advantages and disadvantages of using modelling simulation. The advantage of using modelling techniques and most likely the important aspect is there's no danger and or loss of life at risk of happening. Another advantage is there's no unforeseen costs as the only costs of simulation would be the software itself.

The simulation conditions can be varied to research the effects at near to impossible worst case synario without risk. The outcome of the varied outcomes can be investigated. Another advantage of simulations is that the experiment can

be sped up and extended past the proposed time; however, it can also be slowed down and studied more closely.

[<https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>]

Although there are plenty of advantages of using simulation software, there are still some limitations and disadvantages of using the software. The main disadvantage of using the software is that its expensive to initially set up. The company will more than likely be required to purchase a custom-built computer to operate the software due to its high memory usage when using it.

Another disadvantage is that the user of the software might require specialised accessories such as mouse, keyboard, monitor and any other equipment that will make the simulation and modelling more fluid. Training would be required for the engineer to use the software resulting in return of profit for the original investment to pay for itself. It's also worth noting that unless the engineer using the software and fully understood what is required and aware of all the factors involved then the report created by the software will be incorrect.

[<https://www.bbc.co.uk/bitesize/guides/zvxp34j/revision/3>]

There are always benefits and side-effects to everything however the benefits in relations with modelling techniques out ways the disadvantages. The software should be used to gain an understanding of an expected result and an actual experiment to be used to combine and give a collective research result.

6) PROTOTYPE LABORATORY EXPERIMENT



[\[https://carfromjapan.com/article/car-maintenance/what-color-is-gasoline-the-real-answer/\]](https://carfromjapan.com/article/car-maintenance/what-color-is-gasoline-the-real-answer/)

A new butterfly valve has been developed and a prototype of the new design has been delivered to the university so that an experiment can be carried out to confirm if the 3d modelling simulation report is accurate. The experiment is to be carried with the onsite laboratory located within the university. The proposed experiment to be carried out the task is the Osborne Reynolds Experiment. The equipment to carry out the experiment is still based on the original experiment carried out back in the 1880's however it's been modernised to the current manufacturing era.

The equipment would be set upon a fixed surface where no vibration is caused as this would affect the experiment. Once the equipment has been placed the team would commence setting up the relevant inflow and outflow connections to their

correct location. Therefore, the bench outlet would be required to be connected the inlet tank where the fluid is to be stored. The overflow of the tank would then be required to be connected to the hydraulic bench volumetric tank. Once that has been done the team would then be required to connect the outlet tube to the proposed new butterfly valve; the outlet would be positioned in the sink where a measuring tank would also be located.

The tube would run into the measuring tank. Now that all the connections have been installed the team would then turn on the pump, slightly open the prototype valve and bench valve. Once these steps have been carried out the inlet tank would require to be filled with the relevant fluid for the experiment. Due to the onsite fluid tank where the proposed prototype is being installed is petroleum, the company and university came to the concluded to use unleaded petrol as it as the clearest fluid used on the petrochemical site. This would also allow the dye to be seen once it had been released into the pipe.

The fluid visualisation tube where the dye is to be released is required to be filled as well as the inlet tank above the tube. The inlet tank should be at the level just under the overflow pipe. The valve for the overflow should be opened slightly to create a subtle stream of fluid to flow back into the bench tank where it can re-join the experiment flow. Once the flow has been established the dye valve is required to be checked if it's closed prior to adding dye to the cup.



Figure 3 A image of the equipment used to carry out the experiment on the prototype butterfly valve.

[\[https://armfield.co.uk/product/f1-20-osborne-reynolds-demonstration/\]](https://armfield.co.uk/product/f1-20-osborne-reynolds-demonstration/)

The needle of the dye will then be required to be lowered down to the correct position by the lab team where it resides centrally vertical above the bell mouth.

Now that the dye needle is in position the bench valve and prototype valve is required to be adjusted to allow a small trickle of fluid flow. However, the experiment will be required to be stationary for a couple of minutes to insure everything is calm and no interference is caused.

After the small brake the team would then be required to open the valve of the dye to allow a steady stream of dye to flow. Using the measuring tank, the fluid flow and

temperature is recorded. Now that the experiment has truly began it is advised that the team is to take images of the dye stream in the fluid, thickness, and characteristics after a period the team is then required to increase the opening of the prototype to allow more fluid to pass. This sequence is then repeated until the valve is fully open.

The result would collect and compared to the simulation result giving the customer their request in the test carried out. The equipment would be deconstructed, cleaned, and stored for the next experiment when needed. The equipment used to carry out the experiment can be visually seen at figure 3.

7) CONCLUSION

- Overall success
- Discuss the difficulty on finding the relevant information.
- The good and bad points of the research report.
- Discuss how I would have approached it if I was to carry out the same tasks.

To conclude it can be concluded that the report was a success as most if not all the criteria has been met. The aim of the report was for class to carry out several tasks to build upon the knowledge gained throughout the year on fluid flow.

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