

PROJECT PROPOSAL AND FEASIBILITY STUDY



TEAM 7: AIM TO PLEASE

(PURE LIQUID ELIMINATING AIR SHOCK EQUIPMENT)

ENGR. 339 – Senior Design Project

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1 PROBLEM STATEMENT

The purpose of this project is to build a bench top machine for Naake Motorsports that removes all the air from a preassembled non filled QA1 shock and fills it with pure lightweight shock oil. This is done by creating a vacuum on the shock and also a vacuum on the shock oil. This oil is then pulled and sealed into the shock. The machine must be small enough to keep in a race trailer.

This machine would be beneficial to Naake Motorsports because it would cut down on the amount of time the spending filling shocks. On a race track where time is very important, solving this problem would be very beneficial to them. Also it is very important to get as much air out of the shock as possible. This is because the less air there is in a shock the better the performance of that shock. Better shock performance on a race car would improve the handling and this would also be beneficial.

2 PROJECT OBJECTIVES

2.1 Size

The size of the whole machine must be small enough to sit on a regular work bench and light enough to easily handle. This is because the machine should be easily movable as it would have to shuttle between different race tracks on a race trailer.

2.2 Cycle Time

The cycle time for filling a shock with oil and removing air out of the shock must be below five minutes. Currently, the manual shock filling process at Naake Motorsports assuming there are no hitches and everything goes as planned, takes between 3 to 5 minutes. We would like to keep the cycle time less than 5 minutes so that the machine can save time as well as deliver a better quality shock.

2.3 Reservoir Capacity

2.3.1 Main Reservoir Capacity

The capacity of the main reservoir should be no more than a gallon. This is primarily because this would help maintain our size and weight constraints without sacrificing our functionality. However it does imply that the machine would need to be filled with oil regularly based on how many shocks are being filled at a particular time.

2.3.2 Secondary Reservoir Capacity

The capacity of the secondary reservoir should be about 1 pint. This is also to maintain our size and weight constraints without losing functionality and this is because the secondary reservoir only needs to contain the quantity of oil that is needed to fill the shock.

2.4 Vacuum Pump Capacity

The vacuum pump needs to be strong enough to extract as much air out of the shock oil which is about 5wt. This vacuum also needs to be powerful enough to reduce the air pressure in the shock to at least 15% of atmospheric pressure.

2.5 Durability

The machine needs to be strong enough for regular daily use. Currently, Naake Motorsports manufactures about 12 shocks per day and the machine needs to be able to do this. Also it should be able to withstand the stress of the work environment it would be in. It is probably going to get dropped and maltreated a little bit.

2.6 Power Supply

The machine should also be powered by an AC power source delivering 110/220V, because this is the power source that would be available where it is to be used.

2.7 Target Budget

Our target budget should be in the range of \$1,000 - \$1,400. Out of this budget, \$300 is going to be made available by Calvin College. The remainder is going to be provided by our sponsor Naake Motorsports.

2.8 Level of Functionality

The machine should also be relatively easy to operate. Operators should be able to simple attach the shock to the machine and the push a button to begin the shock filling process. In addition, there is the possibility of delivering a short owners manual to aid in the operation of the machine.

2.9 Weight Goal

For easy movement, between race tracks in a race trailer, this machine should only weigh between 40 and 60 lbs.

2.10 Seals

These all need to be air tight.

3 ALTERNATIVE SOLUTIONS

There are a number of different ways we could accomplish this project. It is our responsibility to come up with the most effective way that meets all the project objectives as best as possible and still remaining within our budget constraints. These are a number of other solutions:

Alternative Solution 1

- 3.1.** The shock will be dipped into an oil bath and filled up. The shock will be sealed before leaving the bath. This solution does not make it possible for the air in oil to be removed. The quality of the shock would be poor and the shock oil would need to be completely clean
- 3.2.** One vacuum pump could be used to suck the air out of the shock and out of the secondary reservoir and could be regulated using valves

- 3.3. The waste oil could be put through a filtration system and reintroduced into the reservoir tank, rather than onto an oil pan and throwing away
- 3.4. Instead of using vacuum pumps, a piston or plunger could be used to push oil into the shock
- 3.5. The system could be fully automated. This could be done by running controls off of a computer and programming the system to run through a cycle
- 3.6. The oil could be pressurized with compressed air and pushed into the shock with a piston by air pressure
- 3.7. The fitting to the shock could be a screw on fit rather than a suction fitting
- 3.8. The main reservoir could be above the shock to eliminate the use of a pump into the secondary reservoir

4 TASK SPECIFICATION

A comprehensive list of the different task that we would need to undertake in this project has been put together. This list also contains the total amount of time all tasks are estimated to take.

4.1 FEASIBILITY STUDY

Research and identify an appropriate

- Vacuum pump size and capacity
- Hoses, valves, and fittings sizes
- Reservoir and bladder size
- Overall machine size, weight
- User interface, aesthetics

Create a mechanical schematic

- Decide on a material for the stand
- Frame and support shape and style

Research other similar products in the industry

Research solution to sealing shock

Create a list of part suppliers, prices, and part numbers

Test if a vacuum can be pulled in shock oil without vaporization

Compare speed of filling with a vacuum as opposed to using gravity

Space minimization study

Incorporate safety into design

- Pressure relief valves and return path on pumps

Meet with outside consultant to discuss project

4.2 BUILD PROTOTYPE

Fluid flow schematic

Instrumentation and wiring

Wiring schematic

Design Integration

Construction

4.3 PRESENTATION OF DATA

Oral

- PowerPoint
- Practice

Web page

- Design
- Debugging

Total Estimated Time for All Tasks – 200 hrs.

5 FEASIBILITY STUDY

We have carried out a number of test and calculations to help us determine the feasibility of this project. This was important because it not only tells us if we should go ahead and build a proposed prototype, it also helps us understand the project better and deal with problems ahead of time. The steps carried out to determine feasibility are now going to be discussed.

5.1 TEST 1 – Effect of vacuum on oil properties

In this test we wanted to determine if the properties of the shock oil change when it is under a vacuum. This is important because if for example the viscosity of the oil changes by 50% our shock oil is no longer going to perform as expected. Another thing we wanted to observe in this test was if air re-entered the oil after a vacuum was pulled on the shock oil and then re-introduced into the atmosphere. The steps carried out are as follows:

1. Procure Materials:
 - a. Shock oil – 2.5% wt
 - b. Glass jar (to hold vacuum)
 - c. Vacuum pump
 - d. Tubes to connect the system
2. Procedure
 - a. Connect the system
 - b. Pull vacuum at different intensities/speeds on oil in jar
 - c. Wait for air bubbles in oil to rise and document results
 - d. Remove vacuum and observe if air reenters the jar, record observations and time
3. Analysis of Data collected
 - a. Compare results of different vacuum intensities
 - b. Derive conclusion on most efficient vacuum
 - c. Make decisions based on amount of air reintroduced in the oil

5.2 RESULTS– Effect of vacuum on oil properties

- We used a vacuum that pulls out to a pressure 27% of atmospheric pressure (0.27atm)
- For a 300mL volume of oil, the time required to pull a part vacuum (without seeing anymore air bubbles) was about 1min 35secs
- After pulling this part vacuum the shock oil was introduced back to the atmosphere (1atm) and allowed to sit for about 2mins

- We then tried pulling another vacuum on the shock oil that was introduced into the atmosphere. However, we could not see any more bubbles leaving the shock oil

5.3 CONCLUSIONS - Effect of vacuum on oil properties

- This shows that air does not re-enter the shock oil when it is re-introduced to the atmosphere
- Also, the more times you pull a vacuum on the shock oil and then agitate this oil to get air bubbles in, the less time it takes to draw the vacuum on the shock oil
- We would be able to pull a vacuum on this shock oil without changing physical properties such as density and viscosity
- After air has been pulled out of the shock oil, it is possible to re-introduce this oil into the atmosphere without getting more air bubbles into this oil. This also proves the theory that the shock oil is a lot more dense than air.

5.4 TEST 2 – Atmosphere vs. Vacuum for shock filling time test

This test was to find out how much time it would take practically to fill the shock with shock oil. This was done in two scenarios, the first scenario was keeping the shock enclosure at atmospheric pressure and the second scenario was drawing a vacuum to 27% of atmospheric pressure on the shock enclosure. The steps taking in this experiment include:

1. Procure Materials
 - a. Shock provided by Naake Motorsports
 - b. Machine Aluminum threaded connection point for filling the shock (Appendix B)
 - c. Hose – Heavy duty fitting
 - d. Vacuum source
 - e. Shock fluid
 - f. Services from machine shop
2. Procedure (Refer to Fig 2)

- a. Drill and tap 6-32 screw for the other side of the shock
 - b. Make aluminum fitting in machine shop
 - c. Connect system (refer to Fig 3-fluid schematic)
 - d. Gravity test - Place reservoir 1 foot above shock, connect with tube, measure the time it takes the fluid to fill the shock for a specific volume
 - e. Vacuum test - Perform tests with vacuum over second fitting
3. Analysis of Data collected
- a. Compare results of gravity test vs. vacuum test
 - b. Derive conclusions and implement efficient mechanism

5.5 RESULTS - Atmosphere vs. Vacuum for shock filling time test

- We used a vacuum that reduces air pressure to 27% below atmospheric pressure
- Letting the shock oil flow in by gravity. We observed that it took about 3min 50 sec to fill the shock with 100mL of oil.
- When we pulled a vacuum on the shock before filling it with oil. We observed it took about 15 sec to fill the shock with 100mL of shock oil. This took less than 10 % of the time that gravity alone took.

5.6 CONCLUSIONS - Atmosphere vs. Vacuum for shock filling time test

- This shows us we could save a lot of time by pulling a vacuum on the shock before filling it with oil

- It would not be feasible to have a cycle time of about 4mins without pulling a vacuum on the shock

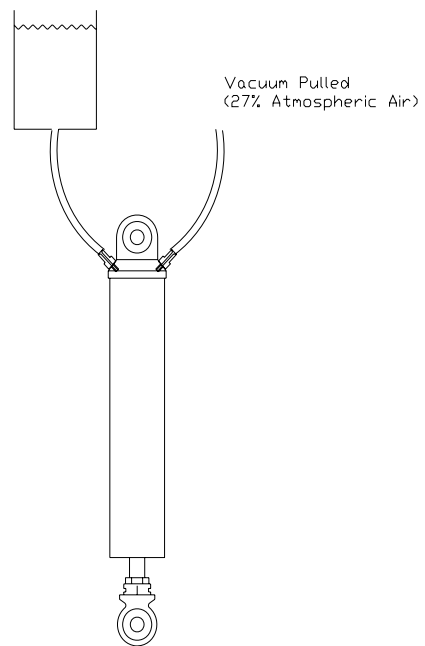


Fig 1 – Experiment 2 setup

5.7 FLOW CALCULATIONS

We also did some calculations using the Bernoulli energy equation to find how fast theoretically, the shock would fill given all our constraints and variables (refer to Fig 2). This is found in appendix A. From our calculations we found that it would take about 30 sec to fill the shock, based on the assumption that a vacuum is drawn on the shock and that we are using a suction fitting.

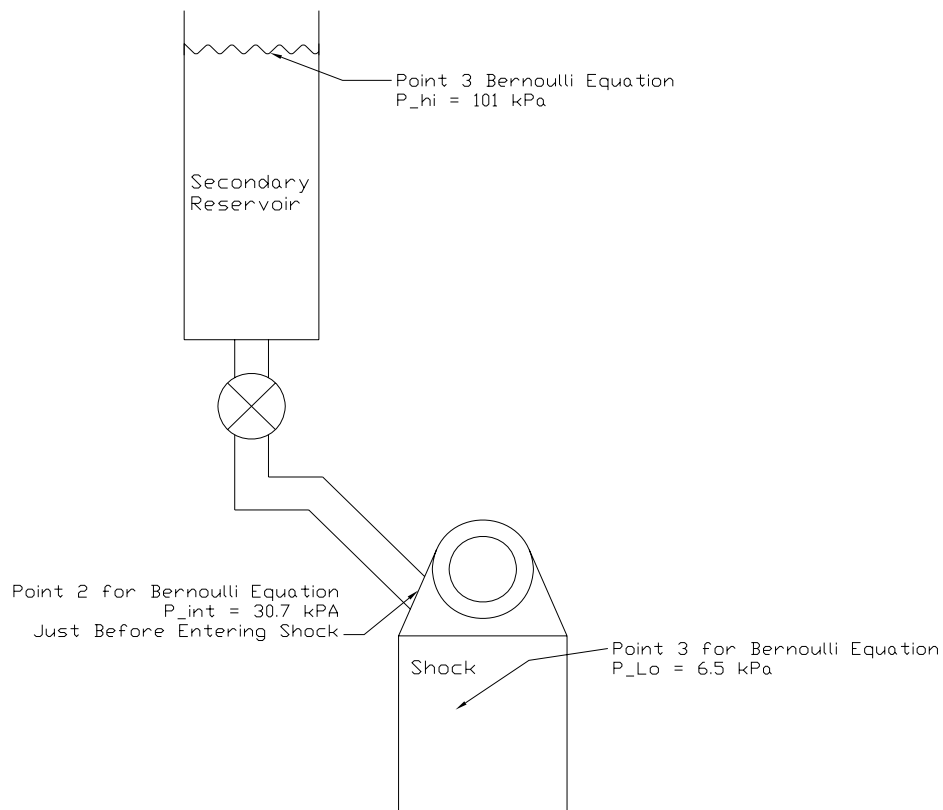


Fig 2 – Bernoulli Setup

5.8 FLOW CALCULATION RESULTS

Note: The filling hole for the shock oil is 0.106in

Parameter	Value
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P_1 (kPa)	101
P_2 (kPa)	30.7
P_3 (kPa)	6.5
Time for Filling (sec)	30
Oil Velocity, V_2 (m/s)	6.54

6 COMPONENTS OF DESIGN

6.1 MAIN RESERVOIR

This is going to hold all of the shock oil. It is where oil is poured into the machine. It is going to have a gauge indicating oil level and when it needs to be re-filled with oil.

6.2 SECONDARY RESERVOIR

This reservoir is the housing for the "clean oil," (oil that has had all the air taking out of it and is ready to be poured into the shock).

6.3 PUMP

The pump is going to be used to send the shock oil from the main reservoir to the secondary reservoir where the air is removed from the oil and the oil is stored until it is ready to be sucked into the shock.

6.4 VACUUM PUMP

This pump is going to serve two functions. First, it would be used to remove air out of the fluid and secondly it would also be used to remove air from the shock.

6.5 VALVES

The flow of the shock oil through all the other components is going to be regulated by with 5 solenoid valves controlled by PLC. These valves are all going to be timed and will have a manual emergency switch.

6.6 PROGRAMMABLE LOGIC CONTROLLER (PLC)

The PLC will be programmed in order to control operations of the valves. The PLC will also direct the sequence of the valves and the time that each one opens and closes.

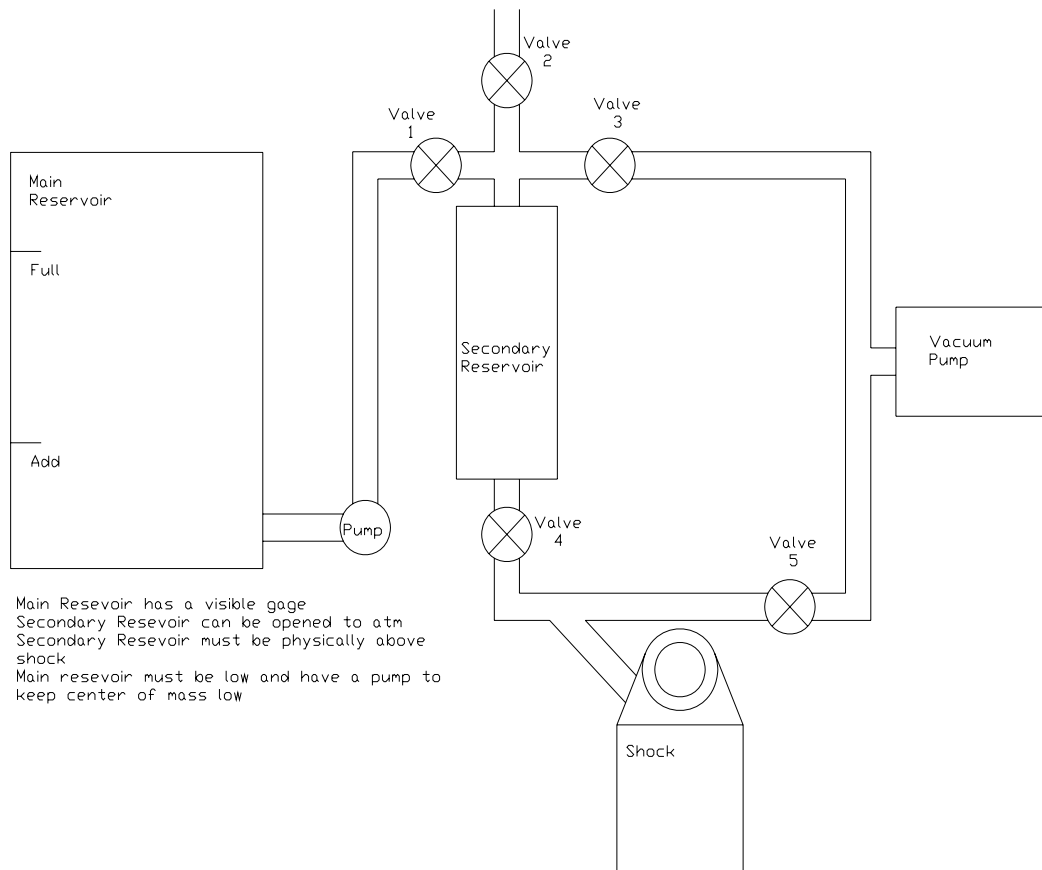


Fig 3 – Design

7 DESIGN PROCESS

Sequence:

1. The first step for the operation of the machine is to fill the main reservoir with shock oil
2. The second step in the machine would be to pump some of the main reservoir oil into the secondary reservoir. This would be accomplished by opening Valve 1 and using the pump to fill the reservoir. The pump would then be turned off and the valve closed. This would be the oil that is used for the next shock filling.

3. Valve 5 would then be opened and the vacuum pump would be used to pull the air out of the shock body.
4. Valve 3 would then be opened and the vacuum pump would then be used to extract the air from the fluid. This oil would then be used to fill the next shock.
5. Valve 2 would then be opened and introduce the fluid back to atmospheric conditions. Valve 4 would then be opened and the fluid would flow into the shock due to the difference in pressures and the force of gravity.
6. The shock would now be full of pure oil and a final vacuum could be pulled on the shock fluid to make sure no cavitations were introduced during the filling of the shock.
7. The shock would then be removed from the stand and the process would be repeated for the next shock until the main reservoir would need to be filled.

8 PRELIMINARY BUDGET

This proposed budget shows cost estimates for various components in our design. With these estimates we are under the amount of available monetary resources we have which is about \$1,400.00.

Component	Cost (\$)
Frame Work (Aluminum)	150.00
Vacuum Pump	330.00
Primary Reservoir	75.00
Secondary Reservoir	100.00
Tubing	50.00
Valves and Fittings	200.00
Instrumentation, PLC	300.00
Pump	30.00
TOTAL	1,235.00

9 DESIGN NORMS

9.1 STEWARDSHIP

We want to provide Naake Motorsports with this equipment because we believe it is going to help them economically by reducing the amount of time that is currently spent filling shocks. This project would help improve the quality of shocks by eliminating air and also reducing the amount of oil that is wasted during the shock filling process.

9.2 TRANSPARENCY

This project also seeks to increase the ease of the shock filling process at Naake Motorsports. This would be done by delivering equipment that fills the shock by the push of a switch rather than the manual filling process that currently goes on.

9.3 TRUST

We want to deliver a machine that our customer can rely on for quality, functionality and durability. The machine should eliminate most of the air out of the shock. There can never be complete elimination of all the air because a perfect vacuum cannot be created. The machine is also going to be easy to operate and sturdy for use on a daily basis to match the demand for use.

10 CHRISTIAN PERSPECTIVE

In this project we approached the design from a Christian perspective. We want to be good stewards of the resources that have been made available to us by Calvin College and Naake Motorsports and deliver a quality product that solves the problem. We also want to come up with a design that is profitable and fulfills the needs of our customer.

11 CONCLUSION

We have determined this project to be feasible from our assumptions, experiments and calculations. We have also put together a proposed design which meets our project goals. This project is also on schedule and the building and testing of our prototype is coming up next semester.

12 APPENDIX A – Bernoulli Calculations (Time to Fill Shock)

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Simultaneous Equations

$$\frac{P_2}{\rho_{oil}} + \frac{V_2^2}{2} + 9.807 \text{ [m/s}^2\text{]} \cdot h_L = \frac{P_1}{\rho_{oil}} + \frac{V_1^2}{2} + Z_1 \cdot 9.807 \text{ [m/s}^2\text{]} \text{ [J/kg]}$$

$$P_2 - P_3 = C_D \cdot 1 / 2 \cdot \rho_{oil} \cdot V_2^2 \text{ [Pa]}$$

Variables

$$P_{atm} = 101325 \text{ [Pa]}$$

$$P_1 = P_{atm} \text{ [Pa]}$$

$$P_3 = 0.064 \cdot P_{atm} \text{ [Pa]}$$

$$\rho_{oil} = 1030 \text{ [kg/m}^3\text{]}$$

$$V_1 = 0 \text{ [m/s]}$$

$$Z_1 = 0 \text{ [m]}$$

$$Z_2 = 0.3 \text{ [m]}$$

$$C_D = 1.1$$

Head Loss

$$K_{L,Resv,out} = 0.03 \text{ Sharped Edge inlet/Well Rounded (0.5/0.03)}$$

$$K_{L,bend} = 0.3 \text{ 90 deg miter bend w/out vanes/90 deg smooth bend flanged or threaded (1.1/0.3 or 0.9)}$$

$$K_{L,elbow} = 0.4 \text{ 45 deg threaded elbow (0.4)}$$

$$K_{L,total} = K_{L,Resv,out} + K_{L,bend} + K_{L,elbow}$$

$$h_L = f \cdot \frac{L_{pipe}}{D_{pipe}} \cdot \frac{V_2^2}{2 \cdot 9.807 \text{ [m/s}^2\text{]}} + K_{L,total} \cdot \frac{V_2^2}{2 \cdot 9.807 \text{ [m/s}^2\text{]}} \text{ [m]}$$

$$L_{pipe} = 0.45 \text{ [m]}$$

$$D_{pipe} = 0.01 \text{ [m]}$$

$$A_{cs,pipe} = \pi \cdot \left[\frac{D_{pipe}}{2} \right]^2 \text{ [m}^2\text{]}$$

$$v = 0.000007 \text{ [m}^2\text{/s]}$$

$$Re = \frac{V_2 \cdot D_{pipe}}{v}$$

$$\varepsilon = 0.00001 \text{ [m]} \text{ Smoothed Rubber}$$

$$\frac{1}{\sqrt{f}} = -2 \cdot \log \left[\frac{\varepsilon}{D_{pipe} \cdot 3.7} + \frac{2.51}{Re \cdot \sqrt{f}} \right]$$

Shock

$$L_{shock} = 0.254 \text{ [m]}$$

$$D_{shock} = 0.073025 \text{ [m]}$$

$$A_{cs,shock} = \pi \cdot \left[\frac{D_{shock}}{2} \right]^2 \text{ [m}^2\text{]}$$

$$V_{shock} = A_{cs,shock} \cdot L_{shock} \text{ [m}^3\text{]}$$

Hole

$$D_{hole} = 0.1065 \text{ [in]} \cdot \left| 0.0254 \cdot \frac{\text{m}}{\text{in}} \right| \text{ [m]}$$

$$A_{cs,hole} = \pi \cdot \left[\frac{D_{hole}}{2} \right]^2 \text{ [m}^2\text{]}$$

Volume Flow Rate

$$\dot{V}_{hole} = V_2 \cdot A_{cs,hole} \text{ [m}^3\text{/s]}$$

Time to fill Whole Shock

$$\text{Time} = \frac{V_{shock}}{\dot{V}_{hole}} \text{ [s]}$$

Solutions:

$$A_{cs_hole}=0.000005747 \text{ [m}^2\text{]}$$

$$A_{cs_pipe}=0.00007854 \text{ [m}^2\text{]}$$

$$A_{cs_shock}=0.004188 \text{ [m}^2\text{]}$$

$$C_D=1.1$$

$$D_{hole}=0.002705 \text{ [m]}$$

$$D_{pipe}=0.01 \text{ [m]}$$

$$D_{shock}=0.07303 \text{ [m]}$$

$$\text{Epsilon}=0.00001 \text{ [m]}$$

$$f=0.0329$$

$$h_L=4.815 \text{ [m]}$$

$$K_{L_bend}=0.3$$

$$K_{L_elbow}=0.4$$

$$K_{L_Resv_out}=0.03$$

$$K_{L_total}=0.73$$

$$L_{pipe}=0.45 \text{ [m]}$$

$$L_{shock}=0.254 \text{ [m]}$$

$$P_1=101325 \text{ [Pa]}$$

$$P_2=30686 \text{ [Pa]}$$

$$P_3=6485 \text{ [Pa]}$$

$$P_{atm}=101325 \text{ [Pa]}$$

$$Re=9337$$

$$\rho_{oil}=1030 \text{ [kg/m}^3\text{]}$$

$$\text{Time}=28.32 \text{ [s]}$$

$$\text{Upsilon}=0.000007 \text{ [m}^2\text{/s]}$$

$$V_1=0 \text{ [m/s]}$$

$$V_2=6.536 \text{ [m/s]}$$

$$V_{dot_hole}=0.00003756 \text{ [m}^3\text{/s]}$$

$$V_{shock}=0.001064 \text{ [m}^3\text{]}$$

$$Z_1=0 \text{ [m]}$$

$$Z_2=0.3 \text{ [m]}$$

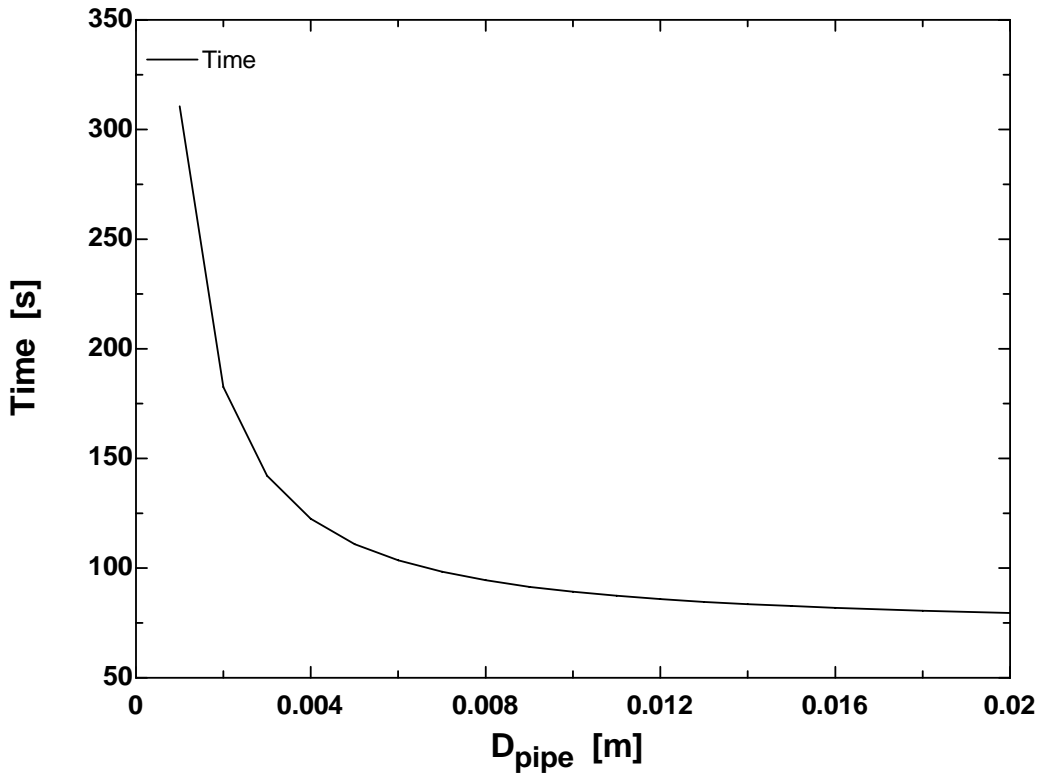


Fig. 1A: Time to fill shock as function of Pipe Diameter.

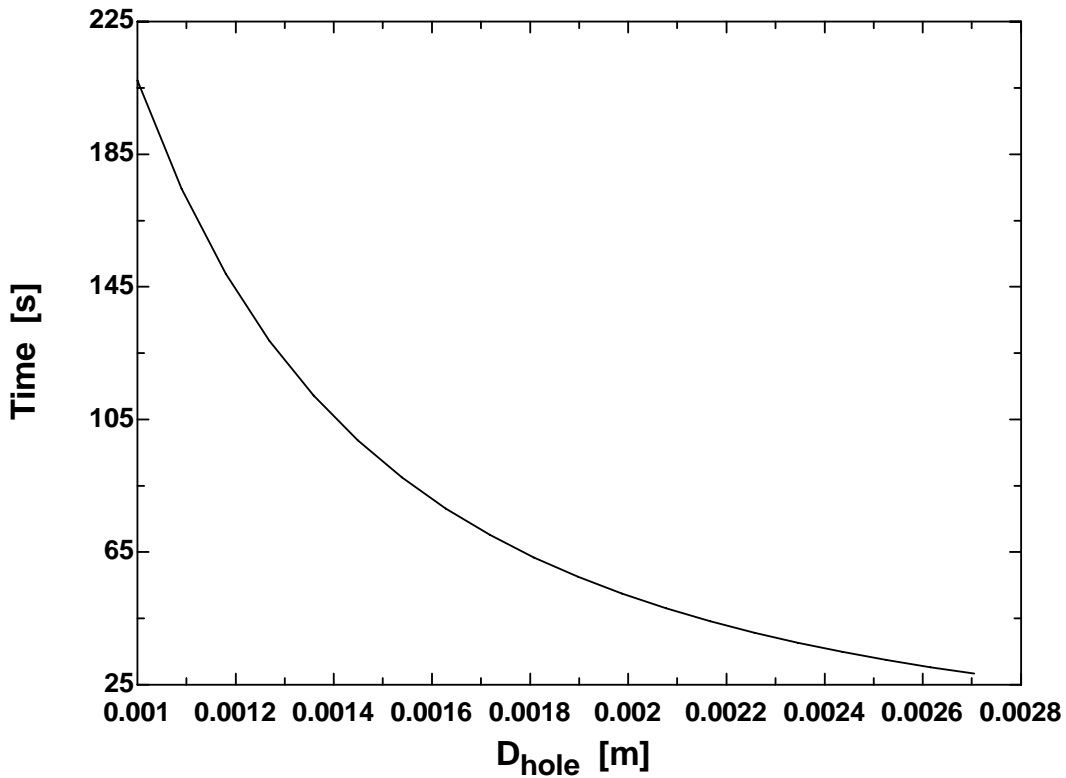
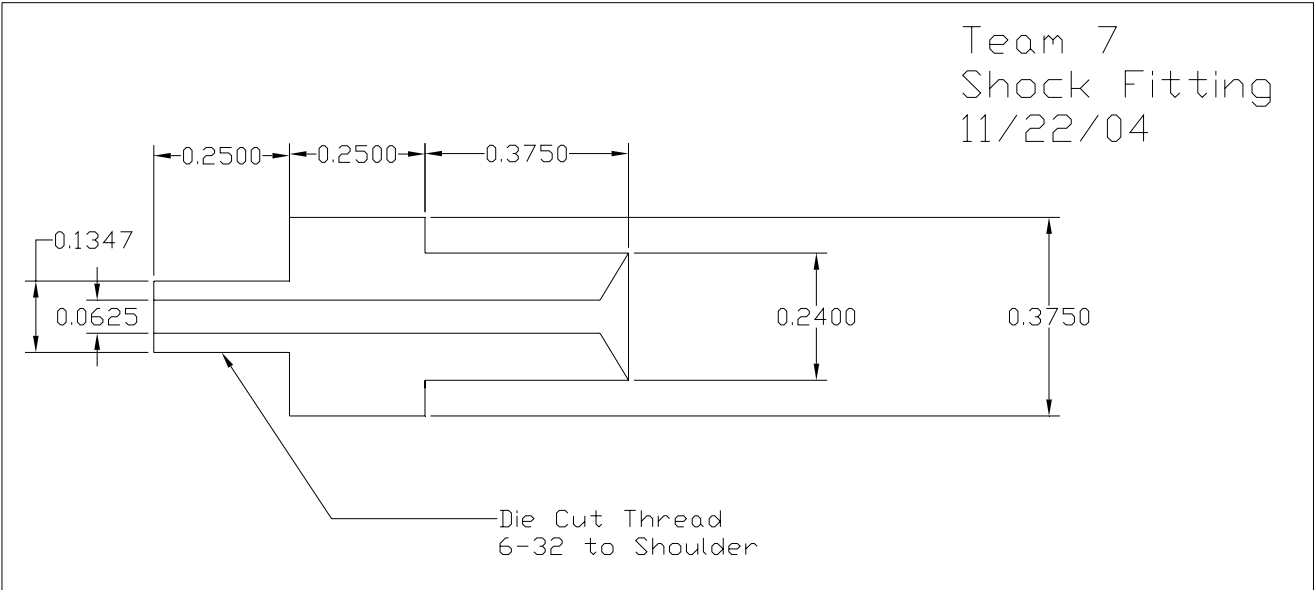


Fig. 2A: Time to fill shock function of shock filling hole diameter

13 APPENDIX B: Shock Fitting Diagram



Team 7: Aim to PLEASE (Preliminary Schedule)

