# EFFECTS OF VARIOUS FACTORS ON HYDRAULIC LIFT EFFICIENCY

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Abstract


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# 1 Contents

# 2 Introduction

## 2.1 Significance of Study

Hydraulic systems are an important tool in mechanics due to their ability to efficiently move heavy objects using little amounts of force, thereby creating a large mechanical advantage. They are used in a wide range of fields including lifts, brakes, and heavy machinery. Due to the popularity of hydraulic systems in mechanical devices, it is important to understand how different factors affect the efficiency of a design. This report analyses how elements of a hydraulic pump design can be altered to increase the mechanical advantage to push an object in a hydraulic lift system. Four factors were explored in this test: the area of the hydraulic press, the viscosity of the liquid, the length of the connecting tube and the contamination level of the liquid.

## 2.2 Aims of Study

The aim of this study is to investigate the amount of force in newtons required to operate a compression tube in order to lift a mass to a height of (5cm) from its resting position and to determine how each of the four variables can be modified to affect the mechanical advantage when operating the lift. The operation of the lift will be tested with a continuous array of contaminants within the liquids ranging from 0% to 10% in 1% increments, this being due to high levels containing more material then liquid and thus being extremely ineffective. The test will also measure the effect of liquids of varying viscosity such as water, oil, honey, milk and paint. Furthermore, the test will modify the length of the tube with 5cm and 10cm modifications. The test will also modify the area of the press with the maximum size being equal to that of the lift.

Along with the main aim of the study there are several other questions from which the study may show an interest.

a) Does the length of the tube have a significant impact on how much force is required to operate the lift?

b) Does the area of the press have a significant impact on how much force is required to operate the lift?

c) Does a liquids level of contamination have a significant impact on how much force is required to operate the lift?

d) Does the viscosity of the liquid have a significant impact on how much force is required to operate the lift?

e) Is there a significant correlation between any two or more elements within the experiment and how it modifies the amount of force required to operate the lift?

f) What is the most efficient combination of the aforementioned variables to affect the mechanical advantage within operation of the lift to the required perimeters.

**Variables:**

| Name of Variable | Type of Variable | Type of Factor | Description |
|---|---|---|---|
| Liquid Contamination | Factor | Continuous | (0%) through to (10%) in (1%) increments |
| Liquid Viscosity | Factor | Categorical | ($H_2O$), (Oil), (Honey), (Milk), (Paint) |
| Press Area | Factor | Continuous | (1/1),(½),(¼),(⅛) pump area to lift area |
| Tube Length | Factor | Continuous | (15cm) (30cm) (45cm) (60cm)<br><br>(90cm) |
| Mechanical Advantage | Numeric | Continuous | Force out per Force in |
| Force | Numeric | Continuous | Newtons |

The following variables were chosen due to the assumption they would have a significant impact on the amount of force required to operate the lift and as such would be best to apply modifications towards.

## 2.3 Assumptions and Limitations

Several assumptions have been made when designing this experiment. One assumption is that the temperature of all the components of every test is at a constant room temperature level. While measures were taken to ensure that all components would be at the same temperature, it cannot be guaranteed that this is always the case. Thus, this experiment assumes that temperature is not a factor that would greatly affect the efficiency of the hydraulic system, and that varying temperatures in components would not have a significant effect. It is also assumed that the results gathered from the simple hydraulic system can also be applied to more complex systems. As the hydraulic system used in this experiment is greatly simplified from most real world systems, there is a possibility that some factors may be more or less effective than found.

Additionally, there are several limitations to the experimental design. One example of this is the contamination level of the liquid. The contamination only considers a single type of contamination, being sand. This results in the experiment only being able to infer how that specific contamination type affects the hydraulic lift, and not any other type of contamination such as air or another solid material. This was decided on as there are so many different types of contaminants, that it would not be feasible to test a large amount of them. The design is also limited in that there are a significant number of ways that human error can affect the calculations, such as when measuring the force or the liquid used, which can possibly cause significant anomalies in the design. Also, the liquid viscosity is limited in that it is treated as a categorical variable. As the means to measure the liquid viscosity were not available for this experiment, it was decided that the liquids were tested based on type (e.g. water, oil, etc.). This allows for some findings to be made on the viscosity, but not any specific data.

# 3 Literature Review

There are a number of factors which affect the efficiency of a hydraulic lift system. In this experiment, four factors will be observed and experimented upon, namely the area of the pump, viscosity of liquid used, the length of the connecting tube, and the contamination of the liquid. The main law in action within this experiment is Pascal's law, which states that 'when there is an increase in pressure at any point in an incompressible liquid, there is an equal increase at every other point in the container.' For example, if two cylinders are filled with an incompressible liquid and are connected via a tube, and the first cylinder which has an area of 1 square inch is applied a load, this would naturally cause an increase in pressure of the fluid in the entire system. If the second cylinder has a cross-sectional area of 10 square inches, said pressure is applied to every point of that area, allowing it to lift an equivalent load proportional to the larger area. Thus, the larger the cross-section area of the second cylinder, the larger the 'mechanical advantage' of the system, and therefore, a larger mass can be lifted. (Hodanbosi, 1996).

The viscosity of the liquid used also has an effect on the efficiency of the hydraulic lift experiment. Viscosity refers to the consistency and state of a liquid due to internal friction, described as a fluid's resistance to flow (Elert, 1998). As hydraulic liquid flows through the pipeline, or the tube which connects the two cylinders together, a high level of viscosity will naturally cause greater internal friction, causing both the liquid to rise in heat and an increase of resistance to the fluid flow. A similar decrease in effectiveness also occurs with low levels of viscosity, where it may lead to leaking of the liquid and thus reduce volumetric efficiency of the system. Another factor that may affect the viscosity of a liquid is temperature (Anson, 2013). Generally, the viscosity of a liquid decreases as temperature rises in an inverse manner. This is due to the fact that higher temperatures increase the average speed of molecules within a liquid, which decreases the average intermolecular forces (Elert, 1998). Some hydraulic systems show that the oil's viscosity fluctuates when its temperature increases, which is undesirable as this makes fluids compressible and lowers efficiency of the entire system (Mobile Hydraulic Specialties, 2017). Therefore, it is imperative to both choose a liquid with an appropriate level of viscosity and desirable viscosity-temperature properties, as well as taking note of temperature as a nuisance variable, possibly alleviated by conducting the experiment at room temperature.

The third experimental observed factor is the length of the tube connecting the two cylinders. There has not been much literature in the past that has covered how this factor affects hydraulic lift systems, though 'Anson Lifting Platform' notes that the flow of fluid within the tube naturally has pressure loss along the way and keeping the design of the pipe as short as possible while 'reducing elbow' is a method to alleviate this (Anson, 2013). Due to this, it would be experimentally beneficial and of interest to find whether this length would have an effect, if any, to the working efficiency of the hydraulic lift system. A possible effect may be pressure loss due to the distance travelled between the fluid from one cylinder to another. In determining pressure drop in circular pipes, pressure drop (Pa) is directly proportional to the length of the pipe (m), fluid density (kg/m^3), as well as twice the fluid flow velocity (m/s) (Engineers Edge, 2000).

The final factor to consider is the contaminants within the fluid. Contaminants disrupt the resistive properties within a hydraulic fluid, which causes the fluid temperature to rise and therefore affecting viscosity. As stated previously, lower levels of viscosity lead to a reduction of volumetric efficiency within the system, possibly leading to less mechanical advantage overall. Examples of contaminants in the system include air bubbles and generally any foreign particles. (Mobile Hydraulic Specialties, 2017).

# 4 Methods

## 4.1 Materials and Equipment:

- Two syringes (on syringe must have a equal or larger diameter than the other)
- One connecting pipe
- Three vices
- Liquid of choice
- Contaminant of choice, i.e. sand
- An adhesive (for creating airtight seal on connecting tube)
- Small wood square
- Weight
- Force gauge
- Drill
- Ruler (For measurements)
- Permanent marker
- String
- Scissors

The ruler, permanent marker, string and scissors are not mentioned in the methods but they are important tools for measuring the diameter of the syringe parts as well as measuring the distance each plunger (pump and lift plungers) moved. The permanent marker and string are used to find the volume of parts of the syringe that cannot be done via a ruler.

## 4.2 Experimental Design

### 4.2.1 Experimental Method

1. Both the syringes (the pump and lift) were fixed using vices and the plunger for the pumping syringe was removed. The pump must be able to lift the object (of fixed weight) up a distance (fixed), about 5cm high, without pushing the plunger (of the pump) all the way down.
2. The connecting tube was connected to the hubs of both syringes, making sure that the connection is airtight using an adhesive as a filler
3. A platform was attached to the lift syringe and a weight was placed on top of the platform.
4. The liquid was poured into the simple hydraulic lift system, making sure that there is room for the plunger to be reinserted.
5. A force gauge was held fixed just over the pump, using a vice, with the hook that is being pulled on being connected to the top of the plunger. This was done by drilling a small hole on top of the plunger and then fitting the hook through it.
6. After the experiment is conducted, the liquid was emptied from the cylinder and the next liquid was poured in for the next replicate, ensuring that the cylinder was clean. Steps 4 and 5 were then repeated.

NOTE: The experiment will be done in a room that has its temperature kept constantly at 25 degrees Celsius.

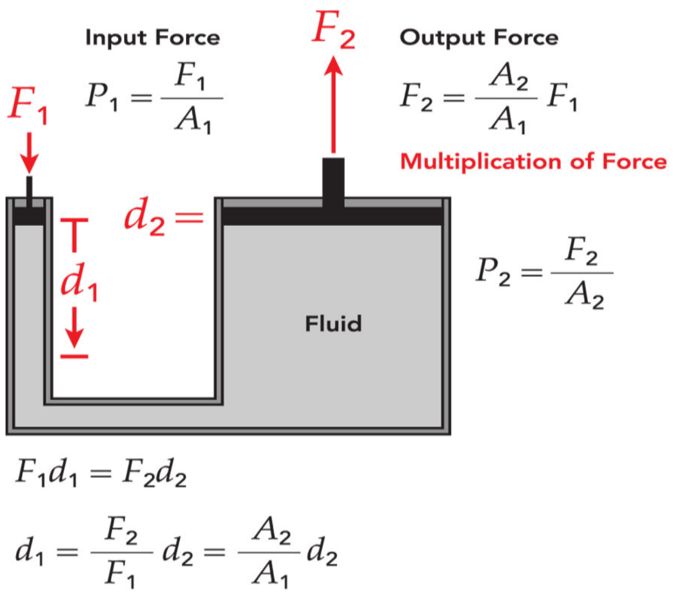


**Figure 1: Diagram of a simple hydraulic lift showing the formulas for Pascal's Law (Clippard, 2012).**

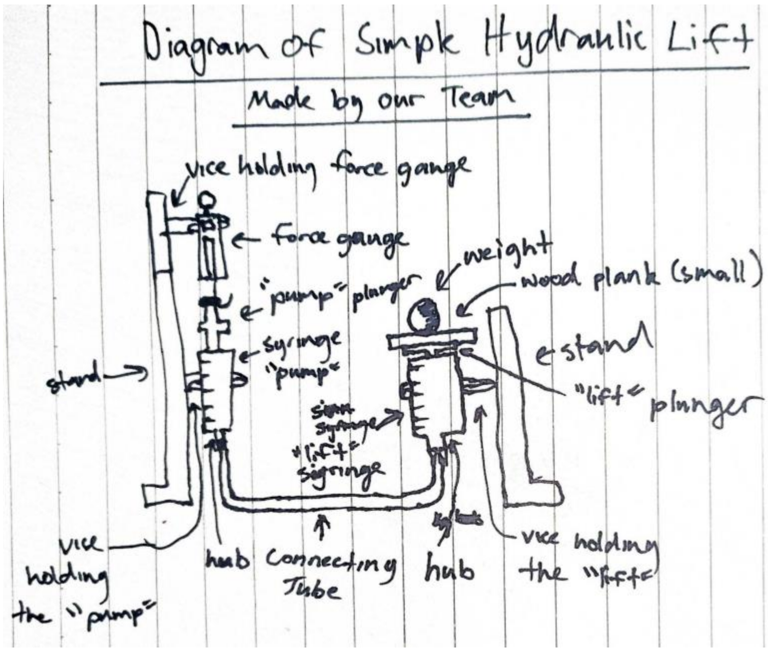


**Figure 2: Preliminary sketch of the assembled simple hydraulic lift. This hydraulic lift is based on the simple one shown in Figure 1.**

### 4.2.2 Data Collection Method

The plunger for the pump was pushed down until the object was lifted to its fixed distance. Then the force from the force gauge is measured as well as the distance the plunger from the pump moved. The force acting on the object was calculated using Pascal's law. Afterwards, the output force was divided by the input force to calculate the mechanical advantage, e.g. $Mechanical\ Advantage\ = \frac{F_2}{F_1}$ of 1.5 states that every 1 newton of force being acted on the pump produces 1.5 newtons of force on the lift.

## 4.3 Methods Reasoning

The simple hydraulic lift was chosen to eliminate as many nuisance variables as possible (including unknown nuisance variables) with the only known nuisance variables being the left-over residues of liquids, contaminants that can enter through the connecting tube, as well as the ambient temperature. The effect of ambient temperature was alleviated by conducting the experiment in room temperature (25 degrees Celsius) via air-conditioning in a closed room. The effect of the left-over residues from previous liquids was alleviated by thorough washing of the tube and syringes with a solvent that the residues can dissolve in and then drying. This was also done between replicates just in case of contamination of the previous replicate. The effect of possible contamination entering was mitigated by creating an airtight seal at all possible sights of entry. The force gauge was fixed over and connected to the pump plunger so that when the pump is pushed down, the gauge measures the force exerted onto it.

## 4.4 Size and Selection Criteria for the Study Sample

This experiment is a complete experiment with all treatments being done in triplicates to minimise the effect of human error. There are criterias for each of the predictors. Firstly, due to pascal's laws of $F_2 = \frac{A_2}{A_1} F_1$ (clippard, 2012) (Hodanbosi, 1996), where the $A_1$ and $F_1$ are the area of the pump and force acting on the pump and; $A_2$ and $F_2$ are the area of the lift and force acting on the object being lifted, in tandem with the mechanical advantage formula, $Mechanical\ Advantage\ = \frac{F_2}{F_1}$, it is not ideal to have an area of the pump being larger than the area of the lift and therefore only pump areas that are less or equal to the lift area were experimented on. Also, fluids with extremely high viscosity were not used as it is already known that it takes a lot of force to "compress" them, such as tar. Additionally, the percentage of contamination per volume is relatively small, with a maximum 10% contaminant to liquid ratio, as too high a ratio would be effectively the same as pushing on solids, which just like extremely viscous liquids, will be extremely ineffective. It is also highly unrealistic that a hydraulic system will have 95% sand contamination.

## 4.5 Potential Sources of Error and Weaknesses

There are multiple areas where error can occur. First of all, there could have been too much adhesive used for the connecting tube gaps which could cause the adhesive to leak in and contaminate the fluid. Unintended air or particle contamination could also occur from undersealing or improper sealing. This has the potential of causing an outlier and possibly an influential point. Also, the method of measuring the force requires a significant amount of human interaction and therefore inaccuracies in the measurements can arise from mismeasuring the force due to human error. Additionally, if the contaminants were not washed out properly when switching fluids then the left-over fluid could contaminate the current fluid which can cause an outlier or influential point in the data. Another source of error can occur from poor assembly of the simple hydraulic lift such as the force gauge being too far from the pump plunger. Most of the effects these errors have on the model will be reduced by conducting the experiment in triplicates, though an outlier can still have an effect on the model.

# 5 References


Clippard (2012). *Pascal’s Law*. Pneumatics 101. Retrieved 19 April 2022, from https://www.clippard.com/cms/wiki/pascals-law

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*How to improve hydraulic lift equipment working efficiency*. Anson. (2013). Retrieved 18 April 2022, from http://www.liftingplatform.net/how-to-improve-hydraulic-lift-equipment-working-efficiency.html.

*Pressure Drop Along Pipe Length - Fluid Flow Hydraulic and Pneumatic*. Engineers Edge. (2000). Retrieved 19 April 2022, from https://www.engineersedge.com/fluid_flow/pressure_drop/pressure_drop.htm.

# 6 Appendices

## 6.1 Appendix 1 (Meetings Summary):

| **Date** | **Time** | **Purpose of Meeting** | **What was achieved during/after the meeting** |
|---|---|---|---|
| 25/03/22 | 1pm-2pm | Brainstorming ideas for what experiment to do as well as getting approval | The team has decided to do a hydraulic lift experiment. |
| 4/04/22 | 5:30pm-6:30pm | Allocate Tasks for Report Stage 1 as well as the due date for our draft. | The team has allocated the tasks and the workload equally amongst everyone<br>**Methods:** Jesse<br>**Literature Review:** Ryan<br>**Introduction:** Nicole (⅔ of it) and Aiden<br>**Reference:** Aiden<br>**Title Page and Appendices:** Everyone<br>**Draft Due Date**: 13th of April |
| 14/04/22 | 2:30pm-3:00pm | Sending through our drafts of the initial report. | Drafts are sent through by everyone. And we all proofread each other's work. |
| 19/04/22 | 5:30pm- 6:30pm | Going through the report, checking for any errors and making any improvements for the draft | Several more details were added in for the draft along with it being submitted with the checklist. |

## 6.2 Appendix 2 (Planning Checklist):

**Part 1**

Please fill in all entries in the following tables and tick boxes to state agreement. It is important as part of your future careers that you take project planning seriously – especially sections relating to ethics (if applicable).

1. We have consulted the unit coordinator and teaching team to discuss this project. ☒

2. This project will not have any physical, emotional or psychological effects beyond those associated with everyday living. ☒

3. We commit to reporting any changes to our plan after any pilot study or at any subsequent stage. ☒

4. This project will not involve issues that are offensive or sensitive. ☒

5. If this project involves peoples' cooperation or assistance, this cooperation will be requested in person. ☒

6. If this project involves a survey or a non-intrusive experiment/study involving peoples' cooperation or assistance, the following statement will be provided to each participant: ☒

   *"For a unit in statistics at QUT, we have been asked to choose a topic of interest to us and collect data to investigate it. We are interested in ................................ and would be grateful for your assistance. These data are for educational purposes only and no individual will be able to be identified in any writing or discussion about the data."*

**Part 2**

It is important that each member of the group reviews this document before submission to verify that they have understood the plan before data collection and assessment commences.

Signed by each member of the group:

| | | |
|---|---|---|
| 1. | Aidan Hay (n10777105) | |
| | *(Name)* | *(Signature)* |
| 2. | Ryan Hafizh Indrananda (n10852565) | |
| | *(Name)* | *(Signature)* |
| 3. | Jesse Travaini (n10747028) | Jesse Travaini |
| | *(Name)* | *(Signature)* |
| 4. | Nicole French (n10212949) | |
| | *(Name)* | *(Signature)* |

If you have four group members, describe the planned additional work in consideration of the fourth member.

The planned additional work for this task will be to include a fourth predictor variable to the design. This fourth variable will be to test how the contamination of the liquid affects the force of the hydraulic pump. This will require a significant amount of extra preparation for the data collection to achieve a complete experimental design.