FACULTY OF ENGINEERING AND BUILT ENVIRONMENT

DEPARTMENT OF INDUSTRIAL AND MECHATRONICS ENGINEERING

A FINAL YEAR PROJECT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR A BSc. HONOURS DEGREE IN MECHANICAL ENGINEERING.

Design of an Automated Lime Dosing system for Bulawayo Mining Company

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DECLARATION

I Zibusiso Jila Dube declare that this project submitted is a composition of my own work except for those referenced and acknowledged authors.

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Signed………………….

Date……………………

ABSTRACT

A dosing system is a device or system that is used to add a precise amount of substance, to a process or product. Dosing systems which rely on manual Dosing have several problems in various applications. These can be inaccurate Dosing, inconsistent dosing, operator error, safety concerns, monitoring and control. This project is to show the design of an Automated Lime Dosing system for Bulawayo Mining company (HOWMINE) using an Arduino microcontroller. The software called Arduino IDE is utilized to create a program that enables a microcontroller to establish communication with various sensors and hardware components. The circuit consists of several devices including a pH sensor an ultrasonic sensor, a servo, a liquid crystal display, and a DC pump. In case the pH level goes beyond a specific range, the DC pump is activated automatically to restore the pH value of the pulp to 9. The LCD shows pH values and water level. The role of lime is to act as a pH control agent for optimal cyanidation leaching of gold as well as being a neutralisation agent. Lime when exposed to people can aggravate disorder to the eyes, skin, gastro internal tract and respiratory system. Prolonged exposure leads to persistent coughing and breathing problems which can lead to chronic lung disorder, silicosis, etc. Current Dosing system is whereby operators add lime from 25kg bags onto a moving conveyor belt that is exposed to air. Hourly additions require employees working in close proximity to evacuate the dosing site leading to an increase in downtime. This project ensures that there is no exposure of operators to lime, the system is automated minimizing operator handling and making it environmentally friendly as the lime is to be dosed in solution form.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

1.1 INTRODUCTION

In the gold processing industries, lime is crucial. Despite its significance, it poses numerous concerns. The operator in the dosing process faces numerous health dangers while applying lime, including the possibility of being grabbed by a moving conveyor belt. This project aims to draw attention to all the drawbacks of the current lime dosing system while also taking into account the health of the operator, neighbouring workers and the environment.

Lime reagents are consumed largely in the gold processing industries. Its role is to act as a pH control agent for optimal cyanidation leaching of gold as well as being a neutralisation agent. Influencing lime consumption and functionality of the overall process are a range of conditions upstream of cyanidation. Cyanidation is the extraction of gold or silver from their ores using the cyanide process. (Law Insider Inc, 2013-2022) As compared to other pH modifiers, Lime positively impacts gold absorption onto carbon in pulp and carbon in solution circuits. In most cases the quantity of lime consumed depends on factors like

- Lime reagent properties
- Methods of preparation
- Gold ore type
- Processing flow sheet

Lime is an odourless white granule. In the form of calcium hydroxide or calcium oxide it is a very common modifying reagent. Its classification is that of an inorganic modifier and its primary function is to alter the pH of the pulp. (Bulatovic, 2007). The chemical properties of Lime are in the table 1.

Table 1: Chemical Properties of Lime ((Kimberlite Softwares Pvt. Ltd, 2022)

Appearance	Soft white powder/ colourless liquid
Basicity	2.37
Chemical composition	Calcium oxide→calcium carbonate→ metallurgical coke
Density	2.211g/cm3 ,solid
Melting point	512 degree Celsius
Molar mass	74.093g/mol
Molecular formula	Ca(OH)2
Other cations	Magnesium hydroxide, strontium hydroxide , barium hydroxide

Lime dosing is a process in which lime and water is also fed into the mill together with crushed ore to facilitate milling at the appropriate solids concentration and viscosity that are suitable for direct cyanide leaching. Lime rates are relatively low, i.e. 0.5-2kg per tonne of dry feed. In gold processing plants, lime dosing reagents are dependent on the extent of acid consuming reactions and the accuracy of pH control that is required. The simplest dosing method which is the one currently used at the Bulawayo mining company is where dry quicklime is directly applied to ore on a conveyor belt. This method is usually applied where the lime consumption demand of processed ore is relatively low i.e. <2kg per ton of ore treated. The similar method is applied to gold heap leaching operations where the dry quick lime is dosed directly from a silo onto the back of a truck before the ore is stacked onto a heap (Kappes, 2002). The disadvantage with these methods is that they do not provide a precise pH control or adjusting pH after lime has been added to the ore.In most gold processing operations and applications, however, dry quicklime is slaked resulting in a suspension of Ca(OH)2 particles that can be pumped and dosed into multiple process operations for flexible and accurate pH control. Slaking can be achieved in a variety of slaking reactors including ball mill slakers, detention slakers, and stirred tank slakers (Oates, 2008).

1.2 BACKGROUND

In gold mines there are different procedures which are done to eventually lead to the extraction gold. Figure 1 shows the simplified process flow sheet of uncomplicated gold process with gravity recovery followed by cyanidation. Variations of this flow sheet include ore directly to milling, lime addition after the milling step and the use of resin instead of activated carbon (Lowes & McGrath T, 2020).

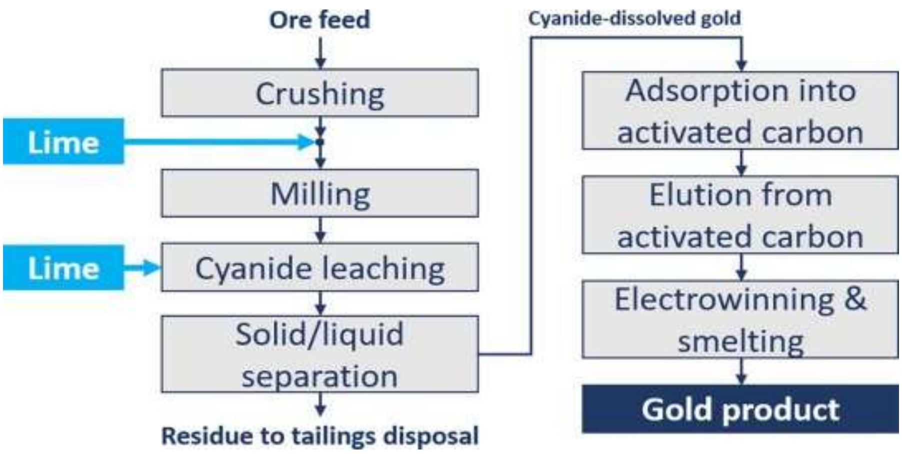


Figure 1.1 : Simplified flow sheet of mining process(Lambert, Ingram, & Eksteen, 2021)

The flowchart is a typical case for ores with reasonable gold grade of about >1g Au per ton ore and have sufficiently low concentrations of iron and copper sulphide minerals that do not interfere with the processing in terms of cyanide consumption .

Hydrated lime has its benefits which eventually make way for the negatives. Prolonged exposure to lime leads to persistent coughing and breathing problems which may cause a chronic lung disorder, silicosis (see figure 1). Silicosis is a long term lung disease caused by prolonged inhaling large amounts of crystalline silica dust. Other health effects include possible blindness, blotches, itching, superficial burns, sore throat, etc.

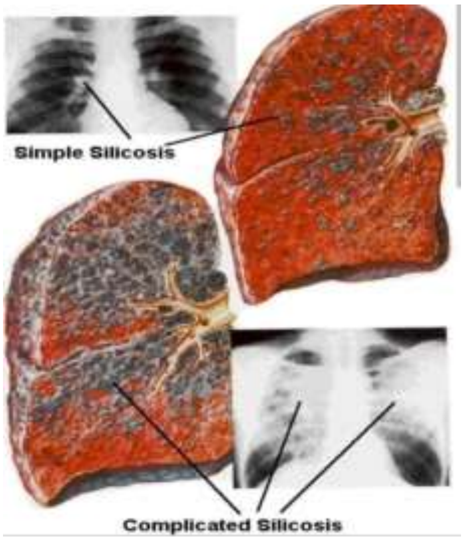


Figure 1.2: Chest X-rays of the Silicosis patient (NIMH, 2012)

There are about 846 employees at the Bulawayo mining company, and each is anticipated to contribute equally to the overall gold output. Each employee is required to contribute roughly 0.197g of gold per hour to reach the monthly production target of about 120kgs of gold. An average of 15 personnel leave the plant for 10 to 15 minutes to avoid exposure to lime dust during the addition of lime on incline conveyor number 2(shown on Figure 3). This means BMC is losing around 532g gold each and every month as employees are being paid for 2hours per day which the spend outside the plant.(HOWMINE, 2022)

CALCULATIONS

- Expected gold production per worker per month= $\frac{targeted\ gold\ production}{total\ number\ of\ workers} = \frac{120kg}{846}$

  =142g per worker/month

  =4.73g per worker/day (0.197g per hour)

- Time lost due to lime addition worker/day= 15minutes x 8 working hours/60mins

  =2 hours per day per shift

- Time lost per day(24hours) =2 x 3shifts= 6 hours
- Amount of gold "lost"per month =0.197 x 15workers x 6workers x 30days

  = 531.9g (19 ounce) of gold per month

- Revenue loss per month =amount of gold(ounce) x gold price/ounce

  = 19ounce x US$1785.40 per ounce (price as of 13/12/2022)

  =US$ 33 922.60(HOWMINE, 2022)

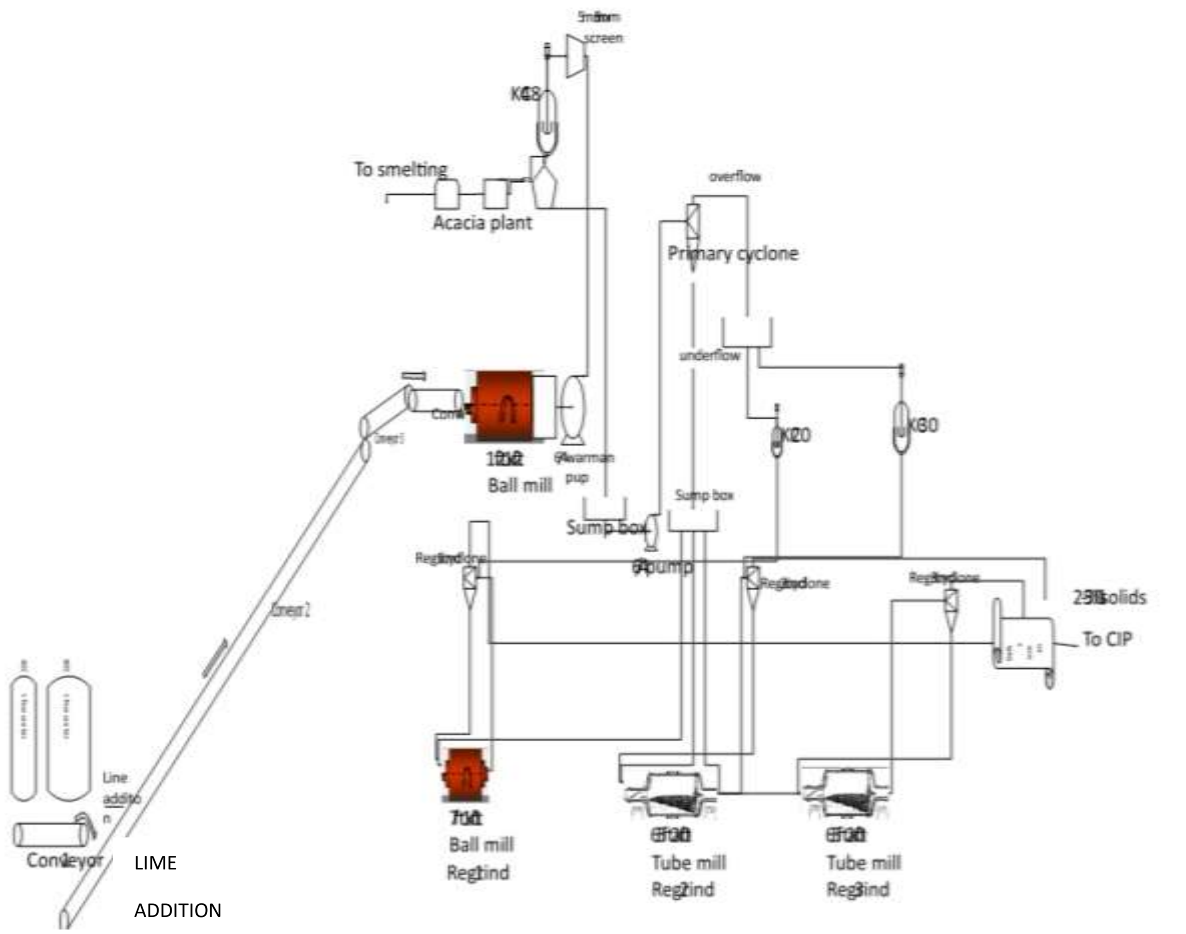


Figure 1.3: HOWMINE milling circuit showing where lime is added

1.3 PROBLEM STATEMENT

Bulawayo mining company uses hydrated lime where it is added to the system. Operators add lime to the milling plant from 25kg bags onto a moving conveyor belt that is exposed to the air as shown in figure 4. Hourly additions of 75kg of lime require operators all other employees working in the milling plant to stop what they are doing and leave the facility for a safer location because airborne lime dust is produced during this operation. Due to insufficient communication mediums, some employees may not hear the call to add lime therefore become victim to the silent killer. Prolonged exposure to impure lime containing 3% to 20% quarts can increase the risk of silicosis. The manual lime dosing process shown on figure 1.4 is inefficient, inaccurate and poses safety hazards to workers. The process requires frequent monitoring, which leads to increased labour costs and potential errors. The imprecise dosing of lime can negatively impact the quality of the end product leading to potential financial losses.

Figure 1.4: A picture of an operator putting lime onto a moving conveyor

1.4 JUSTIFICATION

The main aim of any mine is to produce a safe environment for the employees and those around. An automated lime dosing system can significantly increase the efficiency of the lime dosing system. Automation can reduce the need for manual intervention, which saves time and reduces the likelihood of errors. In turn this would increase productivity and throughput, which ultimately improves the bottom line. An automated dosing system can provide highly accurate and consistent dosing which improves the quality of the product. This is very important in gold processing where even small variations in lime dosing can have significant impact on the final product. The handling of lime can be hazardous, as it is highly alkaline it can cause chemical burns and respiratory issues. An automated system reduces the risk of exposure by minimizing the need for manual handling and providing a more controlled dosing process. When lime is applied all those working in the milling plant have to move to a safer location to get away from the air borne lime and this then increases the amount of down time. This project seeks to show how unreliable the current method of lime dosing is and provide an efficient solution.

1.5 AIM

To design an automated lime dosing system for The Bulawayo Mining Company gold processing plant

1.6 **OBJECTIVES**

- To design an automated system that reduces the operator's chemical handling
- To design a project that meets the international health and safety management standards of Mines(ISO 18001) which outlines the requirements for an effective health and safety management system.
- To design a system that doses lime more efficiently with a flow rate of $0.53m^3/h$, an improvement of current system also providing a prototype

CHAPTER 2: LITERATURE REVIEW

2.1 WHAT IS A DOSING SYSTEM

Adding a specific amount of a substance, such as a chemical or medication, to a process or product is done using a dosing system, a device or system. Dosing systems are commonly used in a various fields like industry, agriculture, pharmaceuticals, and water purification.

Dosing systems are employed in the process of treating water to eliminate contaminants and make it safe for consumption. These chemicals added to the water include chlorine, fluoride, and coagulants. Dosing systems can be used in agriculture to apply nutrients and insecticides to crops to promote growth and ward off illness. Dosing systems can be used in the pharmaceutical industry to add exact dosages of medication to capsules or tablets.

The sophistication of dosing systems can range from straightforward gravity-fed systems to highly automated systems that precisely manage the dosage rate using sensors and controls. To guarantee that the dosage rate is precise and reliable, some dosing systems could also contain monitoring and control tools like pH sensors, flow meters, and controllers.

Dosing systems ensure that the desired amount of substance is added to the process or product, improving quality, efficacy, and safety overall. They are a crucial part of many industrial processes.

2.2 HISTORY

The most affordable and popular alkali is lime. About 200 million tpa of lime products are produced worldwide in China. One of the widely used compounds is lime. The steel, construction, mineral processing, and building industry are the primary users of lime products in the majority of industrialized nations. Although prehistoric man presumably discovered applications for limestone before that time, it has been around since the Stone Age. The Giza pyramids were built during the Second Dynasty of ancient Egypt, according to the earliest records. Limestone has been widely used as an aggregate in architecture and construction for ages. Most nations have limestone resources, which make up around 10% of the earth's natural land area. Climate, geo technics, and sea level are three key interconnected elements that have significantly influenced the distribution of limestone throughout the planet. Thermal decomposition of limestone at temperatures above 900°C results in the production of quicklime, which is mostly calcium oxide (Kumar & Hung, 2007). Calcium hydroxide is created when around half of the quicklime produced reacts with water (in the form of milk or lime putty). In a wide range of industrial operations, lime products are typically the most readily available and most affordable alkaline compounds. In many countries, the main usage of this substance is found in the production of iron and steel, building and construction, environmental protection, and the chemical industry. (Neenu, 2019).

2.3 LIME USE IN MINERAL PROCESSING INDUSTRY

Large amounts of lime reagents are used in the gold processing industries. Its purpose is to act as a neutralizer and a pH control agent for the best cyanidation leaching of gold. The general word for the reagent's numerous forms is "lime"(du Plesis & Naldrett, 2001). Among the formats are quicklime, a dry reagent mostly composed of calcium oxide (CaO), and component, created by oxidizing limestone that contains calcium carbonate ($CaCO^3$); hydrate or hydrated lime, a dry reagent made from the stoichiometric hydration of quicklime with water and mostly consisting of $Ca(OH)^2$; and slaked lime, also known as milk of lime, a slurry of $Ca(OH)^2$; `321`321particles typically in the range of 10 to 25 weight percentile though customized product formulations may contain up to 45%wt solids content, slaking quicklime in a stoichiometric excess of water. All other kinds of lime reagent, including quicklime (with active ingredient CaO), are made by oxidizing limestone ($CaCO^3$); at temperatures between 900 and 1300 °C while employing a variety of kiln types and fuel sources (Pringer, 2017). Typically, calcinations are contracted out to lime-producing enterprises that are typically distant from the mining site.

The properties of the produced quicklime are greatly influenced by the pyrolysis conditions as well as the fuel employed as an energy source (Boynton, 1980). These variables affect the porosity, reactivity, slaking properties, and eventually the size of the $Ca(OH)^2$ particles produced after reacting with water in quicklime (Zanin & Plessis, 2019). Considering the generally low cost of lime as a raw material at the time of production, the far locations of most mining sites make transport logistics a considerable cost component. Because quicklime has a lower mass per unit of reactive component than hydrate and slaked forms, it is frequently utilized for long distance transportation.

2.4 DRY QUICKLIME VERSUS SLAKED LIME REAGENT USE

The amount of acid-consuming processes and the precision of pH control needed determine how lime reagent is dosed in gold processing. The simplest dosing arrangement involves a dosing screw attached to a lime silo directly applying dry quicklime (of particle size 25 mm) to ore on a conveyor-belt ball mill feed. A feedback mechanism based on the pH measurement in the cyanidation process unit regulates the dosing screw feed rate. Such dosing techniques are frequently used in situations where the processed ore's relatively modest (i.e., 2 kilogram per ton of ore treated), predictable, and constant lime consumption need. This method of dosing lime is predicated on the idea that the ball mill offers enough agitation and residence time to achieve quicklime slaking (i.e. hydration) into Ca(OH). In order to administer dry quicklime directly onto the ore on the back of a truck before the ore is heaped into a heap during gold heap leaching operations, a similar dosing approach is used (Kappes, 2002).

2.5 HOW MINE SAFETY MANAGEMENT SYSTEMS OHSAS, AND ISO 140001

OHSAS (Occupational Health and Safety Assessment Standards)

- In line with the Group Safety, Health and Environmental ("SHE") Policy, How Mine is dedicated to ensuring that its employees, contractors, and other affected stakeholders have access to safe and healthy working conditions by:
- Complying with applicable Occupational Health and Safety ("OHS") legal and other requirements
- Identifying and mitigating OHS hazards and risks arising from the mine's operations, in order to prevent occupational injuries and ill health
- Implementing and maintaining an effective OHS management system, in line with international standards, to ensure a systematic approach and continual improvement of OHS management and performance
- Continual evaluation of the mine's OHS management and performance against set objectives, targets and applicable legal and other requirements
- Improving OHS awareness through open communication with employees, contractors, suppliers, relevant authorities and any other affected stakeholders on OHS issues of mutual concern, to enhance individual OHS obligations
- This policy is reviewed regularly and communicated to all employees and any other affected stakeholders

ISO 14001 (Environmental Policy)

In line with its Group Safety, Health and Environmental (SHE) Policy, How Mine is committed to protecting the environment in which it operates, through:

- Compliance with applicable Environmental Legal and other requirements
- Implementation of formal environmental management systems to ensure a systematic approach to environmental management
- Identification and mitigation of adverse environmental of solid and liquid mine waste, hazardous substances and emissions to air to achieve continual environmental performance improvement
- Implementation of programmes to prevent and/or mitigate against pollution arising from its activities, products and services
- Continual evaluation of environmental performance against set objectives, targets and relevant legal and other requirements. This statement is renewed annually and is available to the public and relevant stake holders. Meeting the above requirements means that EMA penalty on environmental pollution is reduced for the mine.

2.6 AUTOMATION

According to Benhabib (2003), automation refers to the utilization of information technologies and control systems to reduce the dependence on human labor in the production of goods and services. Unlike mechanization, automation not only deals with the physical aspects of industrialization but also reduces the need for human cognitive abilities. Mechanization, on the other hand, primarily assisted human workers with the physical demands of labor. The primary aims of utilizing automation control systems in industries are to enhance productivity, improve product quality, and manage production costs.

2.7 CONTROL CONCEPTS SYSTEM

When analyzing and designing modern process control systems, two main types of control systems are utilized: open loop control systems and closed loop control systems.

2.7.1 Open loop control system or Feed forward control

In an open loop control system, the control action is not affected by the output, meaning that the output is not related to the input. The aim of feed-forward control is to identify and compensate for disturbances before the controlled variable deviates from the desired set point. The general method involves directly measuring the disturbance and taking appropriate control measures to mitigate its impact on the process output, as explained by Bequette (2003). Figure 2.1 illustrates the block diagram of a feed-forward control scheme.

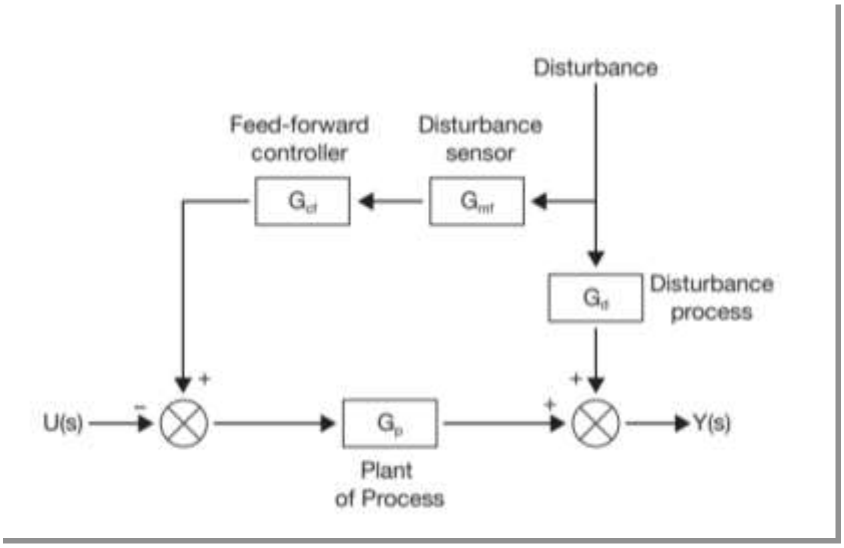


Figure 2.1: Feed forward control (Bequette, 2003)

The following is an instance of a chemical addition pump that has variable speed control. The rate at which the chemicals are fed into the system to maintain its optimal chemistry is determined by an external operator. If the chemistry of the system changes, the pump cannot automatically adjust its feed rate without the intervention of the operator. The benefit of this system lies in its simplicity of design. However, the drawback is that the open-loop control system does not allow the input to have any influence on the output or controlled variable.

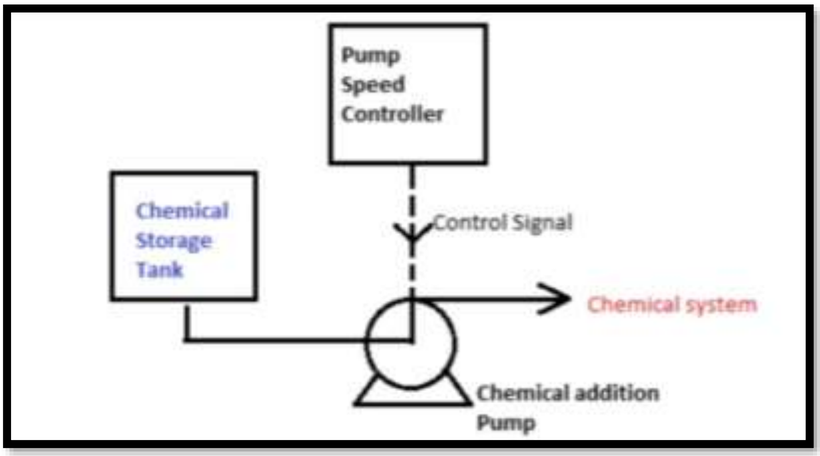


Figure 2.2: Open loop control system

2.7.2 Closed loop or Feedback Control System

A mechanical or electronic device known as a closed loop control system automatically adjusts a system to maintain a desired state or set point without the involvement of a human. It employs a sensor or feedback system. The block diagram representation of a closed-loop control system is shown on figure 2.3.

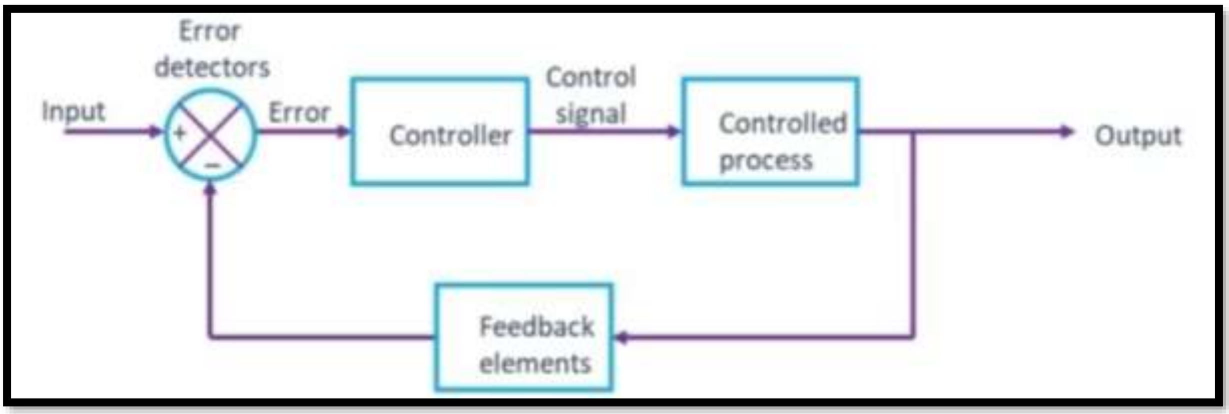


Figure 2.3: Closed loop control system block diagram (Parasher, What is a Closed-Loop Control system?, 2022)

The closed loop control system's precise and efficient output is a result of the feedback structure. We give up some system characteristics to achieve this advantage. The automatic error correction aspect of closed-loop control systems, which makes them more independent or less reliant on human oversight, is their main advantage. Additionally, compared to an open loop control system, it may stabilize an unstable system, enhance or reduce system sensitivity based on user requirements, and respond to outside disturbances more effectively. (Parasher, 2022)

2.7.3 Feed forward plus feedback control

It is possible to employ a feedback system in conjunction with a feed forward system to avoid the challenge of anticipating the load disturbance. Therefore, the controller in this form of control system would get the combined input from the feed forward and feedback system. Figure 2.4 illustrates the integration of feedforward and feedback control. The feedforward controller aims to minimize or eliminate the impact of external disturbances on the system, while the feedback control loop is a basic closed loop control mechanism that responds by adjusting the set point, according to Bequette (2003). The combination of these two approaches results in a superior performance compared to the simple feedback control, particularly in the presence of disturbances that can be measured before they affect the output of the process.

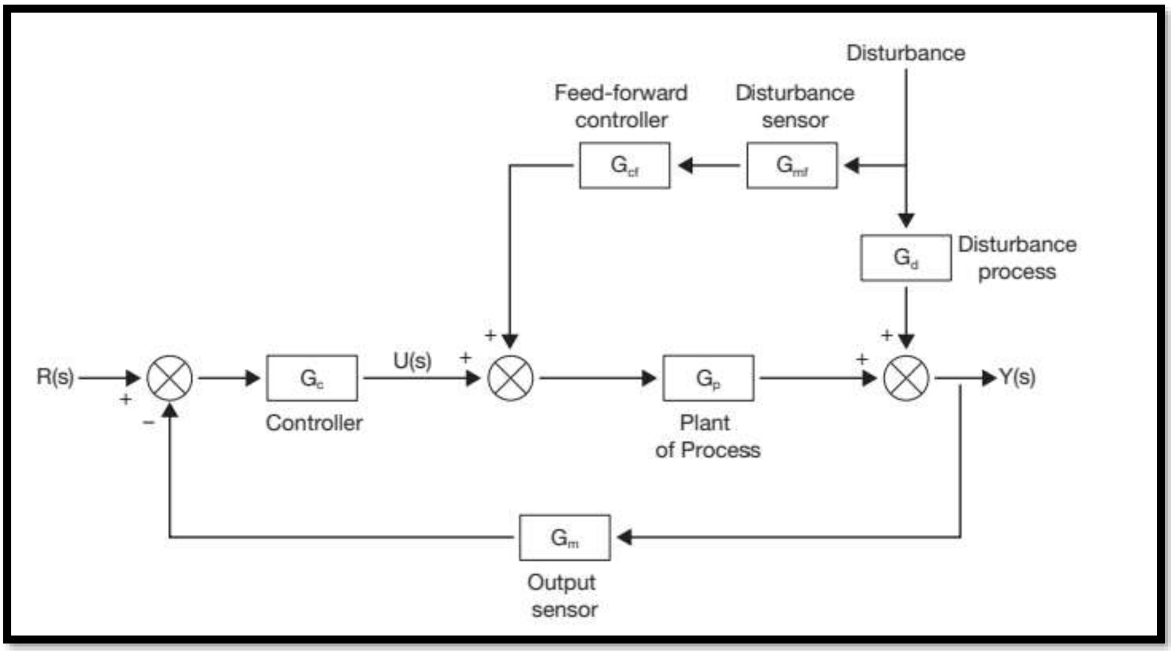


Figure 2.4: Feedback plus feed-forward control (Bequette, 2003)

2.8 TYPES OF CONTROLLERS

2.8.1 PID Controller

The PID controller, which is sometimes referred to as a three-term controller, employs three primary control actions: the proportional, integral, and derivative actions. These control actions are combined to produce a single control output. The PID controller is widely used in various control systems because it is straightforward to set up and implement.. The output from a PID Controller is given as

$$u(t) = K_C \left(e(t) + \frac{1}{\tau_I} \int e(t)\, dt + \tau_D \frac{de\,(t)}{dt} \right) \quad (1)$$

Where u(t) is the control signal, e(t) the error signal defined as the difference between the set point and the output.

K_C =Proportional gain

τ_I =Integral time

τ_D =Derivative time (Astrom & Hagglund, 1995)

2.8.2 PLC Controller

A programmable logic controller (PLC) is a compact computer that has ports for data input and output commands. Its main function is to regulate the operation of a system by analyzing the status of input devices and determining how to control the output devices using customized programs. Many businesses worldwide use PLCs to automate crucial procedures. PLCs receive inputs from various sources, such as automated data collection points and human input points, including buttons and switches. Based on their programming, PLCs decide whether or not to modify the outputs, which can control a variety of machinery, such as motors, solenoid valves, lighting, switch gear, safety shut-offs, and more.

Advantages of PLCs

- Compared to other industrial control systems, the programming languages used in PLCs are relatively straightforward. This makes PLCs an excellent choice for companies that seek to reduce complexity and expenses.
- PLCs are available in wide range of prices, including many extremely affordable basic models that small businesses and start-ups often use
- PLCs are highly adaptable, and the majority of PLC models are capable of controlling a broad range of processes and systems.
- PLCs do not have any moving components, making them exceptionally dependable and better equipped to withstand the harsh conditions commonly found in industrial facilities.
- They have few components making it easy to troubleshoot
- They are efficient and do not consume much of electric power

Disadvantages of PLCs

- PLCs are less capable of managing highly intricate data or large quantities of processes that involve analog inputs rather than digital ones.
- Similar to other electronic equipment, PLCs are susceptible to electromagnetic interference, as well as common malfunctions in electronics, such as memory corruption and communication failures. (POLYCASE, 2021)

2.9 ACTUATORS

An actuator is a device that transforms energy and input signals into motion or force output in a system. It is typically a mechanical apparatus that converts energy from sources such as air, electricity, or liquid into various forms of motion, like blocking, clamping, or ejecting. An actuator is the component by which an agent interacts with an environment, whether it is an artificial intelligence agent or any other autonomous entity like humans or animals. Actuators are commonly utilized in manufacturing or industrial settings and can be found in devices such as motors, pumps, switches, and valves.(Garcia, 1995)Examples of Actuators are explained below.

- **Electric Linear – is an electromechanical equipment that consists mainly of a motor, a set of gears, and a motion mechanism in the shape of a worm and a tube. It transforms the rotary motion of the motor into linear motion by propelling the gears and worm gear.**

- **Electric Rotary-** a mechanical device with an electrical power source that uses output shaft mechanisms and motors to transform electrical energy into rotational motion.

- **Fluid Power Linear-** are mechanical devices that utilize cylinder and piston mechanisms to generate linear displacement by using hydraulic fluid, gas, or differential air pressure.

- **Fluid power rotary- These mechanical devices convert hydraulic fluid, gas, or differential air pressure into rotary motion. They are composed of cylinder and piston mechanisms, gearing, and output shafts with limited rotational movement.**This actuator is used where an object needs to be rotated in a controlled manner to a certain position. Air, hydraulic fluid or other gases are used as different media to power the actuator

- **Linear Chain Actuator-** is utilized in lift applications, push-pull material handling, and window operation. Pinnings positioned on a drive shaft inside of an exterior casing are engaged by a chain. The chain links rotate through the casing at a 90-degree angle while the pinions spin.. For the push and pull actions , this actuator normally includes a single set of drive gears or sprockets that provide necessary forces

- **Manual Linear-** A manual actuator utilizes levers, gears, or wheels to enable movement, whereas an automatic actuator is powered externally to produce the force and motion necessary to remotely or automatically operate a valve. (Harbel, 2020) The manual actuator comprises hand-operated knobs and wheels, gearboxes, and guided linear motion mechanisms that provide linear displacement through the rotation of manually operated screws or gears.
- **Manual rotary- is a mechanical device that converts manually rotated screws, levers, or gears into rotary output. These actuators typically include hand-operated knobs, levers, or hand wheels, as well as gearboxes or threaded nut mechanisms and output shafts.** They are sometimes referred to as manual valve operators. (Kumar, 2020)

2.10 TYPES OF SCREW CONVEYORS

Figure 9 illustrates the use of screw conveyors, which are employed for conveying bulk materials from various positions, including vertical, horizontal, or inclined. Screw conveyance is widely recognized as one of the most dependable methods of material transfer. Screw conveyors come in different types, such as horizontal, inclined, shaftless, vertical, and live bottom screw conveyors. (KWS, 2016)

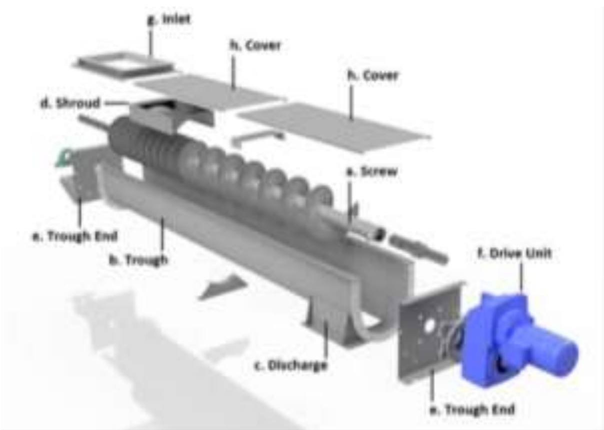


Figure 2.5: Labelled diagram of a screw conveyor (KWS, 2016)

The main factors to consider when selecting a screw conveyor include:

- The type and state of the bulk material to be conveyed, including its maximum particle size and specific bulk density

- The desired capacity or feed rate for the bulk material being conveyed, which is usually expressed as a specific value

- The necessary distance and incline for conveying the bulk material

- The design conditions, such as the materials of construction, inlet feed conditions, and operating temperature.

In order to select a screw conveyor there are five main steps that need to be considered

- Identify the properties of the bulk density that needs to be conveyed.
- Determine the appropriate conveyor size and speed based on the required capacity.
- Compute the horsepower necessary for the operation of the conveyor.
- Confirm the torque rating of the components.
- Choose the conveyor components. (KWS, 2016)

2.10.1 Horizontal screw conveyor

Horizontal screw conveyors are the most commonly used type of screw conveyor, utilized for conveying bulk materials from one part of a process to another. They are available in various sizes, lengths, configurations, and materials of construction. Screw conveyors are usually designed to convey bulk materials at 15%, 30%, or 45% trough loading, depending on the specific characteristics of the material being conveyed. For light, free-flowing, and non-abrasive bulk materials, a trough loading of 45% can be used. For denser, sluggish, and more abrasive bulk materials, trough loadings of 15% and 30% are typically utilized. Another device, such as a screw conveyor, screw feeder, belt conveyor, rotary airlock, or volumetric or gravimetric feeder, always control feeds the inlet of a screw conveyor. (KWS, 2016)

The drive unit should be positioned on the screw conveyor's discharge end, which pulls bulk material to the drive end. As the bulk material is transported toward the discharge of a screw conveyor, each screw segment is put in tension, decreasing wear and stress on conveyor parts.

Benefits of utilizing screw conveyors

- When compared to alternative conveying mechanisms like belts and pneumatics, it is cost-effective for moving dry to semi-fluid bulk materials (free flowing to sluggish).

- Uses several inlet and discharge points to transfer bulk material to different areas in an efficient manner.
- Completely enclosed for conditions that are corrosive, dangerous, or dusty (KWS, 2016)

2.10.2 Inclined screw conveyors

Inclined screw conveyors (figure 10) typically operate from slightly above the horizontal position to 45-degrees from the horizontal position. Above 45-degrees an inclined screw conveyor is considered a vertical screw conveyor. . As the degree of incline increases, conveying efficiency is reduced and horsepower requirements increase due to the effects of gravity and bulk material fall back. Conveying efficiency is affected by angle of incline, characteristics of the specific bulk material, type of screw conveyor trough and screw pitch. (KWS, 2016)

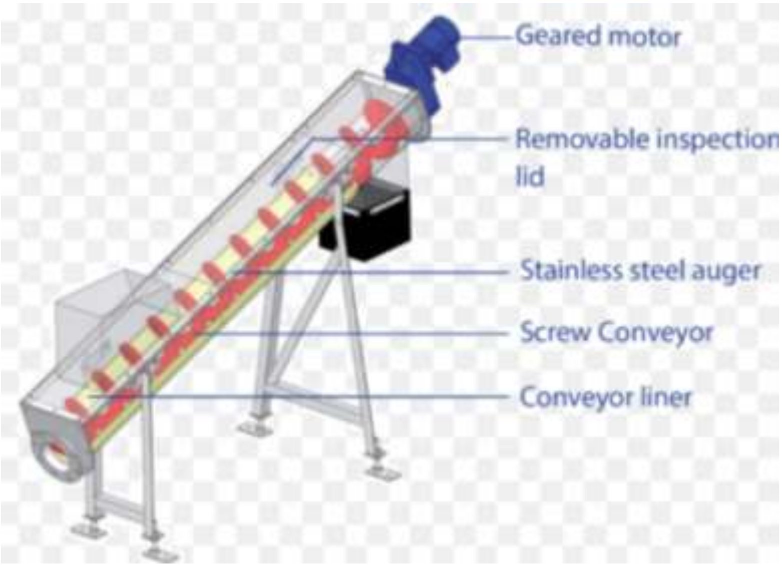


Figure 2.6: Labelled incline screw conveyor (KWS, 2016)

2.10.3 Shaftless screw conveyors

Shaft less Screw Conveyor makes it simple to move bulk materials released from centrifuges, filter presses, or mixers. Shaftless conveyors have a non-clogging conveying surface that makes it possible to transport materials that are typically challenging. The Shaftless screw conveyor (figure 11) works best for moving bulk goods with a lot of moisture.

For conveying everything from catalysts to dewatered bio solids, these are successfully employed in the chemical, food, minerals processing, and wastewater treatment industries.(KWS, 2016)

Figure 2.7: Shaftless screw conveyor

Shaftless screw conveyor benefits include

- **better conveying efficiency compared to other types of conveyors**
- **suitability for handling sticky and sluggish bulk materials.**
- **provides more flexibility for plant layout due to the available configurations**
- **There are no internal bearings**

2.10.4 Vertical screw conveyors

A variety of bulk items can be raised using vertical screw conveyors at very steep angles or in the vertical position. The vertical screw conveyor is a reliable and affordable aspect of any bulk material handling process since it has a small number of moving parts.


Figure 2.8: Vertical Screw conveyor (KWS, 2016)

Vertical screw conveyor advantages

- Ideal for handling materials ranging from dry to semi-fluid
- up to 6,000 cubic feet per hour in capacity.
- Ability to lift heavy objects up to 30 feet without the aid of internal bearings.
- For dust and vapour-tight requirements, an entirely enclosed design is used. (KWS, 2016)

2.10.5 Screw feeders

Screw feeders are often found at the start of a process and are meant to meter bulk materials. Screw feeders provide for precise control of capacity or feed rate. A wide range of feed rates can be offered by variable speed drives, which also increase metering accuracy. There are numerous sizes, lengths, layouts and building materials for screw feeders.

The screw feeder's input is always flood loaded at 100%. Typically, a screw feeder is mounted directly to a:

- Hopper, a square, rectangular object with a sloping bottom and little storage space
- A bin with a huge storage capacity and a square or rectangular shape.
- a silo with a huge storage capacity and a cone- or mass-flow bottom

2.11 DOSING PUMPS

Dosing and metering pumps inject a chemical into a tank or pipe that contains the fluid that is being dosed after drawing a specific volume of liquid into its chamber. It is driven by an electric motor or an air actuator, and it features a controller that controls the flow rate and turns the pump on and off. More advanced control mechanisms are included in some models (All-Pumps, 2022). Dosing pumps are positive displacement oscillating pumps intended to inject a range of media to a process at a highly precise flow rate. Dosing pumps are inclusive of peristaltic pumps, lobe type pumps and diaphragm pump.

2.11.1 Peristaltic pumps

A flexible tube is used by peristaltic pumps to transport the product. This tube has a cross section that is semi-circular. Due to their simplicity in sterilization and the ease with which the pump mechanism may be replaced if it becomes contaminated or broken, these pumps are extensively employed in the medical sector. Peristaltic pumps are incredibly precise. They can only withstand pressures up to the burst pressure of the flexible tube discussed before; therefore they quickly wear out and can't manage pumping into a high pressure stream (Xie, Lin Q, & YC, 2004).

Working Principle -

- Between the tube bed and the rotor, the tubing is fixed. Squeezing occurs on the tubing at each roller site.
- The tubing is crossed by the rollers on the rotating rotor. The rollers continuously squeeze the tube, pushing the liquid in the direction of the rotating rotor.
- The tubing in back of the rollers takes shape again, makes a vacuum, and sucks liquid into the space behind it.
- The liquid between the rollers forms a pillow. The pillow, which serves as the pump chamber, controls the flow rate and volume per roller step. The pump system, the tubing, the liquid, and the application conditions all affect the roller step volume, which is determined by the pillow volume (Xie, Lin Q, & YC, 2004).

  The flow rate is calculated as follows

  - Volume per roller step **x** number of rollers= VOLUME PER REVOLUTION

- Volume per revolution **x** rotation speed per minute = FLOWRATE PER MINUTE

Advantages

- Liquid has no contact with mechanical parts
- Tube is only part to wear
- Maintenance cost are minimal
- Easy to clean
- Multi-channel systems available
- Insensitive to dry running
- Self-priming
- Excellent suction height
- No siphoning effect when pump is stopped
- Suspensions and sludge can be pumped
- Liquids of high viscosity can be delivered
- Gentle delivery due to very low shearing forces

Disadvantages

- Slight pulsation is inevitable
- Tubing requires recalibrating and changing
- Tubing may leak after extensive use
- Depending on the pump head system the flow rate is sensitive to varying differential pressure conditions
- Accuracy and repeatability of the flow rate also depend on the tubing age and material used
- Max differential pressure is lower in comparison to gear and piston pumps (Xie, Lin Q, & YC, 2004)

2.11.2 Diaphragm pump

The diaphragm pump gets its name from the RUBBER MEMBRANE that it employs to carry out its pumping action. Air displacement is the basis for the diaphragm's operation. The membrane is mechanically pushed into and pulled out of a pumping chamber. When the diaphragm chamber collapses, all of the air is released. When the diaphragm is extended, slurry or whatever else is being pushed is drawn into the diaphragm chamber through the intake line. The EXPULSION or DISCHARGE STROKE, which is the INDUCTION or SUCTION STROKE, merely causes the diaphragm to collapse once more. The sludge will be discharged through the discharge line. One-way valves will be used on the intake and exit lines to control the suction and discharge. The material is only accessible from the right line. The discharge valve will remain closed throughout the induction, or suction, stroke thanks to the vacuum. During the discharge stroke, the one-way valve on the intake line won't open. This kind of pump can be utilized in multiple applications because it has an air motor (Michaud, 2015).

Types of diaphragm pumps

- Air operated double diaphragm pump
- Motor driven pump
- Small motor driven pump
- Small air operated pump
- Wanner Hydra-cell pump

Advantages of Diaphragm pumps

- This pump is oil free and has less seal
- It has excellent wear resistance
- It has self-priming until six meters
- Easy cleaning/ maintenance
- Has a multifunctional design and functions (Michaud, 2015)

Disadvantages of diaphragm pumps

- It has low speed
- Not very energy efficient
- Pulse flow: dampers are required for the decline
- Do not deliver high pressure when pumping (Michaud, 2015)

Table 2.1: differences between a peristaltic pump and a diaphragm pump (All-Pumps, 2022)

DIAPHRAGM PUMP	**PERISTALTIC PUMP**
A diaphragm pump moves fluid by creating suction by a vibrating diaphragm	A peristaltic pump moves the fluid by squeezing a liquid-filled hose
These have a complex design	These have a simple design
The diaphragm pumps have more valves than the peristaltic pump	These have lower number of valves
These have a complex operation	These pumps have an easy operation
This pump has a check valve	It doesn't have any check valve

Most of the time, a dosing apparatus's parts change or differ depending on the brand and application. The main pieces, based on their design and functionality, are as follows:

TANK: This is the dosage container.

A non-return valve called a "FOOT VALVE" is put into the product's drum and coupled to the suction line. It connects to a float switch at the bottom of the drum to check for product availability and to sound an alert when the latter is low or runs out.

The corrosion-resistant PVC, PE, and other plastics, rubbers, and occasionally stainless steel are used to make dosing pumps.

Its inlet is where the suction line attaches, and the suction line is where the dosing line attaches.

DOSING LINE: This component can incorporate a variety of bleed, pressure relief, or air release valves and is made of hard PVC or PE tube or a reinforced hose.

An injector is a delivery nozzle that dispenses a precise flux of product into a line that is fed by a dosing pump. It is made to be stronger than the dosing pump's pressure.

The product is discharged in pulses at varying flow rates. The non-return valve has a self-actuating mechanism that stops the liquid in the delivery line from rising once the required flux rate has been supplied or the pump has stopped. In order to reduce product waste and guarantee that the fluid is sent to the center of the flow rather than the side walls, the injector also makes sure that the fluid is delivered to the center of the flow

- CONTROL SYSTEMS- To guarantee the accuracy of the dosing pump and to enable automation, modern facilities use control systems and software. For this purpose, variable rate control and pH, and other sensor-equipped central control systems are used.

2.12 APPLICATIONS OF AUTOMATED DOSING SYSTEMS

Automated dosing systems are employed across multiple industries to precisely and effectively dispense liquids or powders in fixed quantities. Some illustrations of the applications of these systems include:

- In pharmaceutical manufacturing, automated dosing systems are used to accurately dispense active pharmaceutical ingredients and excipients, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: Transparency Market Research's "Automated Dosing System Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2018 - 2026")
- In food and beverage production, automated dosing systems are utilized to add exact amounts of ingredients such as colours, flavours, and preservatives, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: Mordor Intelligence's "Global Automated Dosing Systems Market for Food & Beverage Industry - Trends and Forecast 2020-2025")
- In water treatment plants, automated dosing systems are used to add precise amounts of chemicals such as chlorine, fluoride, and coagulants to ensure that the water is safe to drink and adheres to regulatory standards. (Source: Grand View Research's "Automated Dosing Systems Market Size, Share & Trends Analysis Report By Application (Water Treatment, Food & Beverages, Pharmaceuticals), By Region (North America, Europe, APAC, CSA, MEA), And Segment Forecasts, 2021 - 2028")
    - Water treatment: In water treatment plants, dosing systems are used to add chemicals such as chlorine, alum, and fluoride to the water to remove impurities

and make it safe for consumption. These systems can precisely control the dosing rate and ensure that the correct amount of chemicals is added to the water.

  - Borehole management: Dosing systems can be used to add chemicals or acids to boreholes to dissolve minerals, such as calcium and magnesium, that cause scaling and blockages in the borehole. This can help to maintain the flow rate and prolong the life of the borehole.
  - Sewer systems: In sewer systems, dosing systems can be used to add chemicals such as disinfectants to prevent the growth of bacteria and reduce odours. They can also be used to add coagulants or flocculants to help settle solids and improve the efficiency of the sewage treatment process.
  - pH control: Dosing systems can be used to adjust the pH of water in various applications, such as swimming pools, industrial processes, and agricultural irrigation. This can help to prevent corrosion, improve plant growth, and ensure that the water is safe for use.

- In agriculture, automated dosing systems are used to add precise amounts of fertilizers, pesticides, and herbicides to crops, resulting in increased efficiency in farming processes, reduced waste, and minimized chances of over or underuse of chemicals. (Source: Mordor Intelligence's "Global Automated Dosing Systems Market in Agriculture - Trends and Forecast 2020-2025")
- In chemical manufacturing, automated dosing systems are used to accurately dispense raw materials and reagents, resulting in a consistent and high-quality final product with lower waste and reduced chances of errors. (Source: MarketsandMarkets' "Automated Dosing System Market - Global Forecast to 2024")

Overall, automated dosing systems offer a wide range of advantages in terms of precision, efficiency, and safety across multiple industries.

2.13 CHALLENGES BROUGHT BY AUTOMATED DOSING SYSTEMS

While automated dosing systems offer numerous benefits, there are also some challenges associated with implementing them. Here are some of the challenges:

- Initial cost: The cost of implementing an automated dosing system can be high, including the cost of the system itself, installation, and training. This can be a barrier for smaller businesses or those with limited budgets.

- Maintenance and repair: Automated dosing systems require regular maintenance and occasional repairs to ensure that they are functioning properly. This can be time-consuming and costly, especially if the system experiences a breakdown.
- Compatibility with existing equipment: In some cases, automated dosing systems may not be compatible with existing equipment in a facility. This can require additional investment in new equipment or modifications to existing equipment to ensure compatibility.
- Complexity: Automated dosing systems can be complex to operate and require specialized training. This can be a challenge for companies with a high turnover rate or a workforce with limited technical expertise
- Calibration and accuracy: Automated dosing systems require regular calibration to ensure that they are dispensing the correct amount of material. Inaccuracies can lead to waste, product quality issues, or safety concerns.
- Regulatory compliance: Depending on the industry and application, automated dosing systems may be subject to regulatory requirements and compliance.

Challenges above require careful consideration and planning to ensure successful implementation of automated dosing systems.

2.14 SOLUTIONS BROUGHT BY AUTOMATED DOSING SYSTEMS

An automated dosing system can solve a variety of problems in various applications. Here are some examples:

- Accurate dosing: One of the primary advantages of an automated dosing system is that it can precisely control the dosing rate and ensure that the correct amount of chemicals is added to the water. This can help to prevent over-dosing or under-dosing, which can lead to poor water quality or damage to equipment.
- Consistency: Automated dosing systems can help to ensure that the dosing is consistent over time, regardless of operator error or changes in the water quality. This can help to maintain the desired water quality and reduce the risk of equipment failure or downtime.
- Efficiency: Automated dosing systems can be programmed to operate at specific times of the day, or in response to changes in the water quality. This can help to optimize the use of chemicals and reduce waste, which can save money and improve the efficiency of the process.

- Safety: Automated dosing systems can help to improve safety by reducing the need for manual handling of chemicals and minimizing the risk of spills or accidents. This can help to protect workers and the environment.
- Monitoring and control: Automated dosing systems can be equipped with sensors and monitoring equipment that can provide real-time data on the water quality and dosing rates. This can help to identify potential problems early and allow for quick adjustments to be made to the dosing rates.

An automated dosing system can improve the accuracy, consistency, efficiency, safety, and monitoring of dosing processes in various applications. It can help to ensure that the desired water quality is achieved and maintained while minimizing the risk of equipment failure, downtime, or environmental damage.

2.15 STEPS COMPANIES MAY TAKE TO ENSURE WORKFORCE IS PROPERLY EQUIPPED TO OPERATE AUTOMATED DOSING SYSTEMS

Proper training is essential for ensuring that a workforce is equipped to operate automated dosing systems safely and effectively. Here are some steps that companies can take to ensure that their workforce is properly trained:

- Develop a training program: Companies should develop a comprehensive training program that covers all aspects of operating an automated dosing system, including safety protocols, system operation, maintenance, and troubleshooting.
- Provide hands-on training: Hands-on training is essential for ensuring that workers are comfortable with the system and can operate it effectively. Companies should provide opportunities for workers to practice operating the system under the supervision of a trained instructor.
- Offer refresher training: Automated dosing systems can be complex, and workers may forget some of the details of their training over time. Companies should offer refresher training periodically to ensure that workers are up-to-date on the latest best practices and safety protocols.
- Provide documentation: Companies should provide workers with detailed documentation, such as user manuals and safety procedures, to supplement their training. This documentation should be easy to understand and readily accessible.
- Conduct assessments: Companies should conduct assessments to ensure that workers have retained the knowledge and skills they need to operate the system safely and

effectively. This can include written or practical assessments, as well as regular performance evaluations.

Companies should invest in comprehensive training programs that ensure that their workforce is properly trained and equipped to operate automated dosing systems safely and effectively.

CHAPTER 3-METHODOLOGY

3.1 INTRODUCTION

The processes the researcher followed to develop the final design are described in this chapter. This includes the data gathering process that was carried out.

3.2 DATA COLLECTION METHODS

The researcher had the opportunity to invest in Primary and Secondary data during the course of this research which includes on site research, as well as revenue from other mines during site visitations, use of articles documenting the uses of lime and best approaches in lime dosing. The collected data will aid in coming up with the final design that best solves the problems currently brought by the current lime dosing system at the Bulawayo Mining company.

3.2.1 Primary Research

The researcher was industrially attached at the Gold processing plant for about 6 months. The researcher was exposed to the crushing circuit, milling circuit and the CARBON in Pulp circuit. These circuits enhanced the understanding of why lime is added and when it should be added. During this time the student was able to conduct interviews with plant operators who handle the lime and this showed the dangers that lime had added to their wellbeing. The interviews and surveys conducted are included in the Appendix section of this write-up. The researcher had the opportunity to visit the online clinic in order to see the cases admitted as a result of excessive intake of the chemical lime. The results are also included in the appendix as well as the graphical presentation of this information.

3 2.2 Secondary Research -Literature Review

The student was exposed to the company archives which contains information of the processes done in depth. The archives also contain effects of the lime on operators and other relevant information which was used in this project Generation. The researcher made use of existing documents, articles, manuals and books of Mines that use lime in their gold processing plants, how they use it and methods of dosing that are used. This assisted as it eye opened the researcher to different dosing methods and which best to select for the Bulawayo Mining Company.

3.3 STEPS TAKING IN PROJECT GENERATION

In order to come up with a good, efficient design the following steps were taking during the research process.

- Study of current methods used in lime dosing and modifications that can be made
- Setting a reasonable timeline
- Study of preliminary studies and progress reports
- Choosing the ideal control system to use
- Choosing the ideal sensors and the dosing pump to be used
- The use of a decision matrix to aid in selecting which is the best option and why
- Fully exhausting the research for the final design
- Relevant calculations for the flow rates, volumes, etc
- Cost benefit analysis

3.4 TOOLS USED

For word processing the applications below where used

- Microsoft word
- Microsoft excel

For the engineering drawings and simulations, the applications below were used

- AutoCAD
- Solid works
- Arduino

CHAPTER 4 – POSSIBLE SOLUTIONS

The three design considerations utilized for the lime dosing design, the optimum solution chosen, and the material analysis for the design components are covered in this chapter. This chapter also provides CAD drawings as well as Arduino circuits in order to show the automation aspect of the solutions.

4.1 CONCEPT 1

To curb the problem of operator chemical handling, this concept proposes the bulk delivery of lime into a welded box through a pipe system. The lime is added into the milling section onto a conveyor belt making use of a screw conveyor which regulates the output of the lime as it is at a fixed rate. The screw conveyor is driven by an electric motor. As the lime should be added at fixed intervals an operator then uses a control panel to ensure that the conveyor is running accordingly. Figure 13 shows the AutoCAD design of the above described concept. The angle of repose of hydrated lime which is 42° therefore the screw conveyor is selected to suit that angle such that the lime does not form sediments on the shaft of conveyor.

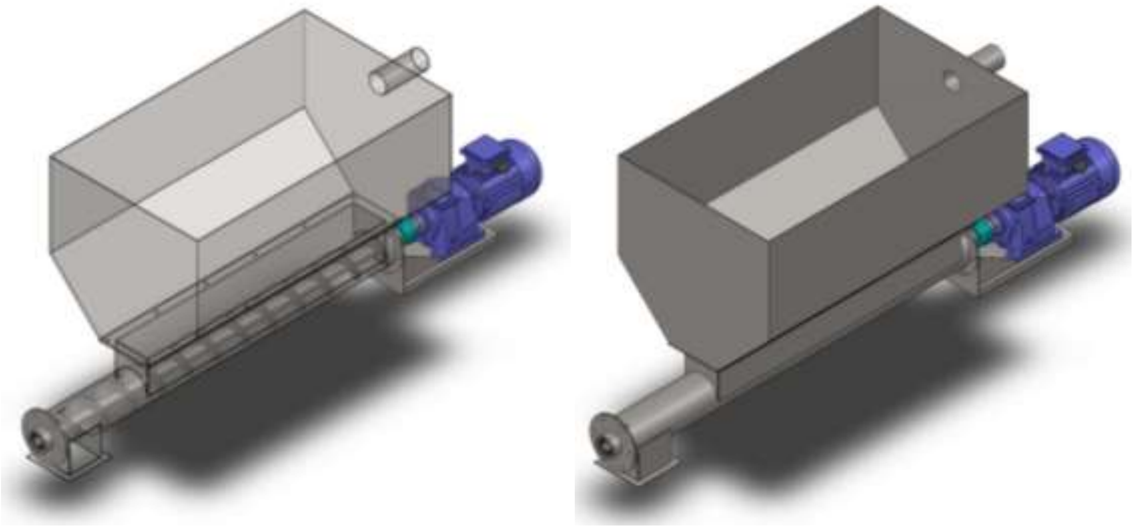


Figure 4.1: AutoCAD drawing of welded box and screw conveyor assembly

4.1.1 Advantages of concept 1

- Material is cheap and readily available
- Welding can be done in the fully equipped How Mine workshop
- No chemical handling of the operator
- Easy to operate

- Simple design/ concept which makes it easy to troubleshoot
- Easy maintenance

4.1.2 Disadvantages of concept 2

- Screw conveyor can be difficult to clean
- Sticky materials can get stuck on the belt

4.2 CONCEPT 2

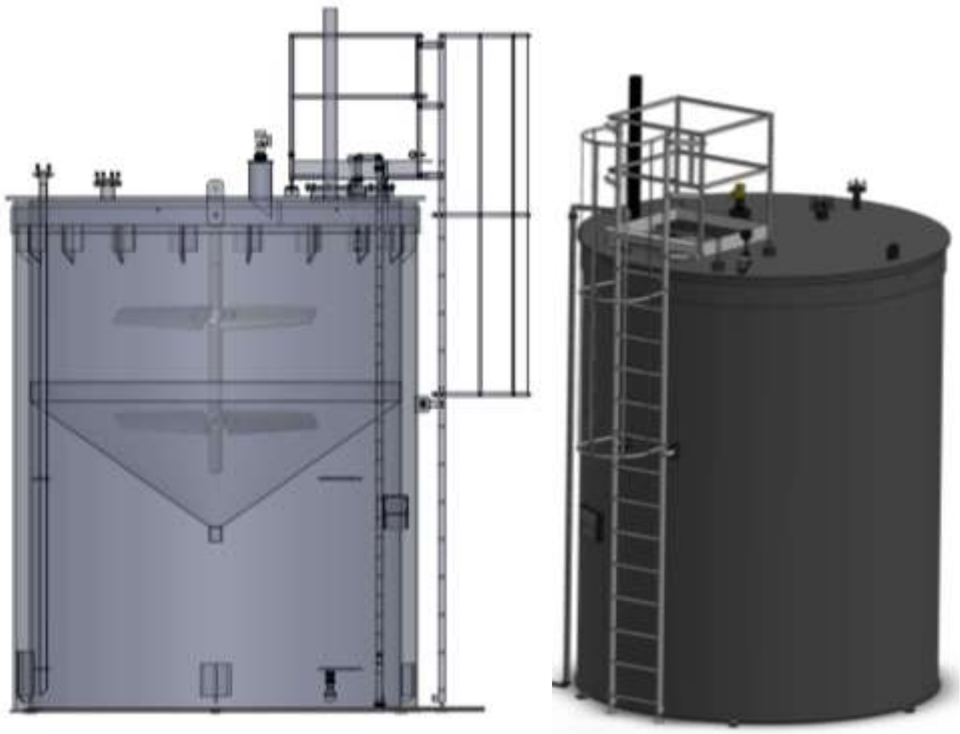


Figure 4.2: Two in one dosing tank mechanism

The second concept is a large tank that has two divisions as shown in figure 14, the top part being the mixing tank which has a valve that leads to the second part of the tank which has the dosing mechanism. The agitator helps to keep the lime particles suspended in liquid in order to promote the mass transfer. It works by rotating an impeller to impart energy to the lime which enhances the interaction and mixing.

Figure 15 shows the electrical circuitry of this proposed solution. It makes use of a DC gate valve. The stem of the gate valve is rotated around a hinge, It uses the threads to raise or lower the gate. The valve must be fully opened or closed after more than one 360 turn. In this circuitry a PH sensor is placed in the bottom section of the tank. It then conveys information to the DC gate valve to open when the lime in the tank has become too low, or to close when lime has aided in achieving a PH of 9.

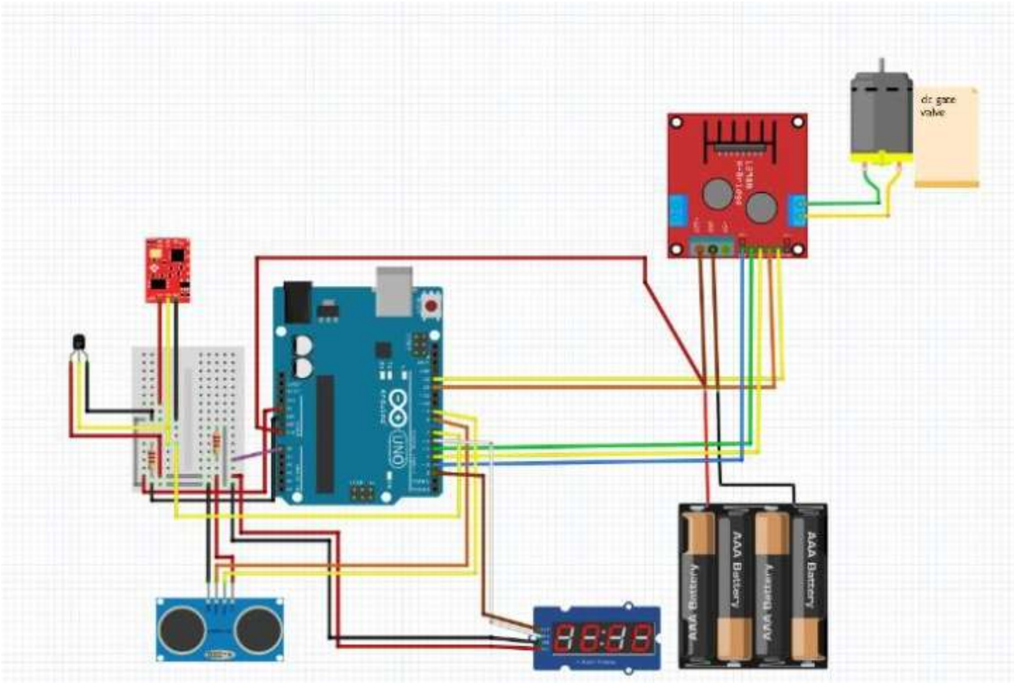


Figure 4.3: Electric circuitry of concept 2 using a DC gate valve

4.2.1 Advantages of concept 2

- Valve has low fluid resistance and superior sealing performance
- PH meter provides numerical value of PH directly

4.2.2 Disadvantages of concept 2

- High friction and corrosion. Sealing of the valve easily get damaged or erode.
- Valve is not fit for applications that need rapid actuation as it is harder to control the motion of valve plate
- Maintenance of valve is hard

4.3 CONCEPT 3

In this concept the micro controller used is Arduino. It works hand in hand with the pH sensor and ultrasonic sensors to achieve the efficient dosing action. The ultrasonic sensors measure distance by using ultrasonic waves. The purpose of the pH sensor is to measure the pulp's pH. As an automatic dosing system for the lime from the mixing tank, the servo system is present. The lime solution is pumped into the second tank using the depicted peristaltic pump to balance the pH, which should be maintained at a pH of 9. The pH level is set to be between 8 and 10. When the pH of the water is outside of the desired range, the LED will light up, turning on the peristaltic pump to begin the dosing process until the LED turns off, indicating that the pH is back within the desired range.This information is displayed on an LCD screen. This LCD screen also shows the pH values as the process is happening. Figure 16 and Figure 17 show the layout of the arduino circuit and engineering drawing of the proposed solution. The agitators aid in mixing the lime solution and the pulp evenly.

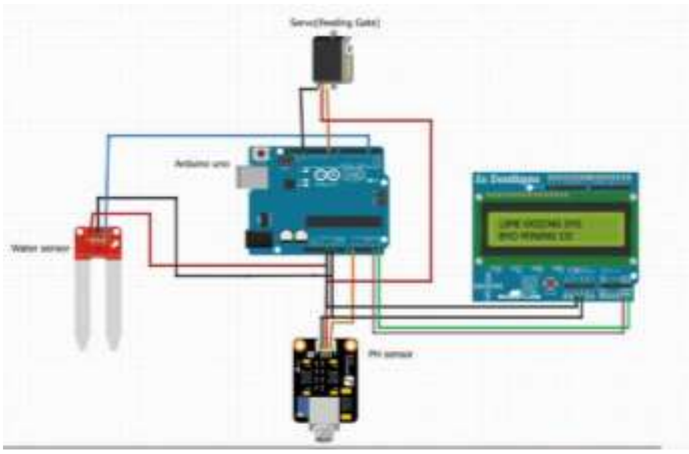


Figure 4.4: Arduino circuit for Concept 3

Figure 4.5: AutoCAD drawing for concept 3

4.3.1 Advantages of concept 3

- Cost efficient as Arduino is cheap
- Less to no operator handling as the system is fully automated.
- Arduino is easy to use
- Maintenance of the system is easy and doable as most components are within reach of operator
- Ultrasonic sensors are highly accurate and can be used to detect very small alterations.

4.3.2 Disadvantages of concept 3

- Sensors can be expensive, susceptible to interference with limited lifespan

4.4 SELECTION OF CHOSEN SOLUTION

The decision of the final concept is also dependent on how well the design can achieve its goals, taking into account both the benefits and drawbacks of each concept. For the numerous selected factors, a selection matrix method is employed. Each factor is given the weight it deserves. The concept with the highest score is taken into account as the chosen concept after all considerations have been taken into account. Binary dominance matrix, a subjective weighting method that contains all the criteria on both the vertical and horizontal axes in a matrix, is used to evaluate the relative importance of the three objectives. The binary dominance matrix is the one to be used for the determination of the final solution.

Table 4.1: Binary Dominance matrix of the 3 concepts

CRITERIA	**WEIGHT**	**CONCEPT RATING/10**		
		A	**B**	**C**
FUNCTION	10	7	5	9
EFFICIENCY	9	5	6	8
COST	8	4	6	8
EASE OF MAINTENANCE	6	6	8	8
RELIABILITY	6	5	5	8
EASE OF MANUFACTURE	4	6	7	9
SIMPLICITY OF LAYOUT	2	5	7	8
QUALITY	1	7	7	8
ERGONOMICS	1	5	8	9

Table 4.2

CRITERIA	WEIGHT	CONCEPT RATING/%		
		A	**B**	**C**
FUNCTION	10	70	50	90
EFFICIENCY	9	45	54	72
COST	8	32	48	64
EASE OF MAINTENANCE	6	36	48	48
RELIABILITY	6	30	30	48
EASE OF MANUFACTURE	4	24	28	36
SIMPLICITY OF LAYOUT	2	10	14	16
QUALITY	1	7	7	8
ERGONOMICS	1	5	8	9
TOTAL SCORE		**259**	**287**	**391**

Solution 3 was then chosen as the final design since it had the highest score rating in the decision matrix when all the parameters were added up.

CHAPTER 5-DESIGN DEVELOPMENT

5.1 INTRODUCTION

This chapter looks at the design development of the chosen solution. It brings about calculations and simulations that were done for the components that make up the entire design in order to fulfil all the set aims and objectives. Mechanical apparatus and control systems were divided up among the solution's component parts. The pumps, valves and tanks make up the mechanical equipment. Sensors and controllers make up the control systems.

5.2 DESCRIPTION OF FINAL CONCEPT

The micro controller in this concept is an Arduino. It collaborates with pH sensors and ultrasonic sensors to deliver effective dosing. The ultrasonic sensors use ultrasonic waves to measure the distance. The pH sensor's job is to determine pulp pH. An an automatic dosing system for the lime from the mixing tank, the servo system is present. In order to maintain pH balance, which should be at 9, the lime solution is pumped into the second tank using a peristaltic pump.

If the LED is turned red (shown if figure 5.2) that means the solution is too acidic and if it is turned yellow that means that the solution is too basic. The ultrasonic sensor helps maintain the minimum amount of volume of solution/pulp in the tanks. When the the volume is way below the required amount the ultrasonic sensor communicates with the microcontroller. Figure 5.1 shows the prototype which the student designed.

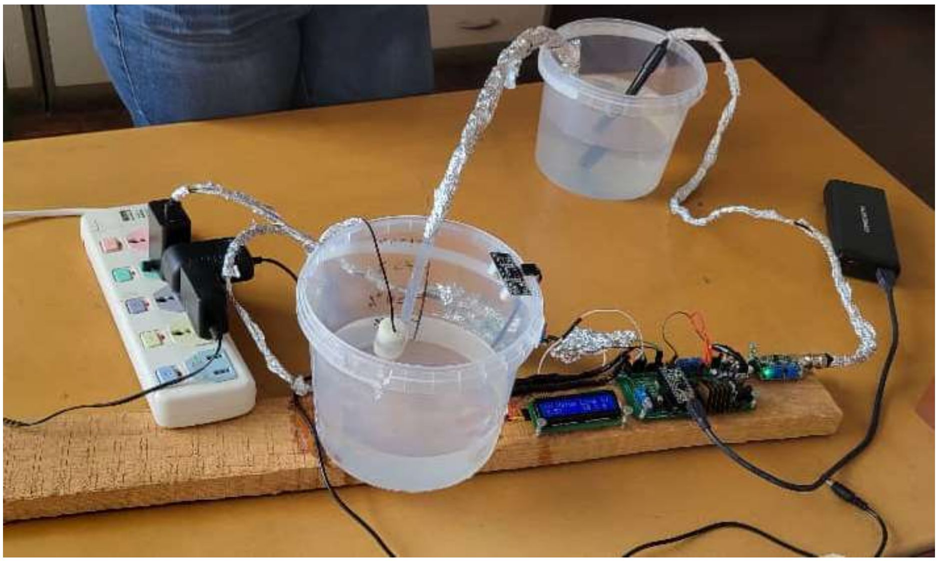


Figure 5.1: Prototype setup

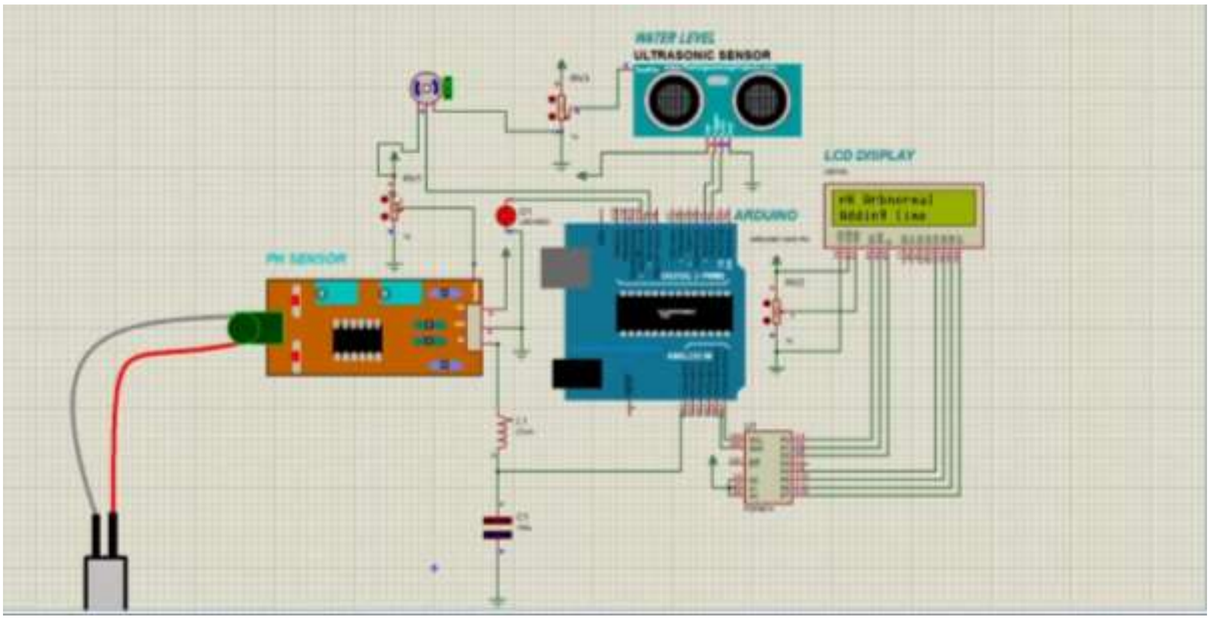


Figure 5.2: Circuit drawing of concept

5.3 MECHANICAL COMPONENTS DESIGN

Figure 5.3: Anatomy of design

Tanks

One tank acts as the dilution for the lime and water, the second tank acts as the dosing tank where lime is added into the cyanidation process. The dimensions for the tanks are

Table 5.1: Tank Dimensions

TANK	INNER D (m)	OUTER D(m)	HEIGHT(m)
MIXING	**4.07**	**4.2**	**10.76**
DOSING	**4.07**	**4.2**	**10.76**

Inside the tanks, the selected agitators used have an output speed of 50rpm for the mixing tank and the dosing tank. The material of these tanks is mild steel due to the high corrosive resistant nature and strength. The selection is also due to the fact that the tanks are subjected to external environmental loads and also the reactive chemicals in them.

The material of the agitators is stainless steel low carbon since it is high corrosive resistant, tough and strong enough to withstand dynamic loading from the fluid.

Pumps

Pumps are used to pump water into the dilution tank and also to pump the lime solution into the dosing tank. An existing centrifugal pump is used to pump the water. A peristaltic pump is used as the dosing pump for the lime as shown of figure 20.

Table 5.2 –Pump selection

TYPE	Capability	speed	reliability	Ease of installation	durability	price	Total
PISTON	3	4	3	5	3	2	20
DIAPHRAGM	5	4	4	4	4	3	24
PERISTALTIC	5	3	5	4	5	4	26

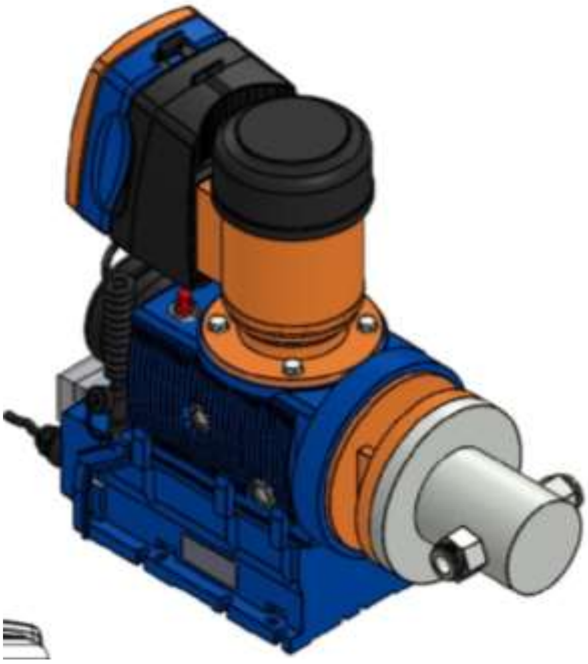


Figure 5.4: Dosing pump

Dosing pump discharge pipe: Using a 25 mm diameter
Effective length = 100m

Static Lift= 10m

Mass balance = 0.35m^3/h

Pump safety factor = 1.5

Design flow rate = 0.35x1.5=0.53m^3/h

$velocity = \frac{4\times0.53}{3600\times\pi\times0.025^2} = 0.29m/s$

Reynolds Number = $\frac{0.025\times0.29\times1.25\times10^6}{4} = 2265$

$$\frac{1}{\sqrt{f}} = \left[1.14 + 2\log\left(\frac{D}{\varepsilon}\right)\right] = 0.629$$

Roughness of steel=0.045

Relative roughness=$\frac{\varepsilon}{d}$=$\frac{0.045}{25} = 0.002$

Friction loss= $f\,\frac{lv^2}{D2g} = 0.629\left(\frac{100\times0.29^2}{0.025\times2\times9.81}\right) = 10.78$

A **25mm** diameter is chosen for the dosing pipe discharge.

Pipe discharge pressure = 10kPag

Head ratio = 1

Therefore, TDH of water= 11.17m

Pump water curve efficiency =0.8

Pump shaft power=$\frac{flowrate \times TDH \times SG}{3.6 \times EFFICIENCY \times 102} = \frac{0.53 \times 11.17 \times 1.25}{3.6 \times 0.8 \times 102} = 0.025kW$

Drive mechanical efficiency = 0.95

Using a VSD derating factor of 0.98

Motor Shaft power =$\frac{Pumpshaft\ power}{derating\ factor \times mechanical\ efficiency} = \frac{0.025}{0.95 \times 0.98} = 0.027kW$

Motor safety factor =1.2

Required motor power = 1.2×0.027=0.0324kW

Selected motor power **= 0.37kW, (it is to be direct coupled)**

5.4 CONTROL SYSTEMS

For industrial application a Programmable logic controller (PLC) is used for the design control system. Feedback plus forward is used to control the dosing process. The sensors used are the ultrasonic sensor and the ph sensor. The ultrasonic sensor measures the height distance of the solution and the ph sensor is there to measure the ph of the dosing tank contents.

5.5 CALCULATIONS

5.5.1 Tank properties

Table 5.3: Tank standards and properties

Yield stress (MPa)	**250**
Ultimate Tensile Stress (MPa)	**400**
Weld joint efficiency	**0.70**
Corrosion allowance (mm)	**3**
Floor plate thickness (mm)	**30**

Maximum allowable design stress (MPa)

$$\frac{2\ x\ Yield\ stress}{3}\ \&\ \frac{2\ x\ ultimate\ tensile\ stress}{5}$$

$$\frac{2\ x\ 250}{3}\ \&\ \frac{2\ x\ 400}{5}$$

$$= 167\ \&\ 267MPa$$

∴ The maximum allowable design stress is the minimum between the two above calculated which 167MPa is

Maximum allowable hydrostatic test stress

$$\frac{3\ x\ Yield\ stress}{4}\ \&\ \frac{3\ x\ ultimate\ tensile\ stress}{8}$$

$$\frac{3x\ 250}{4}\ \&\ \frac{3\ x\ 400}{8}$$

$$= 188\ \&\ \ 150MPa$$

∴ The maximum allowable hydrostatic test stress is the minimum from the above calculated= 150MPa

5.5.2 Agitator

The impeller speed is to be 60rpm

Table 5.4

Motor rating	22kw
Motor RPM	1470rpm
Gearbox ratio	29.4

Agitator rpm (N)

$$N = {}^{Drive\ motor}/_{gear\ box\ reduction}$$

$$N = {}^{1470}/_{29.4}$$

$$N = 50$$

Impeller flow number, N_q

$$N_q = \frac{Q}{N\ \times\ {D_i}^3}$$

Q= impeller primary flow (m^3/sec) [pumping capacity]

$D_i = impeller\ diameter$(m)

Impeller power number, N_p

$$N_p = \frac{P}{N^3 \times {D_i}^5 \times \rho}$$

P= impeller power (w)

N= Impeller rotational speed (rpm)

D_i= Impeller diameter (m) = 3.45m

ρ=density of hydrated lime= $2.21 g/cm^3$

Impeller Reynolds number (Re)

$$\boldsymbol{Re = \frac{{D_i}^2 \times N \times \rho}{\mu}}$$

N= impeller rotational speed =50rpm

D_i= Impeller diameter (m) = 3.45m

ρ=density of hydrated lime= $2.21 g/cm^3$

μ=Viscosity =0.06Ns/m^2

$$\boldsymbol{Re = \frac{3.45^2 \times 50 \times 2.21}{0.06} = 21920.44}$$

∴Flow is turbulent

Pumping capacity (Q)

$$Q = N_q \times N \times {D_i}^3$$

Assume N_q=0.56

N=60rpm

D_i=3.45m

$$Q = 0.56 \times 60 \times 3.45^3 = 1379.7378 m^3/min$$

$$Q = \frac{1379.7378}{60} = 22.99563 m^3/sec$$

Area of tank4

$$A = \frac{\pi {D_t}^2}{4}$$

Where D_t=Diameter of tank

$$A = \frac{\pi \times 4.07^2}{4} = 13.01m^2$$

Bulk fluid velocity

Bulk fluid velocity= pumping capacity/ area of tank

$$Bulk\ fluid\ velocity = \frac{1379.7378}{13.01} = 106.052m/min$$

Annular area

$$Annular\ area = \frac{\pi \times ({D_t}^2 \times {D_i}^2)}{4}$$

$$Annular\ area = \frac{\pi \times (4.07^2 \times 3.45^2)}{4} = 154.8520253m^2$$

Tank Capacity

Tank capacity= volume of slurry in tank

$$Tank\ capacity = \frac{\pi \times {D_t}^2 \times H}{4}$$

Where H is slurry tank level [max=8.608m]

$$Tank\ capacity = \frac{\pi \times 4.07^2 \times 8.608}{4} = 111.9904419m^3$$

Tank turnover rate

Tank turnover rate (tank rotation rate) is a benchmark for optimizing impeller speed. The settling velocity of solid particles can be kept below the rising velocity to avoid settling and accumulation of solids in the tank.

$$Tank\ turnover\ rate = Pumping\ capacity/\ tank\ capacity$$

$$Tank\ turnover\ rate = \frac{22.99563}{111.9904419} = 0.205times/min$$

Agitator shaft power

$$P = \frac{N_p \times \rho \times {D_i}^5 \times N^3}{16 \times 10^3}$$

Where N_p=power number=0.46

ρ=Slurry density=2.21g/cm^3

$$P = \frac{0.46 \times 2.21 \times 3.45^5 \times 60^3}{16 \times 10^3} = 6707.788324$$

Drive motor rating

Considering factor of safety 1.5 and 80% gearbox efficiency

$$Drive\ motor\ rating = \frac{1.5 \times 77.175}{0.80} = 144.703125hp$$

$$Drive\ motor\ rating = 144.703125 \times 746 = 107.948kW$$

Thus the drive motor of about 110kW will be adequate considering factor of safety 1.5

Torque produced at output shaft of gearbox

$$T = \frac{60 \times P}{2\pi \times N}$$

$$T = \frac{60 \times 110000}{2\pi \times 60} = 17507.04374Nm$$

As per design, the gearbox to be installed should have a torque of 17507.04Nmconsidering a FOS of 105 and gearbox output rpm which is 60rpm to agitate the slurry.

5.6 DISCUSSION AND RESULTS

The researcher did some simulations on some components of the project e.g. the tanks as well as the coupling mechanisms using Solid works. The simulations show the reaction of these components to various stresses. Simulations of the circuit were also done using proteus.

5.6.1 Simulation of Dosing Tank

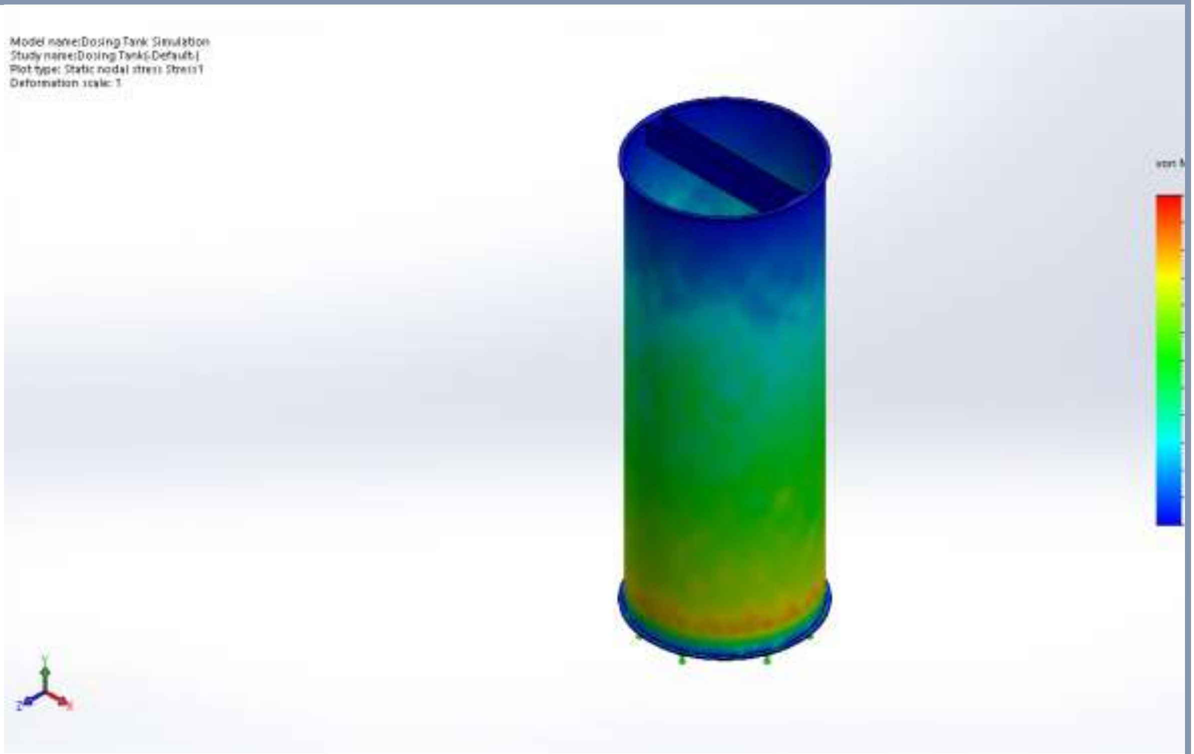
Table 5.5: Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	2.08844	9821.96	-7.90728	9821.96

Table 5.6 Study Properties

Study name	Dosing Tank
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Zibusiso Dube\Desktop\2023 PROJECTS\ZIBBY\FINAL DESIGN)

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.012e+00 N/m^2 Node: 1223	4.256e+04 N/m^2 Node: 5705

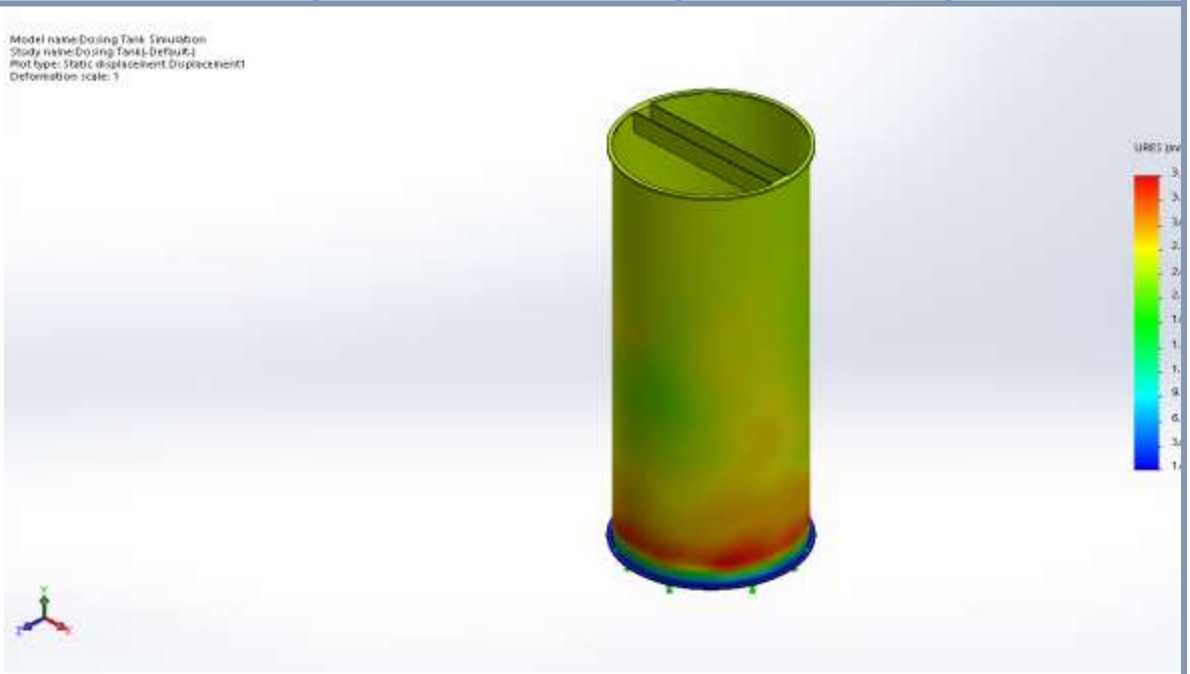


Dosing Tank Simulation-Dosing Tank-Stress-Stress1

Figure 5.5 –Torque simulation results

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1857	3.688e-04 mm Node: 12291

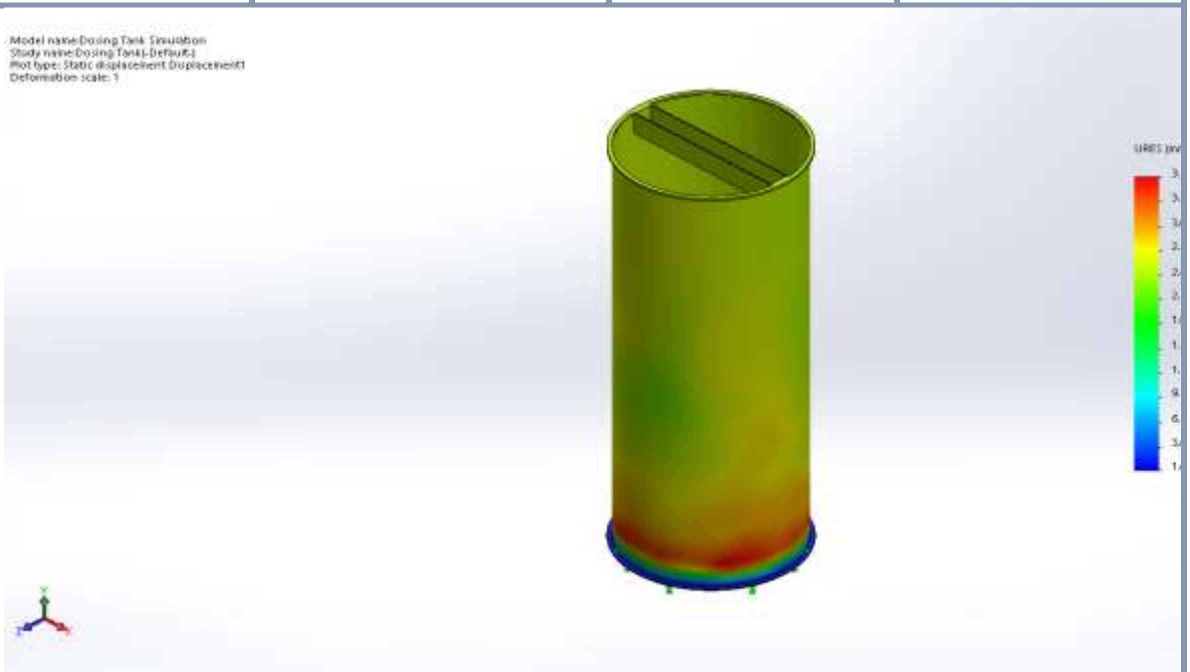
Name	Type	Min	Max



Dosing Tank Simulation-Dosing Tank-Displacement-Displacement1

Figure 5.6- Displacement simulation

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.167e-11 Element: 509	1.736e-07 Element: 4348



Dosing Tank Simulation-Dosing Tank-Strain-Strain1

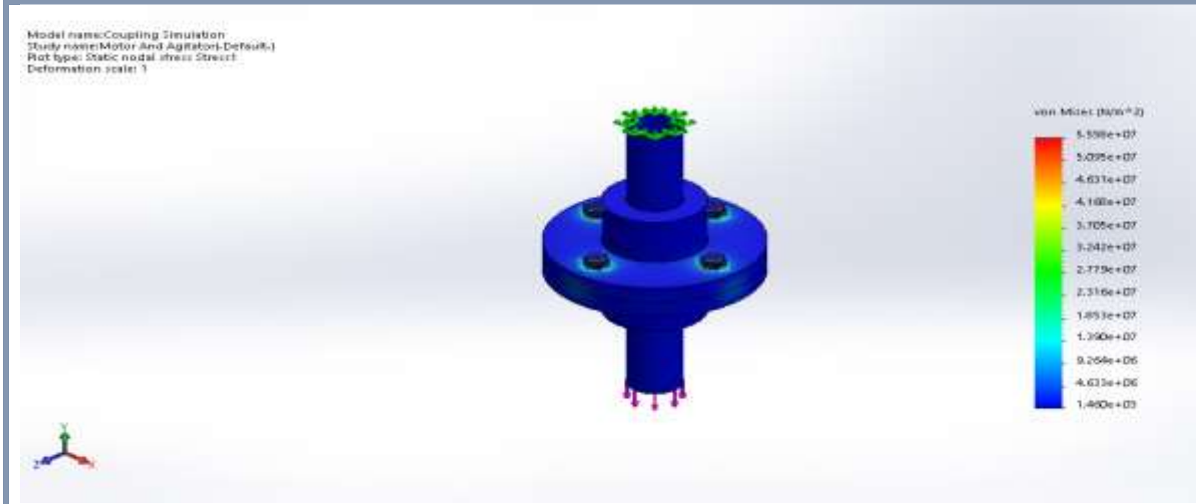
Figure 5.7 Dosing tank strain simulation

5.6.2 Simulation of motor to agitator coupling

Table 5.6: Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.2219e-06	147.15	-1.78814e-07	147.15

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.460e+03 N/m^2 Node: 39572	5.558e+07 N/m^2 Node: 93112

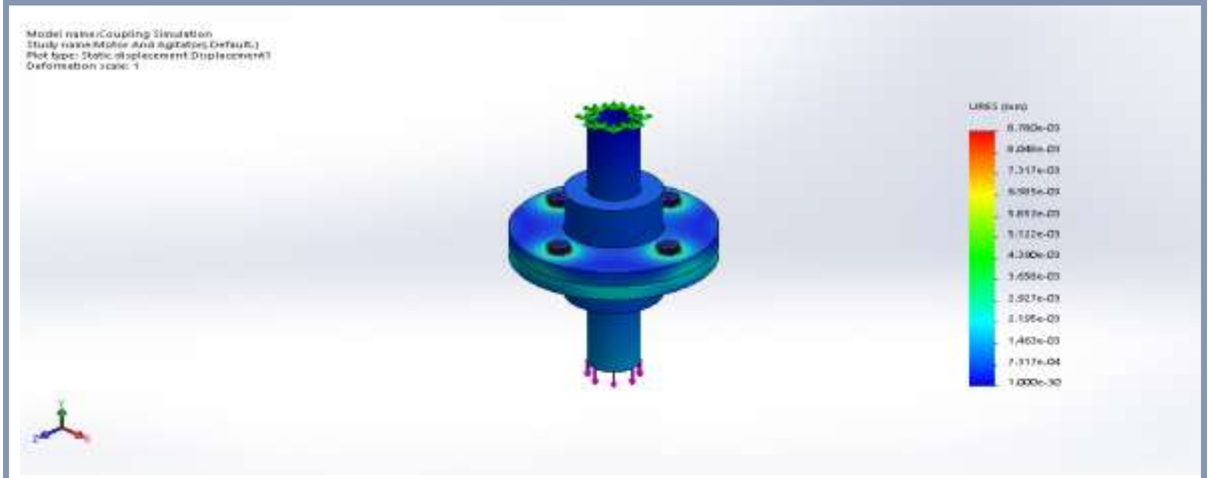


Coupling Simulation-Motor And Agitator-Stress-Stress1

Figure 5.8- Von Mises stress simulation results

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 77	8.780e-03 mm Node: 10

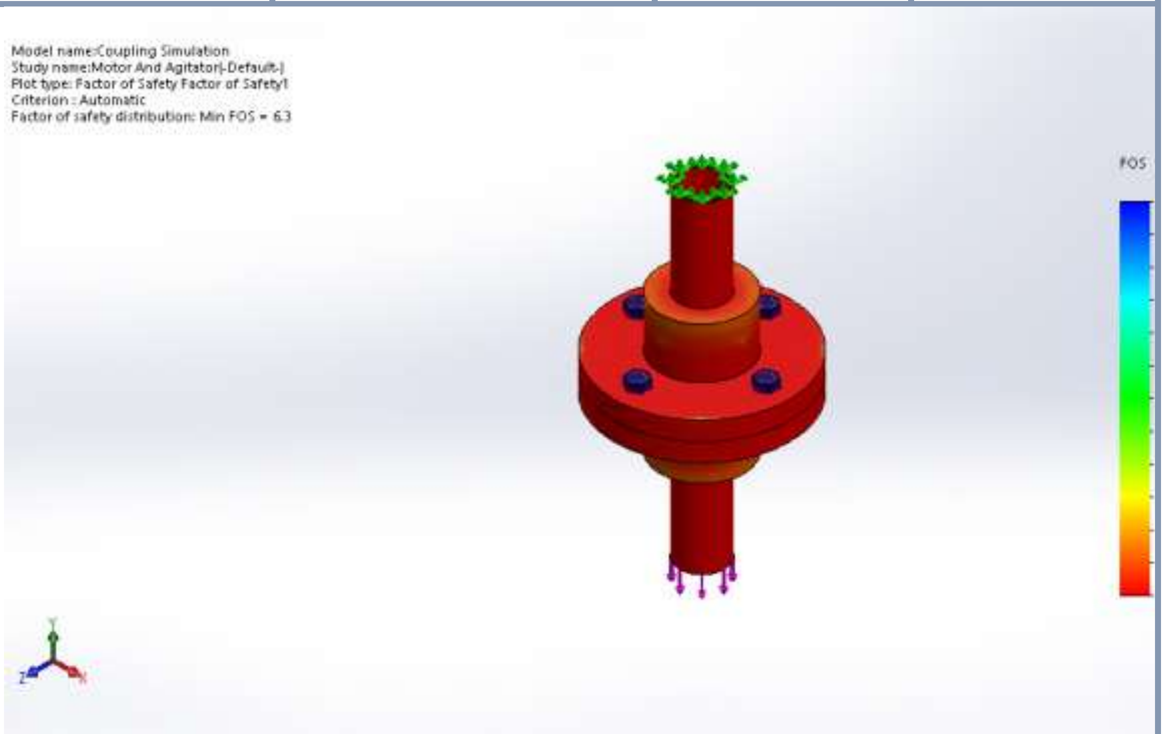
Name	Type	Min	Max



Coupling Simulation-Motor And Agitator-Displacement-Displacement1

Figure 5.9-Coupling simulation

Name	Type	Min	Max
Factor of Safety1	Automatic	6.285e+00 Node: 46482	2.495e+05 Node: 75541



Coupling Simulation-Motor And Agitator-Factor of Safety-Factor of Safety1

Figure 5.9b

5.6.3 Simulation of Circuit

The simulations below show the circuit that comprises of the Arduino Uno, capacitor, inductor, LEDs, motor 3ph, motor DC, servo motor, pH sensor and ultrasonic sensor. The simulations show all the devices to different parameter changes.

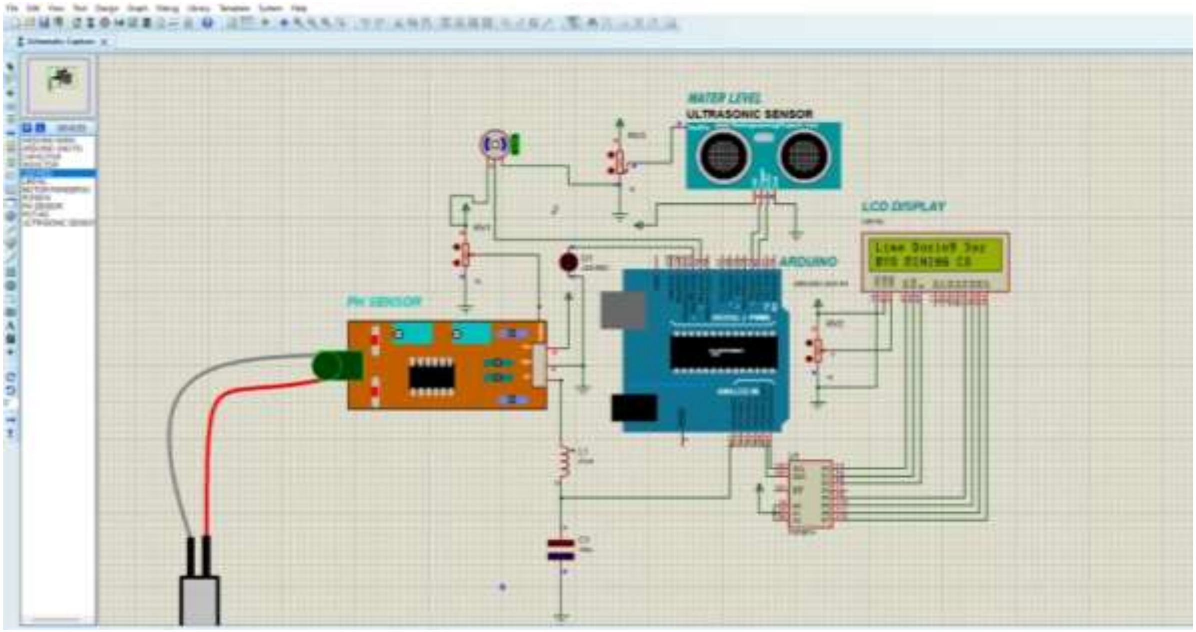


Figure 5.10 Simulation on Circuit

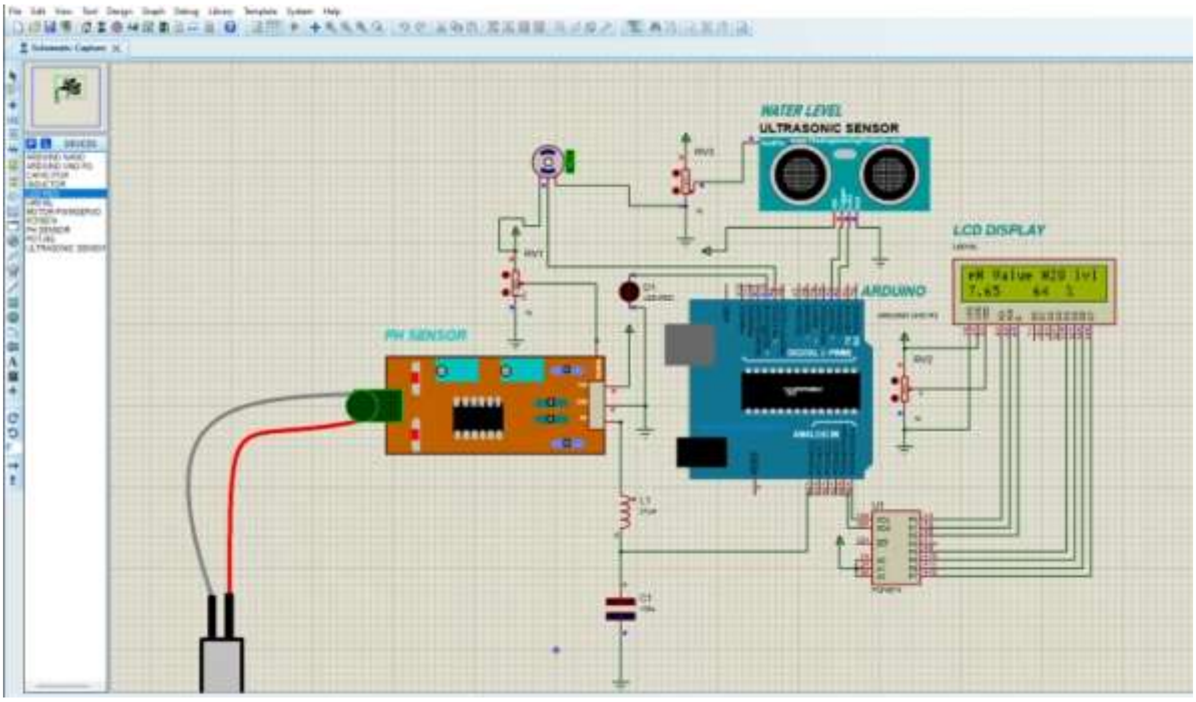


Figure 5.11 Simulation of circuit displaying pH value and water/lime solution level

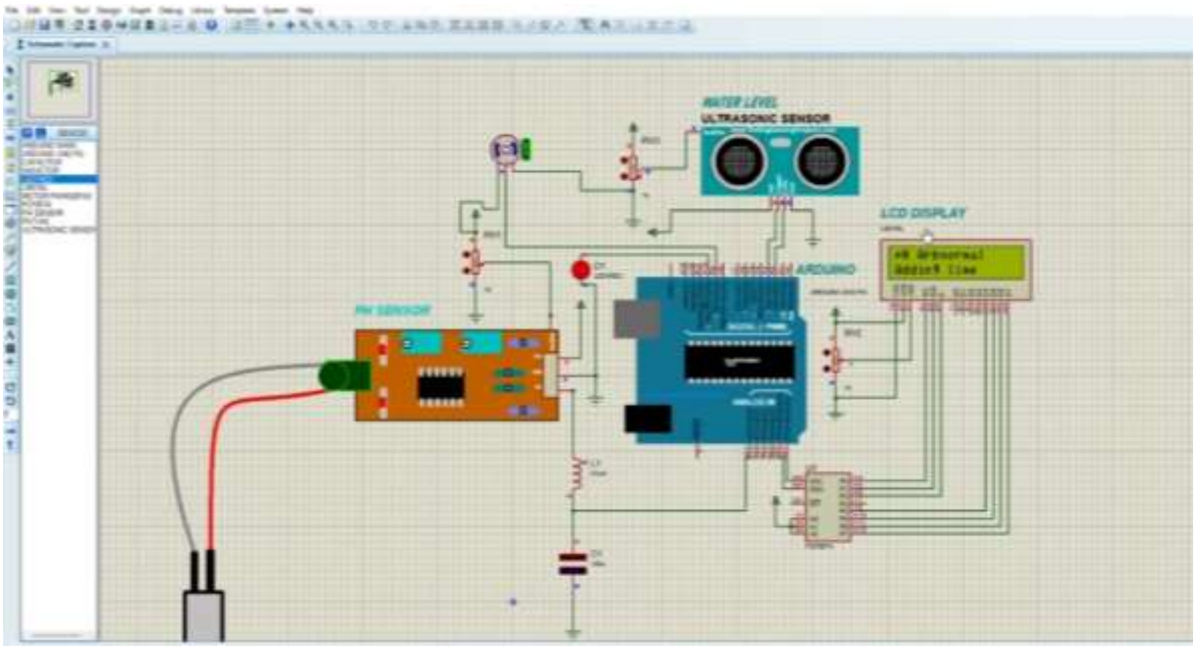


Figure 5.12 Simulation of circuit displaying the addition of lime as pH<9

5.6.4 RESULTS FROM PROTOTYPE TESTS DONE

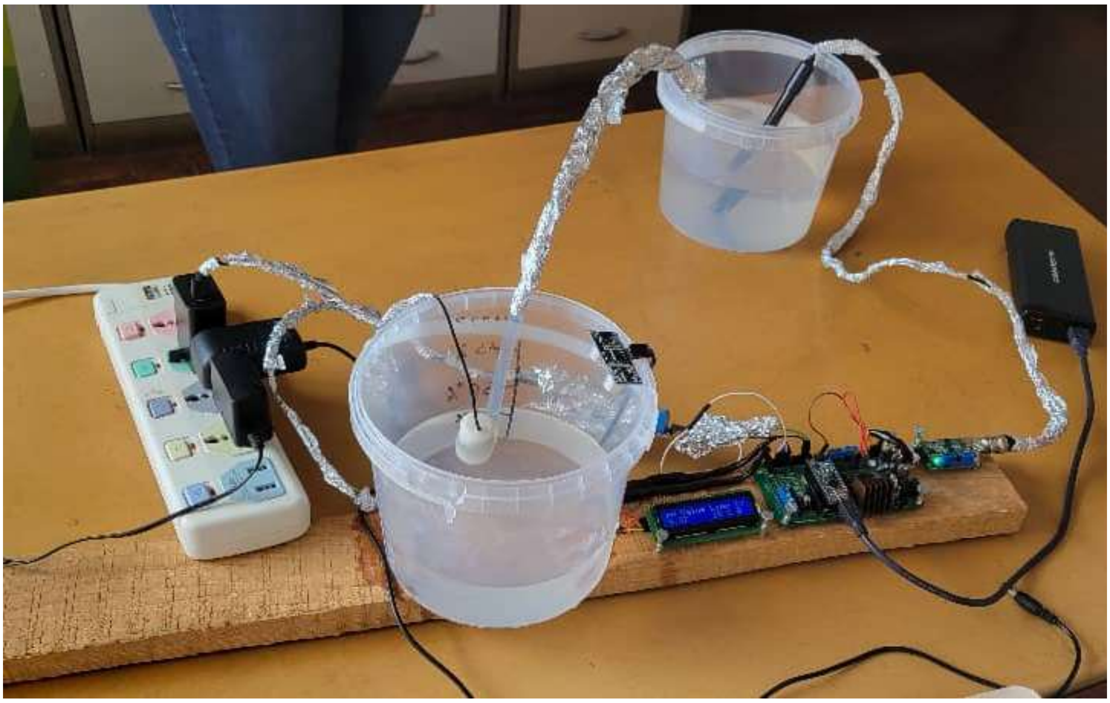


Figure 5.13 PROTOTYPE

Scenario 1: pH below 9

When the pH sensor recorded a value of pH less than 8. The pump which is connected to the circuit by means of a relay automatically switched on and dosed lime for 8seconds. The LCD displayed a notification "pH Abnormal Adding Lime" as lime was being added (shown on figure 5.14). Every 8 seconds the pump would stop pumping to allow the pH meter to capture the value of the newly dosed solution which would be rising with every dose.

Figure 5.14: an image showing the LCD display when pH was less than 9

Figure5.15: LCD display every 8 seconds

Scenario 2: pH above 9

Once the pH value passed 9 the pump would automatically stopped pumping. The pH was displayed on the LCD as displayed in figure 5.16. This meant that the dosing had successfully occurred.

Figure 5.16: pH above the 9

CONCLUSION

The pictorial simulations show us how the different devices act when subjected to various conditions. The simulations showed that, when pH was below 9, a notification was displayed on the LCD SCREEN, to show that lime had to be added. This is also seen on Figure 10c, where pH is abnormal thus lime is added using the servo valve. Once the LED is turned off, the lime addition stops as that meant the pH had been stabilized. The simulation showed that a closed loop system was ideal thus it was selected for the control system. The prototype showed the different results for the two scenarios. Aluminium foil had to be used minimize the interference in magnetic field between the pump and the pH sensor. The Relay was also used to help with the interferences which proved fruitful. A questionnaire was also filled by employees that are directly involved in the dosing of the lime. The results are shown in the Appendix section.

CHAPTER 6- COST ANALYSIS

6.1 BILL OF QUANTITIES

The bill of quantities shown on table 6.2 is that of the industrial setup for the Bulawayo Mining company taking into consideration that the PLC is the ideal controller. For the purposes of the project the student made use of the Aurduino Nano microcontroller to achieve the objectives set. Table 6.1 shows the bill of quantities for the Prototype.

Table 6.1-Bill of quantities for the prototype

ITEM	**DESCIPTION**	**QUANTITY**	**UNIT PRICE (US$)**	**AMOUNT (US$)**
Water pump	Each	1	5	5
Ultrasonic sensor	Each	1	7	7
pH sensor	Each	1	25	25
LEDs	Each	2	0.25	0.50
Arduino Nano board	Each	1	13	13
Power cable	Each	1	7	7
DC motor	Each	1	20	20
Connecting cables	Each	15	0.10	1.5
PCB Board & Printing		1	35	35
2.5l Transparent buckets		2	1.50	3
TOTAL				**US$117.00**

Table 6.2-Bill of quantities for an industrial setup

ITEM	**SPECIFICATION**	**QUANTITY**	**COST INC VAT (US$)**	
			UNIT	**TOTAL**
PLC	EC300 Delta	1	338.00	338.00

ILP Soft Delta software		1	136.90	136.90
Diaview SCADA Software		1	305.78	305.78
Pneumatic valve		1	84.55	84.55
Air/ water separator		1	84.89	84.89
MCB	32A 2Pole	1	24.5	24.5
8 pin relays	6 x 220VA 10A,	8	3.40	27.2
Desktop screen for SCADA Visualisation	3phase, 230V	1	430.00	430.00
Panel	600 x 600mm x 250		40	40
Inline pH meter			65	65.00
Indication lights	AC/DC 12V 20Ma	3	22.50	67.5
Combined start stop buttons for manual override		1	28.80	28.80
Ultrasonic sensor		1	65.38	65.38
pumps	Diaphragm Centrifugal	1 1	1800 2100	1800 2100
Dosing tank			288	288
Electric motors	525V/50Hz, 4 poles	3	1200	3600
Flow meter	Coriolis	2	1355.00	2710
Agitator	5kw,60rpm, Ø90x3525 shaft	1	3200	3200
labour			10000	10000
Bolts and nuts	All sizes(M10-M20) @250 Each	1500	1	1500
TOTAL				**US$26896.5**

6.2 BENEFITS OF THE PROJECT

- Time lost due to lime addition worker/day= 15minutes x 8 working hours/60mins

  =2 hours per day per shift

- Time lost per day(24hours) =2 x 3shifts= 6 hours
- Amount of gold “lost”per month =0.197 x 15workers x 6workers x 30days
  = 531.9g (19 ounce) of gold per month
- Revenue loss per month =amount of gold(ounce) x gold price/ounce
  = 19ounce x US$1785.40 per ounce (price as of 13/12/2022)
  =US$ 33 922.60(HOWMINE, 2022)

The research conducted at HOWMINE in 2022 shows that the amount of revenue lost per month is more than the capital needed for the project. This makes the project relevant and also minimizes the exposure to chemicals to operators. The company will also reduce the medical expenses that come with the employees being exposed to the lime.

CHAPTER 7: CONCLUSION & RECOMMENDATIONS

7.1 CONCLUSION

This project has accomplished the successful design of an automated lime dosing system, which effectively addresses the challenges faced by the gold processing plant. The system can dose lime accurately and precisely, while leading to higher efficiency and reduced costs. The design looks at the selection of suitable sensors and development of a user friendly interface for operators. There is a great potential to integrate the system with other processes in the gold processing plant. Future research could explore the use of artificial intelligence and machine learning algorithms to enhance the system's performance and lower the maintenance requirements. The successful design of an automated lime dosing system has potential to significantly benefit the gold processing industry, by boosting efficiency, reducing costs and improving safety.

The researcher was able to provide a functional prototype which was the visual for this entire project. The challenges faced were the interference of some components in terms of magnetic field which eventually led to implementation of measures like the use of aluminum foil and relays. The cost aspect of the project meant using affordable components which were not entirely the best but were able to serve intended purpose. This study gave insight on the negative impact of the existing lime dosing system of the Bulawayo Mining Company

7.2 RECOMMENDATION

The following recommendations were made in light of the study's findings and findings' conclusions.

1. An automatic dosing system designed in this research is relevant to the current problem. To ensure the reliability and scalability, it is recommended to conduct further tests and optimization before implementation.
2. Operators should have an understanding on the working principle of the dosing mechanism. It is recommended to have trainings on the general operation of the system.
3. This mechanism can also be applied to other sections of the plant like the flocculent dosing system to avoid problems of inconsistent dosing, operator error, safety concerns, monitoring and control.
4. This system can also be included outside the gold mining setup in other industries like, water treatment plants, borehole management, sewer systems, etc.

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Gold Processing Plant Questionnaire by Z J Dube https://docs.google.com/forms/d/e/1FAlpQLSfoGxvY9HJwJaO7bWZLFGiD9XAslJmC7NWLaiKsdgYDaXVBRQ/viewform?

APPENDICES

PROJECT CODE

```
#include <Wire.h>
#include <Servo.h>
#include <EEPROM.h>
#include <LiquidCrystal_I2C.h>
#include <L298N.h>
#include <HardwareSerial.h>

   LiquidCrystal_I2C lcd(0x27, 16, 2);
   float ph, calibration_value = 21.34;
    int  buffer_arr[10],temp=50,  speedofsound=  343,  incomingByte  =
0,percentage, set_val,sensorValue = 0, lime, pos = 0, temp1;
   const int ping = 4, echo = 2,analogInPin = A6, trial = 3, ledPin =
10;
   unsigned long int avgValue,avgval;
    float  distance,cm,duration,  inches,  level,  height,  content,
percent;

//int MOTE = 5;
//int MOTA = 4;
const unsigned int IN1_A = 7;
const unsigned int IN2_A = 8;
const unsigned int IN1_B = 10;
const unsigned int IN2_B = 11;
const unsigned int EN = 9;

// Create one motor instance
L298N MOTA(EN, IN1_A, IN2_A);
L298N MOTB(EN, IN1_B, IN2_B);

void setup()
```

```
{
 Serial.begin(9600);
 //pinMode(MOTE, OUTPUT);
 MOTA.setSpeed(70);
 MOTB.setSpeed(70);

 //MOTA.setSpeed(120);
 pinMode(ledPin, OUTPUT);
  pinMode(trial, OUTPUT);
 lcd.init();
 lcd.begin(16, 2);
 lcd.backlight();
 lcd.setCursor(0, 0);
 lcd.print("Lime Dosing Sys");
 lcd.setCursor(0, 1);
 lcd.print("BYO MINING CO");
 delay(2000);
  lcd.clear();
  lcd.setCursor(0, 0);
 lcd.print("    BY ENG");
 lcd.setCursor(0, 1);
 lcd.print("ZIBUSISO J DUBE");
 delay(2000);
 //myservo.attach(9);
 pinMode(ping, OUTPUT);
 pinMode(echo, INPUT);
 pinMode(ledPin, OUTPUT);

  //myservo.write(0);
 set_val=EEPROM.read(0);
  if(set_val>25)set_val=25 ;
  lcd.clear();
```

```
 }

void loop()
{
                    //  temp  =  DHT.read11(DHT11_PIN);  ///  to  print(
DHT.temperature/DHT.humidity)            lcd.print(DHT.temperature);
lcd.print((char)223) for dec;
   ph = phvv();
       lcd.setCursor(0,0);
       lcd.print("pH Value");
       lcd.setCursor(0,1);
       lcd.print(ph);
       delay (2000);
   phcorection(); //// adding or subtracting lime
   percent= ultra();
       lcd.setCursor(9,0);
       lcd.print("Lime lvl");
       lcd.setCursor(9,1);
       lcd.print(percent);
       Serial.println(distance);
       lcd.setCursor(11,1);
       lcd.print(" % ");
       delay(2000);

   //tempcorrection();
}
float phvv()
 {

    for(int i=0;i<10;i++)
     {
       buffer_arr[i]=analogRead(A6);
```

```
        delay(30);
      }
     for(int i=0;i<9;i++)
      {
         for(int j=i+1;j<10;j++)
        {
        if(buffer_arr[i]>buffer_arr[j])
        {
          temp=buffer_arr[i];
          buffer_arr[i]=buffer_arr[j];
          buffer_arr[j]=temp;
         }
        }
       }
       avgval=0;
       for(int i=2;i<8;i++)
       avgval+=buffer_arr[i];
       float volt=(float)avgval*5.0/1024/6;
       float ph_act = -5.70 * volt + calibration_value;
       return ph_act ;
  }
float ultra (){
   digitalWrite(ping, HIGH);
   delayMicroseconds(10);
   digitalWrite(ping, LOW);
   duration = pulseIn(echo, HIGH);
   distance = 0.017 * duration;
content = 9.5-distance;
  percent = (content/9.5)*100;
 return percent;
 return distance;
  /* inches = microsecondsToInches(duration);
```

```
    if (inches>set_val){inches=set_val;
    percentage=(set_val-inches)*100/set_val;
    }
     else {percentage=(set_val-inches)*100/set_val;}
    return percentage;
   }
    long microsecondsToInches(long microseconds) {
    return (microseconds/speedofsound/2); */
  }
void phcorection()
 {
    if (ph<8)
  {digitalWrite(ledPin, HIGH);
     //myservo.write(90);
     //MOTA.forward();
      //MOTB.forward();
      digitalWrite(trial,HIGH);
     lcd.clear();
     lcd.setCursor(0,0);
     lcd.print("pH Arbnormal");
     lcd.setCursor(0,1);
     lcd.print("Adding lime");
     delay (8000); // changes
     lcd.clear(); //changes
     lcd.setCursor(0,0); //changes
     lcd.print("Checking pH");  //changes
     delay (1000);
     digitalWrite(trial,LOW);
     delay (5000);
     lcd.clear();
   }
    else if (ph>=8)
```

```
      {digitalWrite(ledPin, LOW);
         //myservo.write(0);
         //MOTA.stop();
         //MOTB.stop();
         digitalWrite(trial,LOW);
         //digitalWrite(MOTA, LOW);
        // lcd.clear();

        }

 }
```

QUESTIONAIRRE SAMPLE

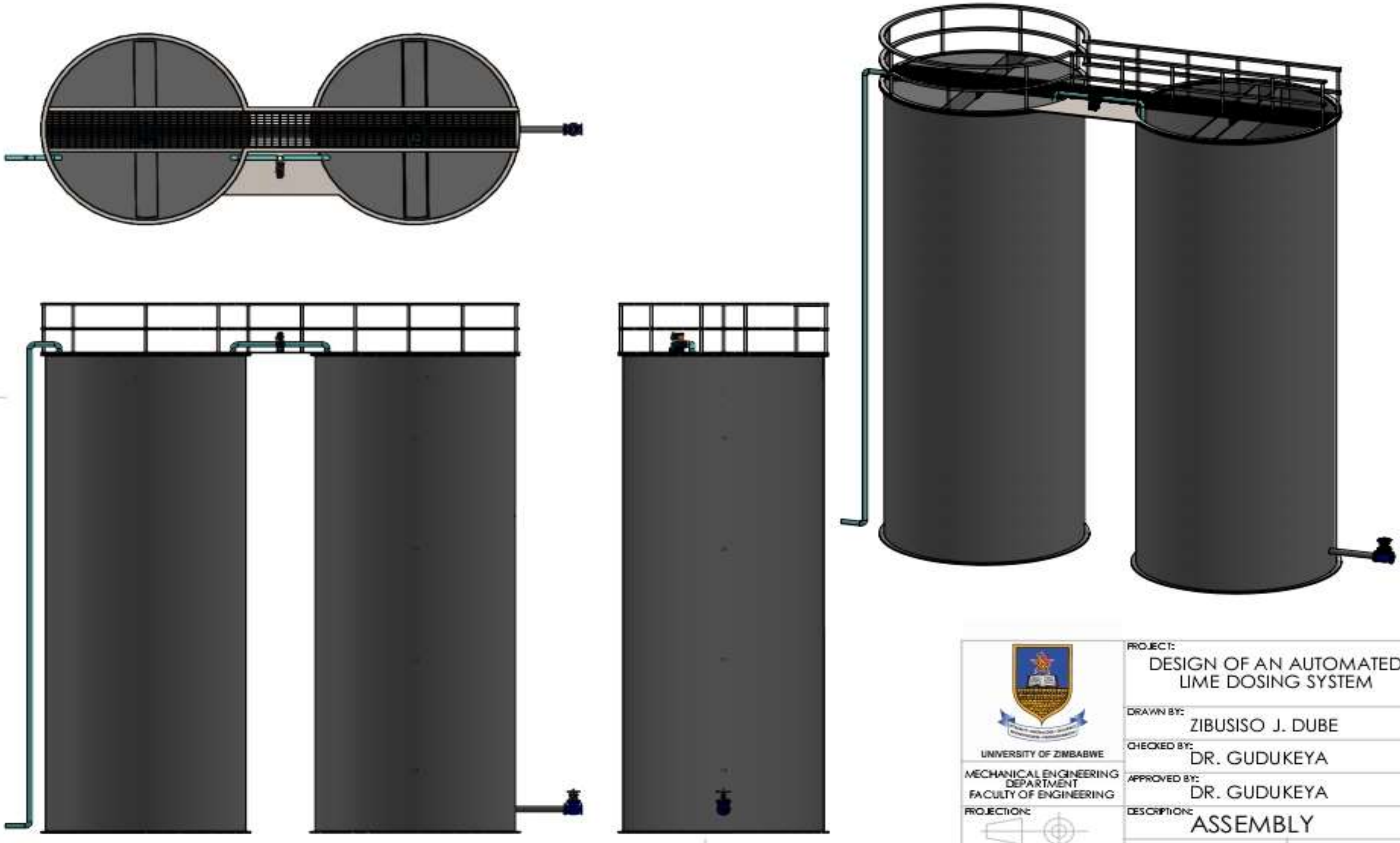
GOLD PROCESSING PLANT QUESTIONAIRRE By Z J Dube

1. Which section of the god processing plant do you work in?
    - **Milling**
    - **Crushing**
    - **CIP**
    - **Other**
2. **How long have you worked in the Gold Processing plant?**
    - **Less than 5 years**
    - **5 years**
    - **More than 5 years**
3. **Do you carry out Hazard and Risk assessment before work?**
    - **Yes**
    - **No**
4. **Are you provided with dust masks when working with lime?**
    - **Yes**
    - **No**
    - **Sometimes**
5. **Is there a safe platform for the lime dosing process?**
    - **Yes**
    - **No**

6. **Have you ever suffered any short-term effects of lime inhalation listed?**
    - **Coughing**
    - **Flue**
    - **Eye irritation**
    - **Sore throat**
    - **Sneezing**
    - **Other____**
7. **Have you suffered any long-term effects of lime inhalation listed?**
    - **Respiratory diseases**
    - **Bronchitis**
    - **Allergies**
    - **Perennial cough**
    - **Migraine**
    - **Other____**
8. **How often are X-Rays/medicals done for employees?**
    - **Every two months**
    - **Every 6 months**
    - **Once a year**
    - **In cases of incidents**
9. **Do you get remedies to reduce impacts of inhaled dust/lime?**
    - **Yes**
    - **No**
    - **Sometimes**
10. **Have you ever operated an automated system before?**
    - **Yes**
    - **No**
    - **Maybe**
11. **If yes, what are the advantages of using automated systems?**

…………………………………………………………………………………………….

DRAWINGS



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT:
DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY:
ZIBUSISO J. DUBE

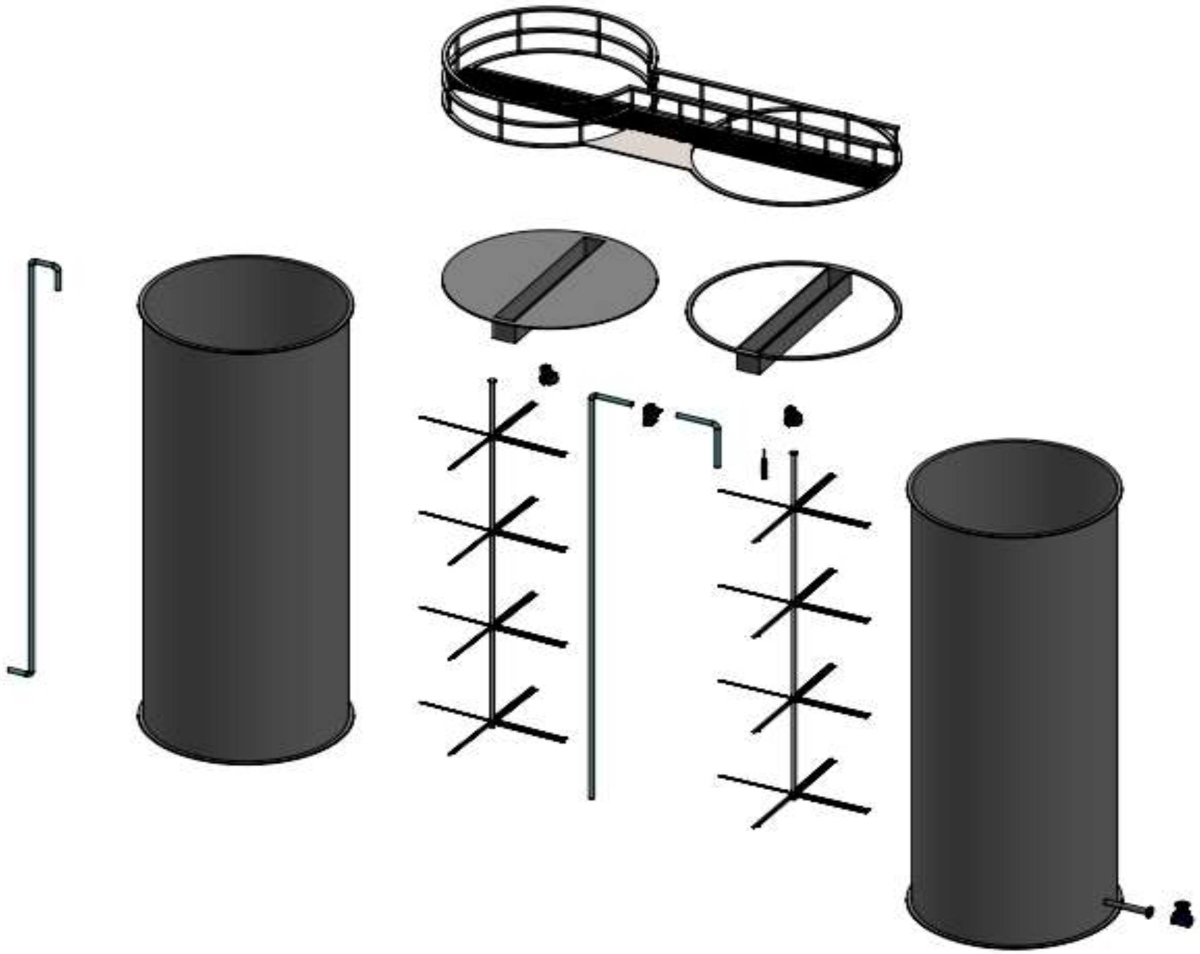
CHECKED BY:
DR. GUDUKEYA

APPROVED BY:
DR. GUDUKEYA

DESCRIPTION:
ASSEMBLY

SCALE1:75

SHEET1 OF 12



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY: ZIBUSISO J. DUBE

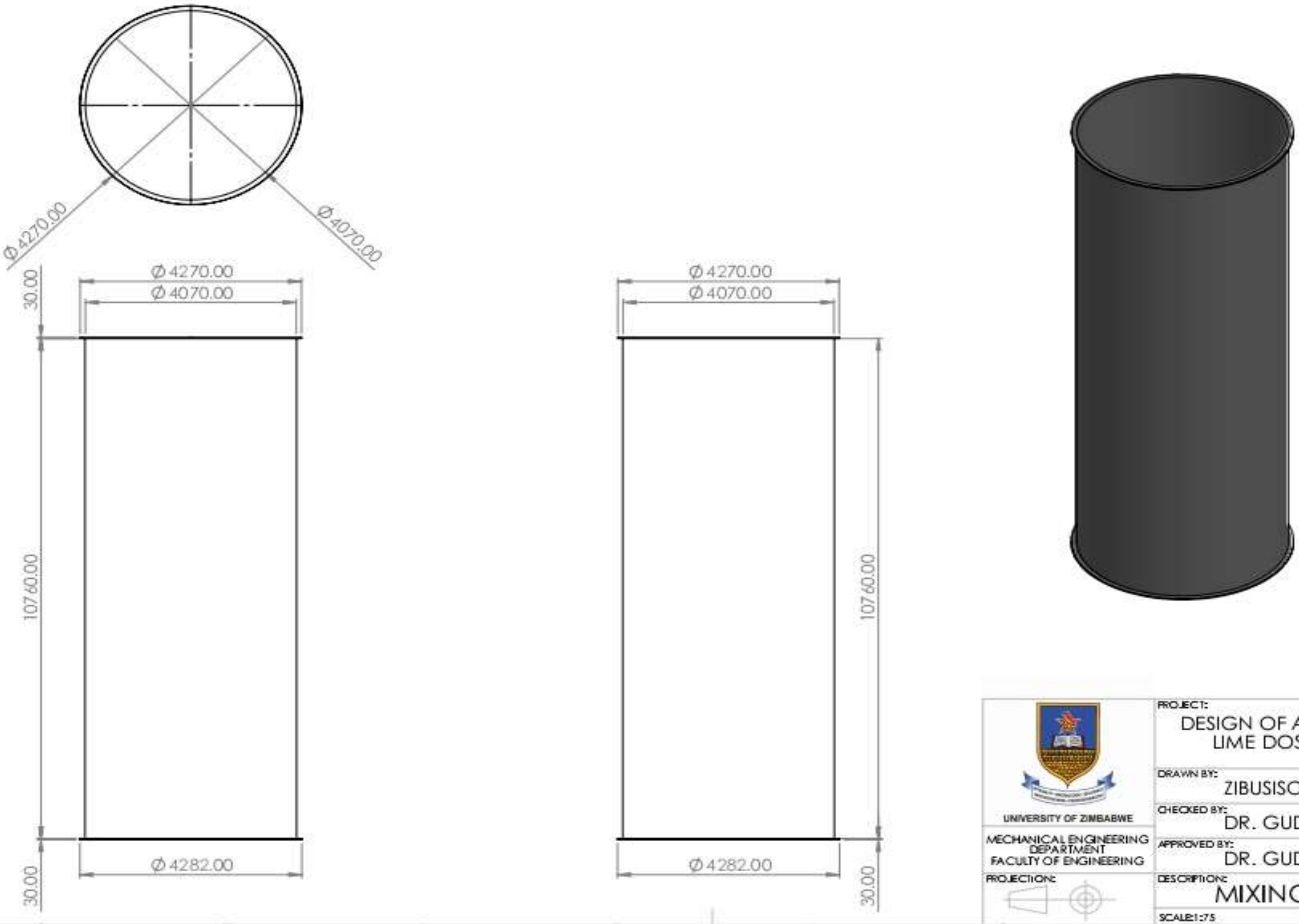
CHECKED BY: DR. GUDUKEYA

APPROVED BY: DR. GUDUKEYA

DESCRIPTION: EXPLODED VIEW

SCALE:1:100

SHEET 2 OF 12



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY: ZIBUSISO J. DUBE

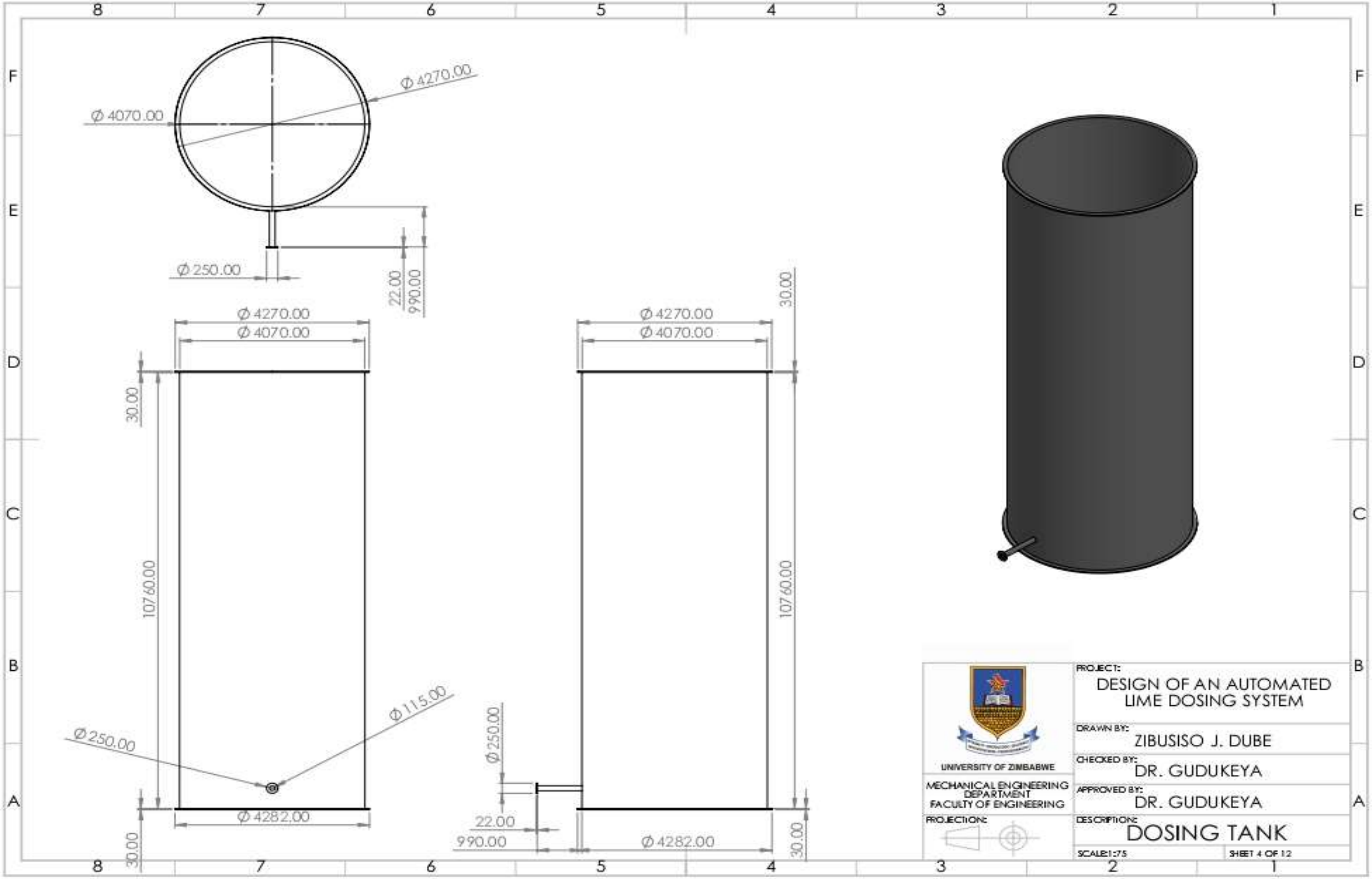
CHECKED BY: DR. GUDUKEYA

APPROVED BY: DR. GUDUKEYA

DESCRIPTION: MIXING TANK

SCALE1:75

SHEET 3 OF 12



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Ø 4070.00
Ø 250.00
22.00
990.00
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30.00
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Ø 4282.00
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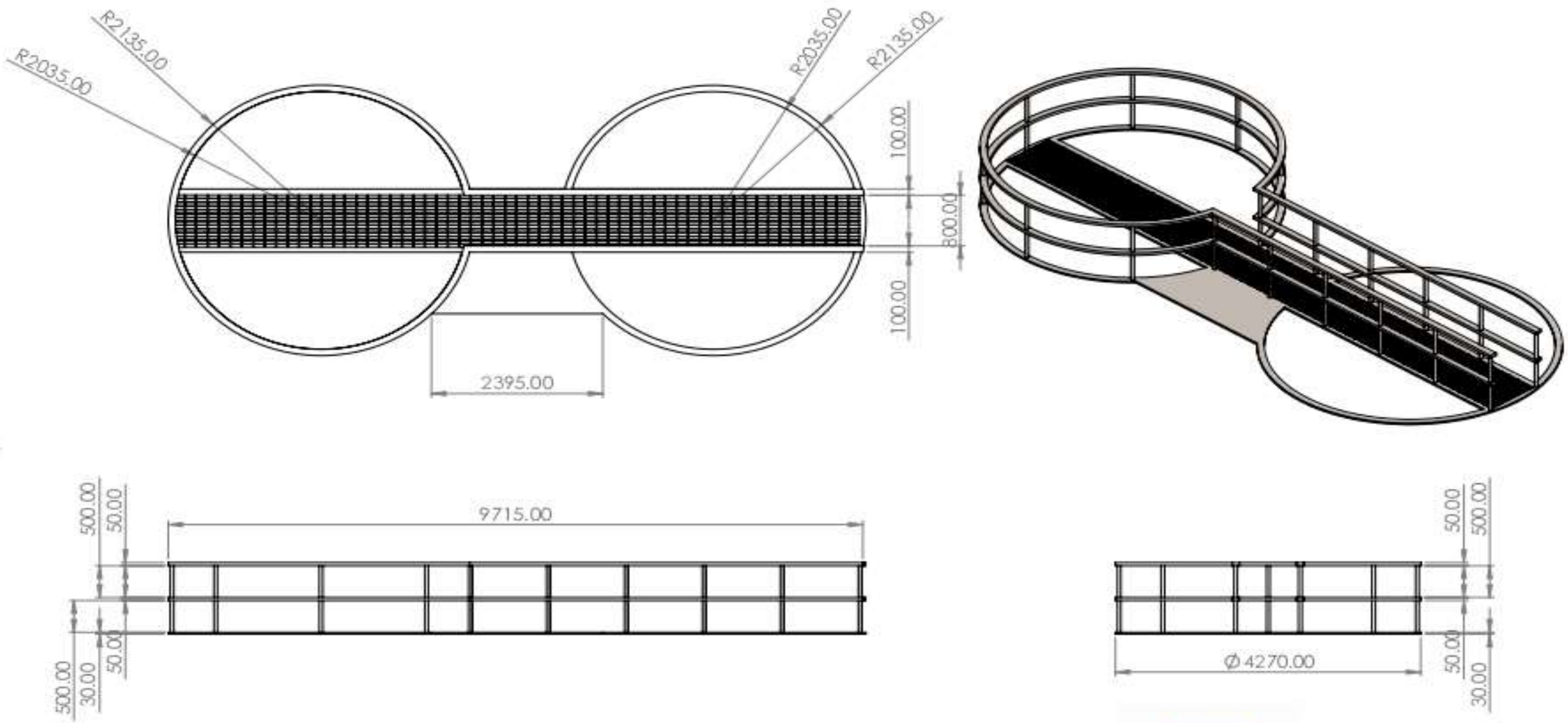
10760.00
30.00
UNIVERSITY OF ZIMBABWE
MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING
PROJECTION:
PROJECT:
DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
DRAWN BY:
ZIBUSISO J. DUBE
CHECKED BY:
DR. GUDUKEYA
APPROVED BY:
DR. GUDUKEYA
DESCRIPTION:
DOSING TANK
SCALE:1:75
SHEET 4 OF 12



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY: ZIBUSISO J. DUBE

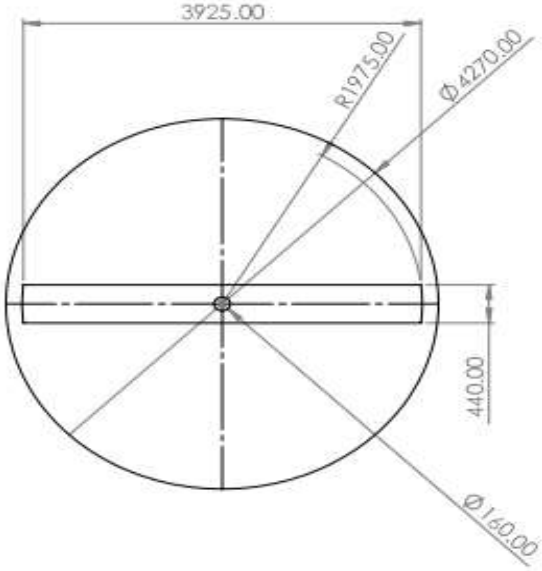
CHECKED BY: DR. GUDUKEYA

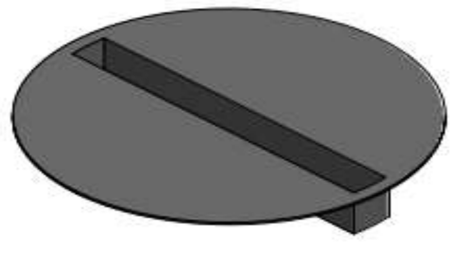
APPROVED BY: DR. GUDUKEYA

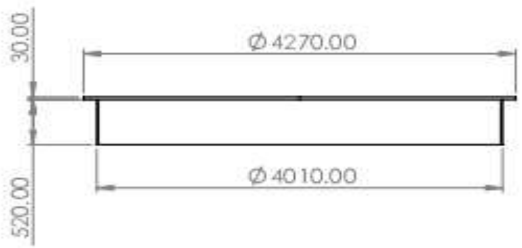
DESCRIPTION: PATHWAY

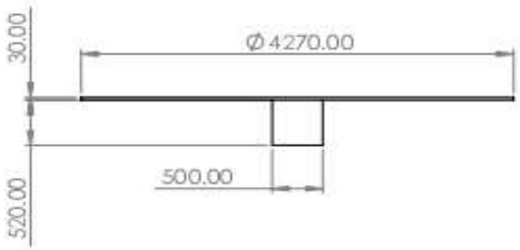
SCALE:1:60

SHEET 5 OF 12

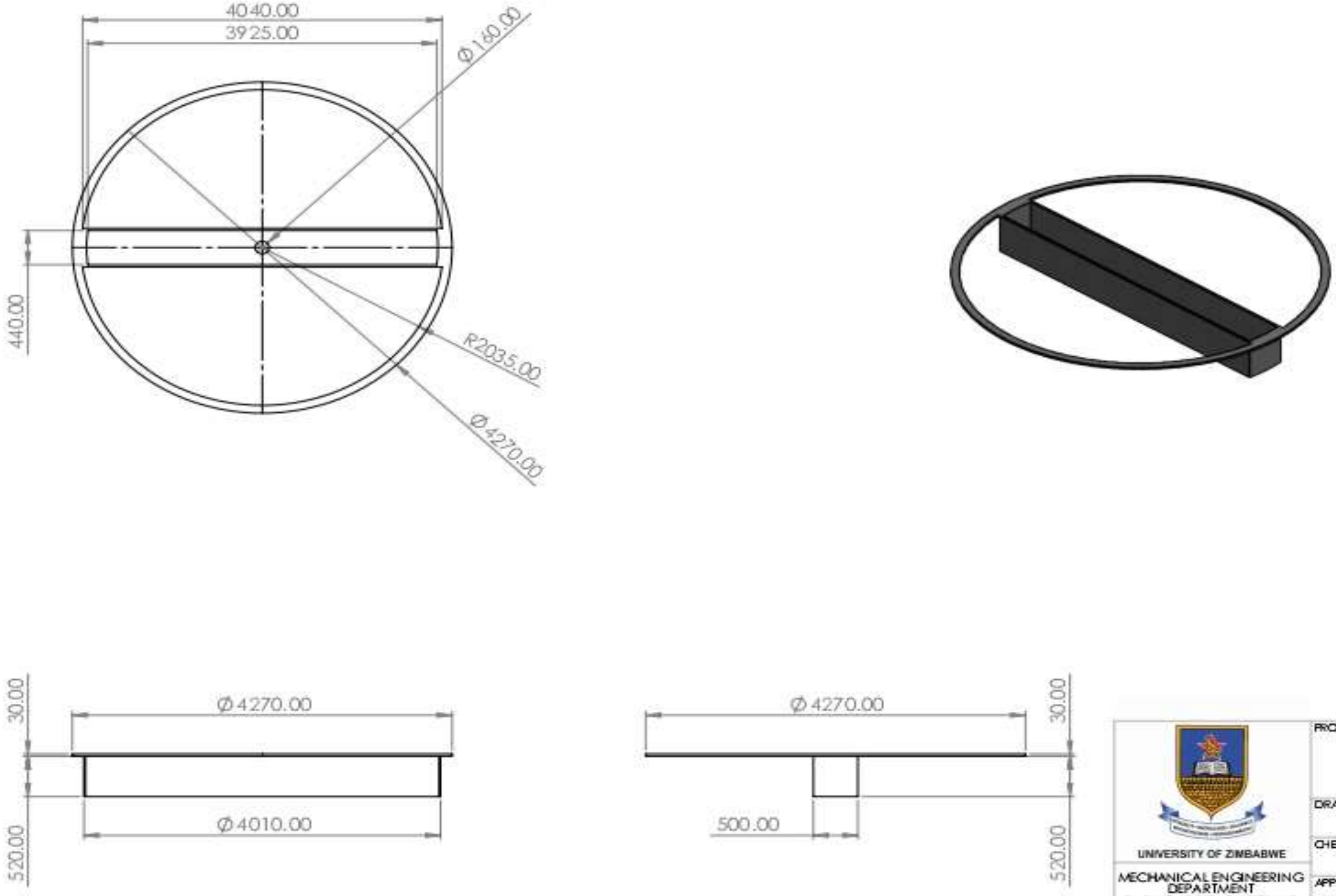








UNIVERSITY OF ZIMBABWE	PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
	DRAWN BY: ZIBUSISO J. DUBE
	CHECKED BY: DR. GUDUKEYA
MECHANICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING	APPROVED BY: DR. GUDUKEYA
PROJECTION:	DESCRIPTION: AGITATOR HOLDER 1
	SCALE:1:50 / SHEET 6 OF 12



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY: ZIBUSISO J. DUBE

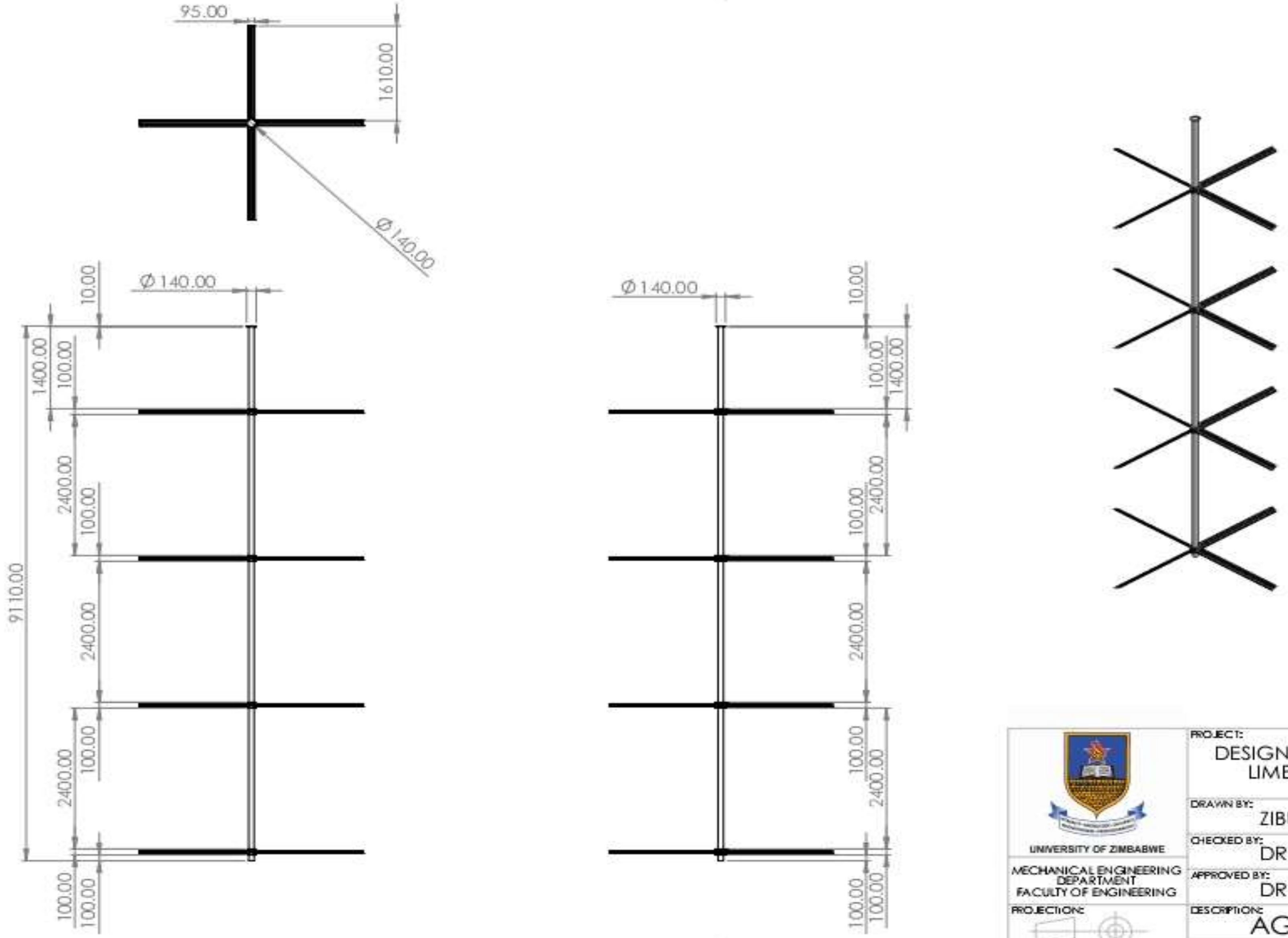
CHECKED BY: DR. GUDUKEYA

APPROVED BY: DR. GUDUKEYA

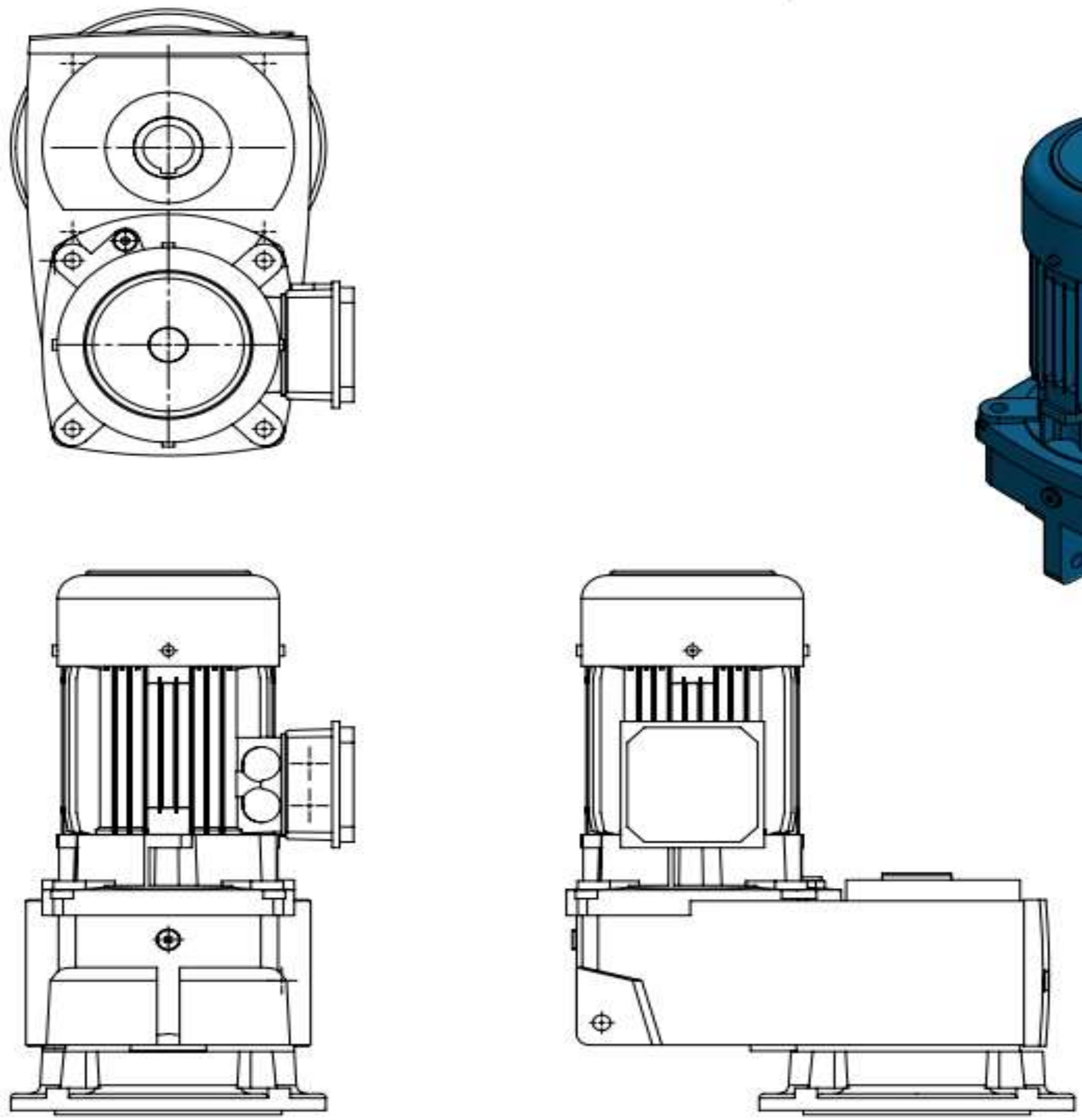
DESCRIPTION: AGITATOR HOLDER 2

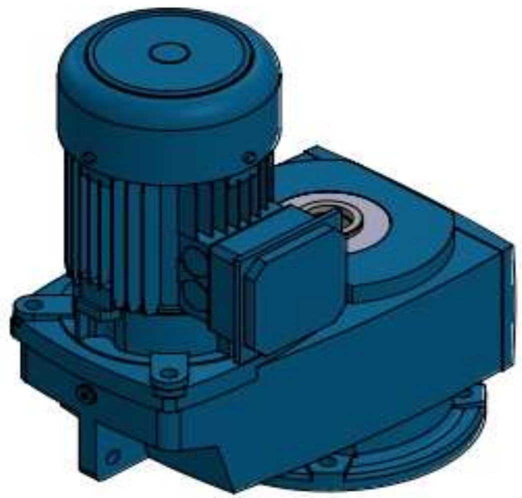
SCALE:1:50

SHEET 7 OF 12

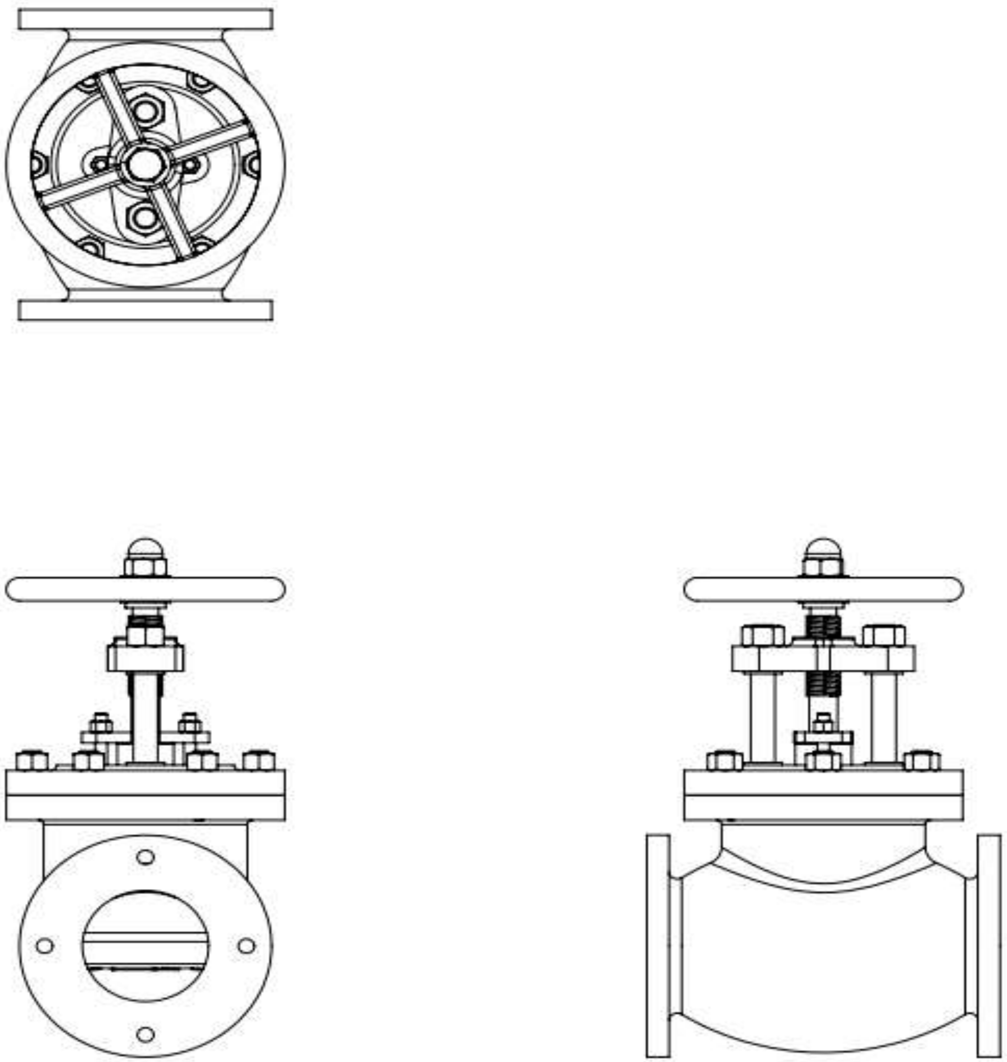


UNIVERSITY OF ZIMBABWE	PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
	DRAWN BY: ZIBUSISO J. DUBE
MECHANICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING	CHECKED BY: DR. GUDUKEYA
	APPROVED BY: DR. GUDUKEYA
PROJECTION:	DESCRIPTION: AGITATOR
	SCALE:1:60 / SHEET 8 OF 12





UNIVERSITY OF ZIMBABWE	PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
	DRAWN BY: ZIBUSISO J. DUBE
	CHECKED BY: DR. GUDUKEYA
MECHANICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING	APPROVED BY: DR. GUDUKEYA
PROJECTION:	DESCRIPTION: MOTOR
	SCALE:1:4 / SHEET 9 OF 12



UNIVERSITY OF ZIMBABWE

MECHANICAL ENGINEERING DEPARTMENT
FACULTY OF ENGINEERING

PROJECTION:

PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM

DRAWN BY: ZIBUSISO J. DUBE

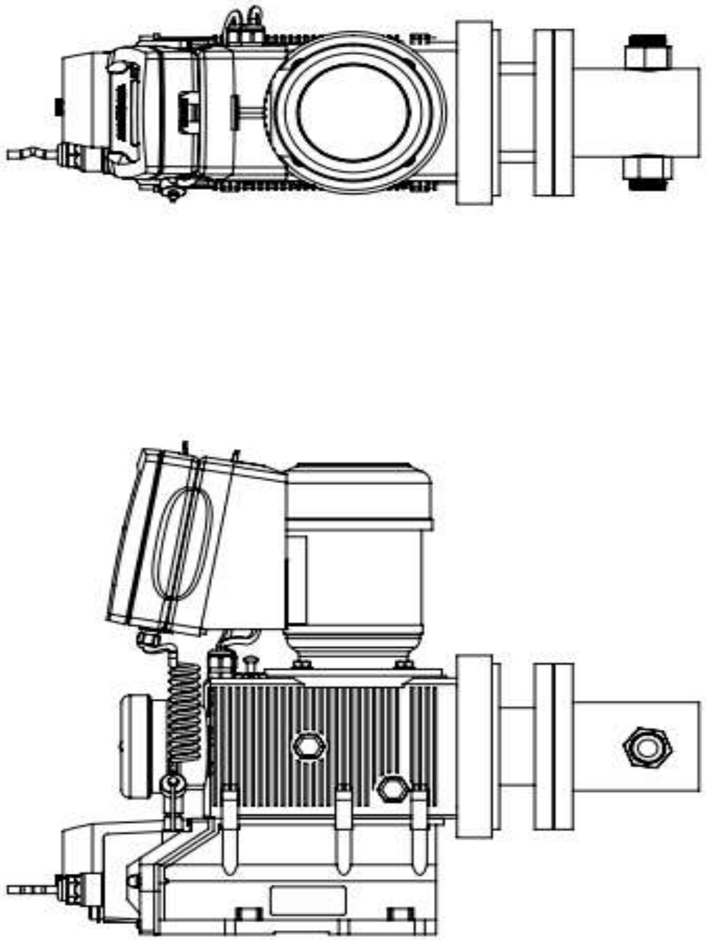
CHECKED BY: DR. GUDUKEYA

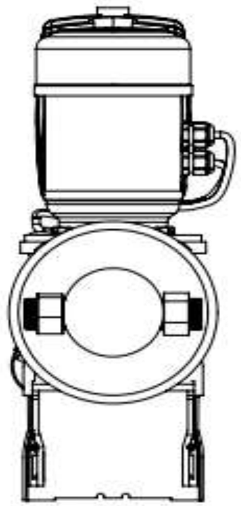
APPROVED BY: DR. GUDUKEYA

DESCRIPTION: VALVE

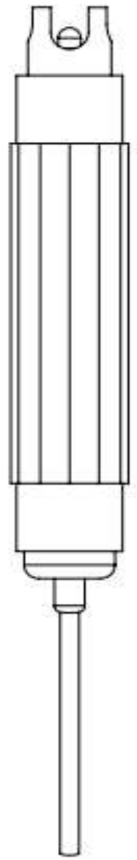
SCALE:1:5

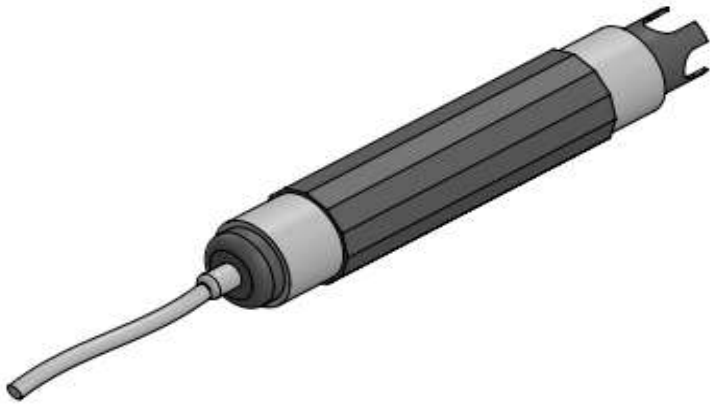
SHEET10 OF 12

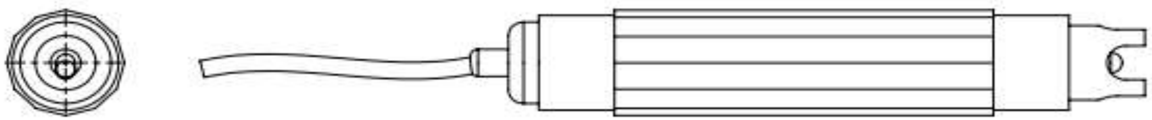




UNIVERSITY OF ZIMBABWE	PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
	DRAWN BY: ZIBUSISO J. DUBE
MECHANICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING	CHECKED BY: DR. GUDUKEYA
	APPROVED BY: DR. GUDUKEYA
PROJECTION:	DESCRIPTION: DOSING PUMP
	SCALE:1:4 — SHEET 11 OF 12







UNIVERSITY OF ZIMBABWE	PROJECT: DESIGN OF AN AUTOMATED LIME DOSING SYSTEM
	DRAWN BY: ZIBUSISO J. DUBE
MECHANICAL ENGINEERING DEPARTMENT FACULTY OF ENGINEERING	CHECKED BY: DR. GUDUKEYA
	APPROVED BY: DR. GUDUKEYA
PROJECTION:	DESCRIPTION: PH SENSOR
	SCALE:1:4 — SHEET12 OF 12