ABSTRACT

This report deals with detailed design, modeling, and fabrication process of an airtight container featuring a mechanism for a detachable cable which can be attached or detached to the container. The project aimed to ensure the container's structural integrity and airtightness under specified pressures, crucial for applications in various industries such as pharmaceuticals, food storage, and environmental monitoring.

The design process commenced with the creation of detailed 3D models of each component using SolidWorks. This modeling phase allowed for optimization of the container's features, including the inlet valve modelling and detachable cable mechanism.

Subsequent theoretical calculations were performed to determine the stress acting on the container wall, ensuring the container could withstand the internal pressures without failure. These calculations indicated a maximum theoretical stress of 0.987 MPa at a pressure of 0.2MPa. The stress was also calculated at different values of pressure for better results. Given the material's yield strength of 137.98 MPa, the design was evaluated against a safety factor of 2, ensuring the applied stresses were well within the allowable limits.

To further validate the design, numerical analysis using ANSYS was conducted, yielding a slightly lower stress of 0.947 MPa at 0.2MPa pressure, thus confirming the reliability of the theoretical model. Finite Element Analysis (FEA) was instrumental in the design validation process. A fine mesh with a 2mm element size and node count 115614 was used to accurately simulate the container's behavior under an applied pressure of 0.2MPa.

The fabrication phase involved procurement of bomb from the bomb calorimeter apparatus. A hole of 15mm was drilled to which the detachable cable mechanism was made. Controllable valve and pressure gauge were also attached to the container to control the air flow to the container and check the pressure inside it. Series of air leak tests were conducted on the container which validated the container's airtightness, confirming it is fully functional.

The project successfully integrated a detachable mechanism within an airtight container, with both theoretical and numerical analyses supporting its structural integrity and safety. This study provides a solid foundation for further improvements and potential applications in various high-stakes environments.

LIST OF FIGURES

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Chapter 1

INTRODUCTION

In today's world of advancing technology and increasing environmental awareness, the need for precise measurement and control of air quality and thermal characteristics is more significant than ever. Air tight containers equipped with sensors play a crucial role in various fields, from food preservation to scientific research.

Pressurized container are containers which have high pressurized fluid inside them. The pressure is variance between inside and outside of the container. The inside pressure is normally greater than the outside pressure.

A pressure vessel functions as a device where a pressure differential exists, resulting from atmospheric pressure. Due to the inherent danger associated with high operating pressures, meticulous attention must be paid during the design process of pressure vessels. The longevity of a pressure vessel subjected to cyclic loads is contingent upon the number and intensity of stress cycles it experiences. The durability of the vessel depends on its ability to withstand stress without experiencing failure

The stresses generated in the vessel are studied and determined using analytical procedures obtained from the codes as well as using the ANSYS software. Software such as SolidWorks help to design and develop the vessels in less time and provide accurate results as per the code selected. Also, care is taken that they work continuously for years without much maintenance.

In general, the physical criteria are governed by the ratio of diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter. A solid wall vessel is also termed as Mono Block pressurized container.

Chapter 3

OBJECTIVES

3.1 OBJECTIVES OF THIS PROJECT

I. To design and fabricate an air tight container.
II. To perform stress analysis on the container for different values of pressure using ANSYS software.
III. To calculate theoretical values of stresses on container for different values of pressure.
IV. To compare theoretical values of stresses with numerical values of the stresses.

Chapter 4

3D CAD MODELLING OF THE AIR TIGHT CONTAINER

The initial phase of the project involved detailed 3D modeling of each component of the air tight container using SolidWorks. This enabled optimization of all geometries and assemblies. The 3D model assembly included the detachable cable mechanism. By using SolidWorks, we could simulate the assembly process, check for interferences, and ensure that all parts fit together seamlessly. This modeling phase was crucial for identifying potential design flaws early in the development process, thus reducing the risk of errors during fabrication.

4.1 REASONS FOR SELECTING BOMB OF BOMB CALORIMETER

- It is made up of **Stainless Steel** which has high strength, chemical inertness, thermal stability.
- It has a yield strength of **137.9MPa** and tensile strength of **550MPa**.
- The project requires a high-pressure withstanding container that can withstand pressure upto 15-20 bar without leakage or getting damaged.
- It was already available at the lab but was not in use as it was damaged.
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4.2 3D MODEL OF THE AIR TIGHT CONTAINER

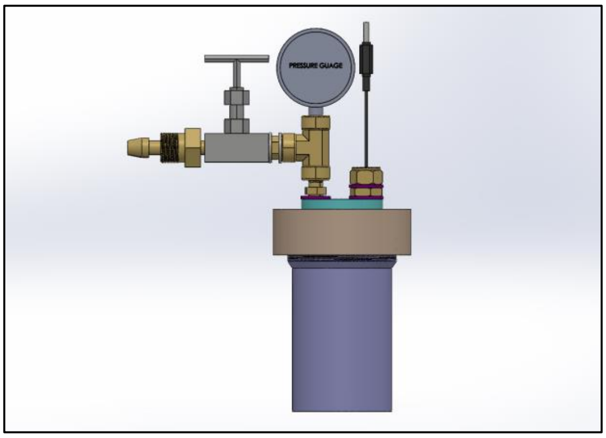

Fig 4.1: Front view of the air tight container assembly

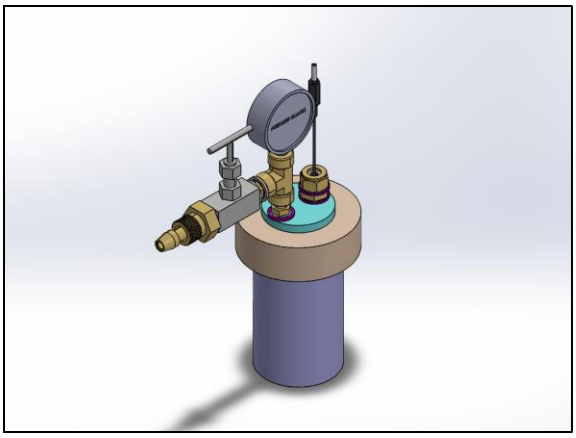

Fig 4.2: Isometric view of the air tight container assembly

4.3 EXPLODED VIEW OF THE CONTAINER

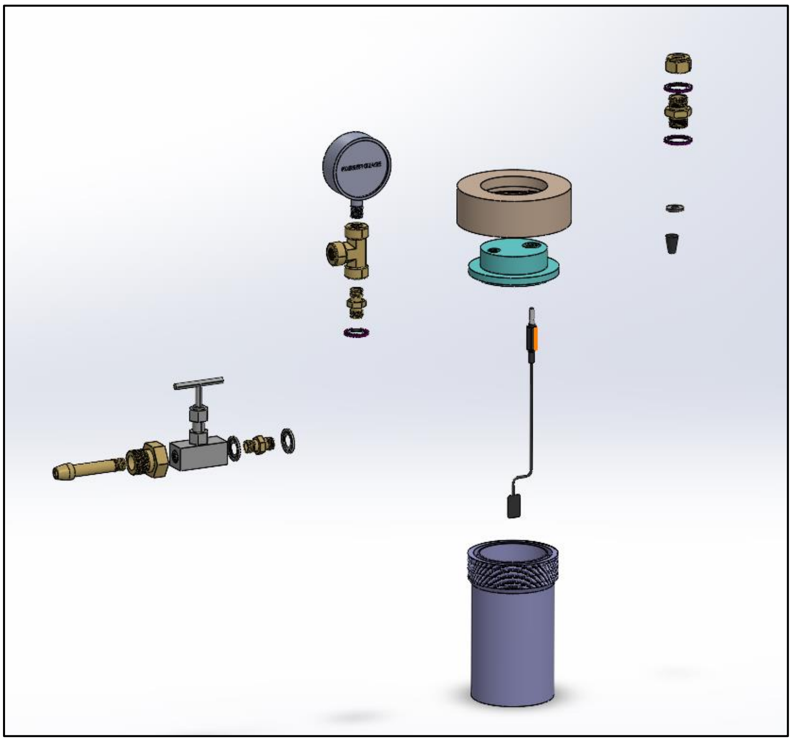

Fig 4.3: Exploded view of the air tight container assembly

4.4 DRAWING OF THE AIR TIGHT CONTAINER ASSEMBLY

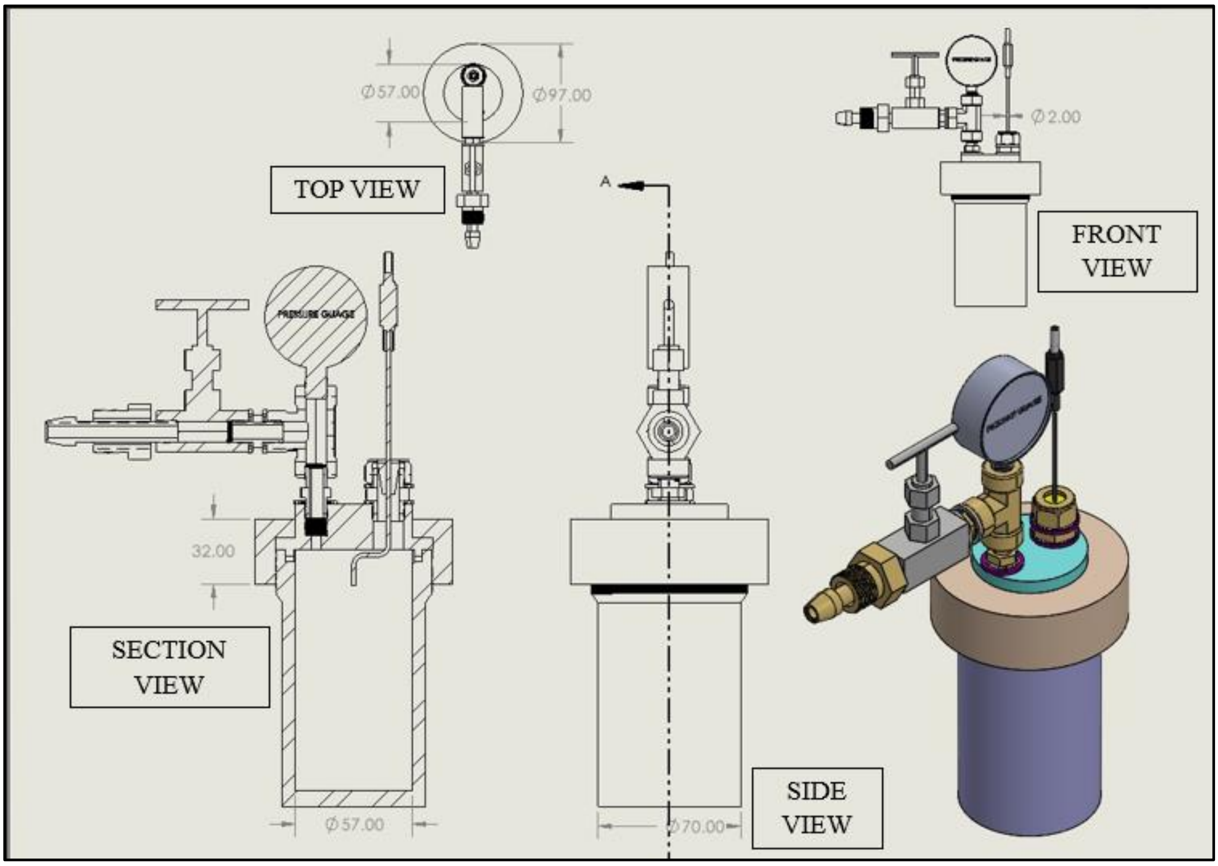

Fig 4.4: Drawing of the air tight container

4.5 DIFFERENT PARTS OF THE AIR TIGHT CONTAINER

Table 4.1: Different parts of the air tight container

PART	PART NO.
CONTAINER	01
INNER CAP	02
OUTER CAP	03
SENSOR CONNECTOR	04
SENSOR CONNECTOR'S BONDED WASHER	05
SENSOR RUBBER	06
SENSOR CONNECTOR WASHER	07
SENSOR CONNECTOR CAP	08
SENSOR	09
PRESSURE GAUGE	10
CONTROL VALVE	11
BULL NOSE	12
BULL NUT	13
INLET VALVE'S CONNECTOR	14
TEE CONNECTOR	15
INLET VALVE'S BONDED WASHER	16

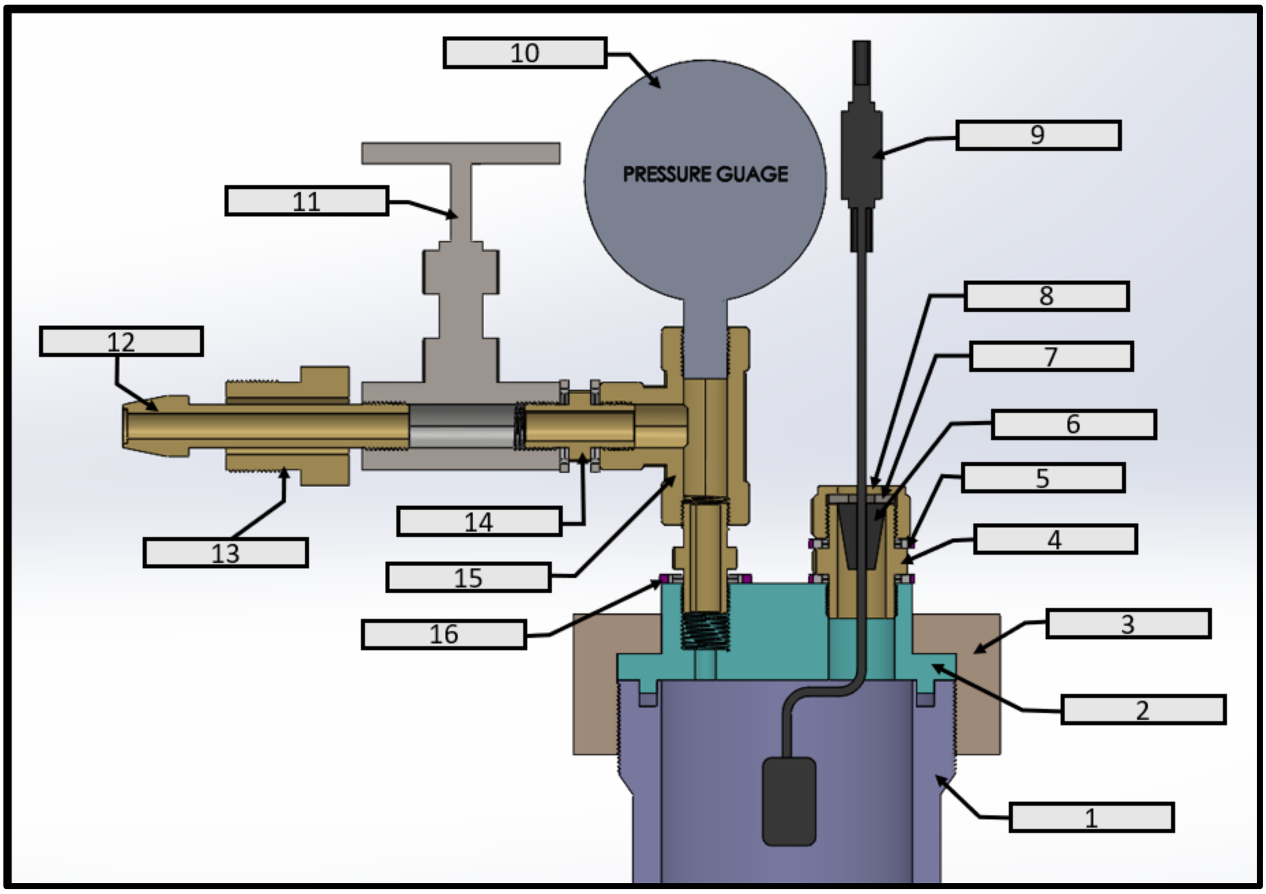

Fig 4.5: Cross-sectional view of all components of the air tight container

4.6 DIMENSIONS OF EACH PART

4.6.1: PART 01- CONTAINER

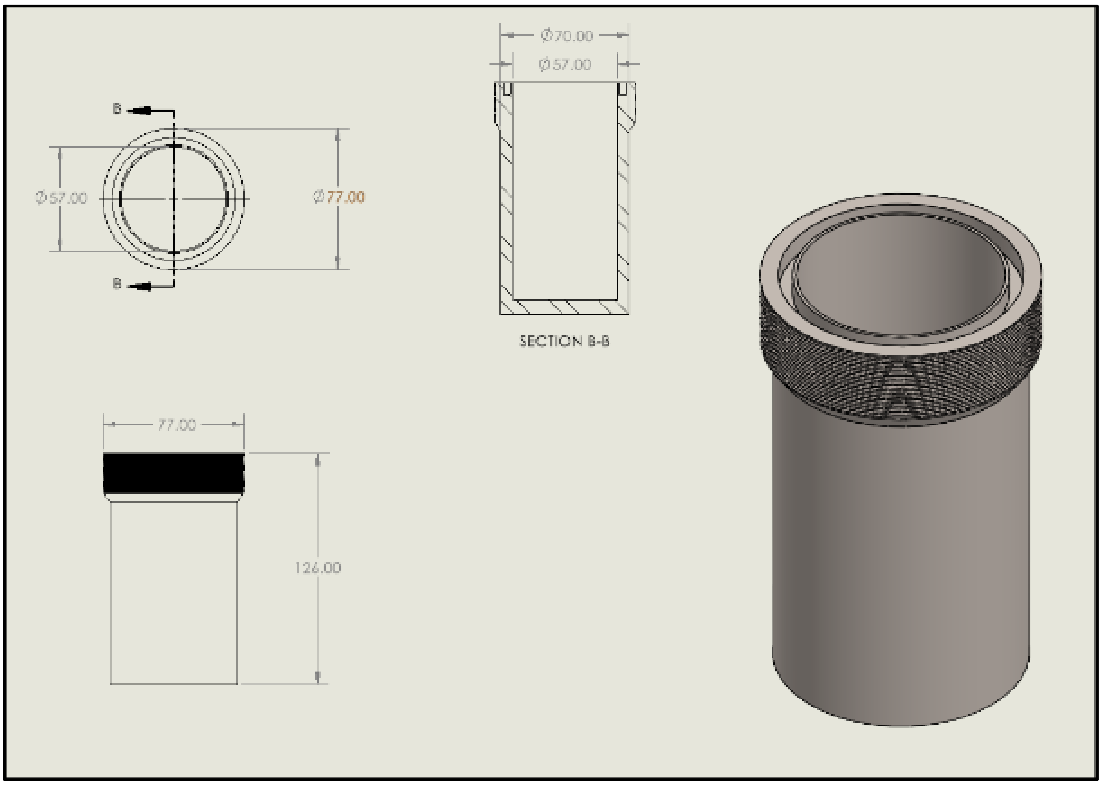

Fig 4.6: Part 1

4.6.2: PART 02- INSIDE CAP

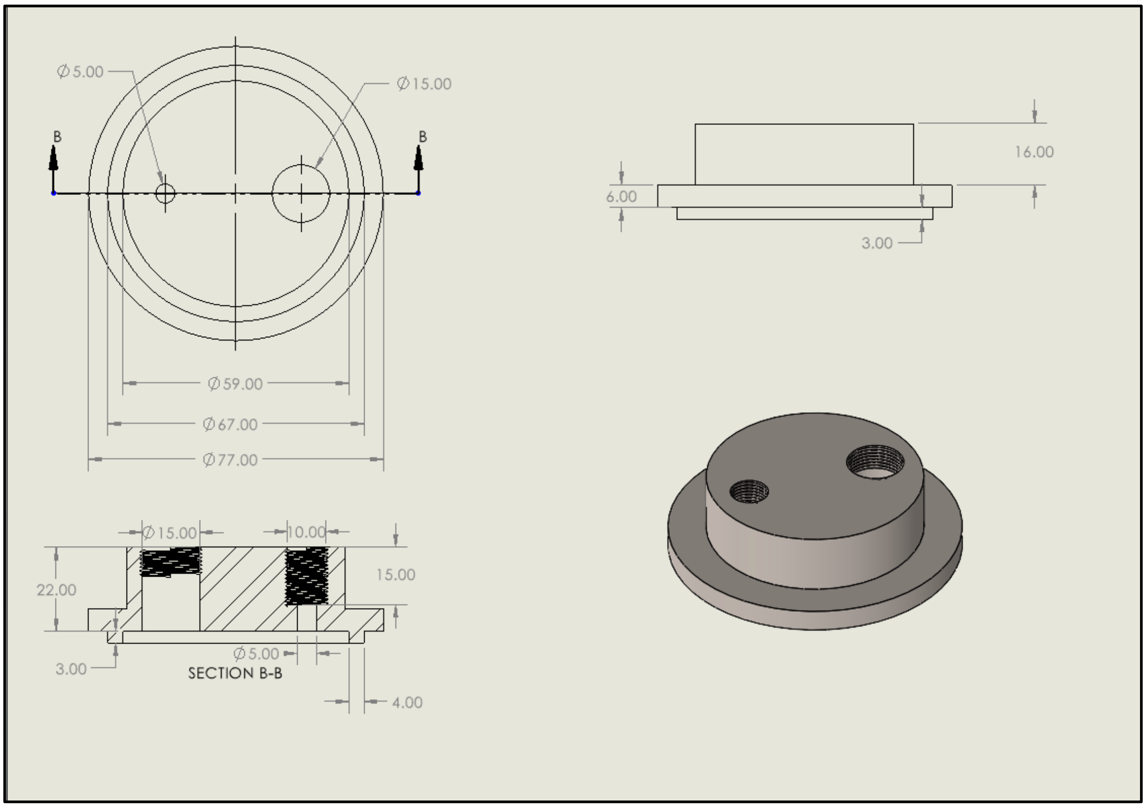

Fig 4.7: Part 2

4.6.3: PART 03- OUTSIDE CAP

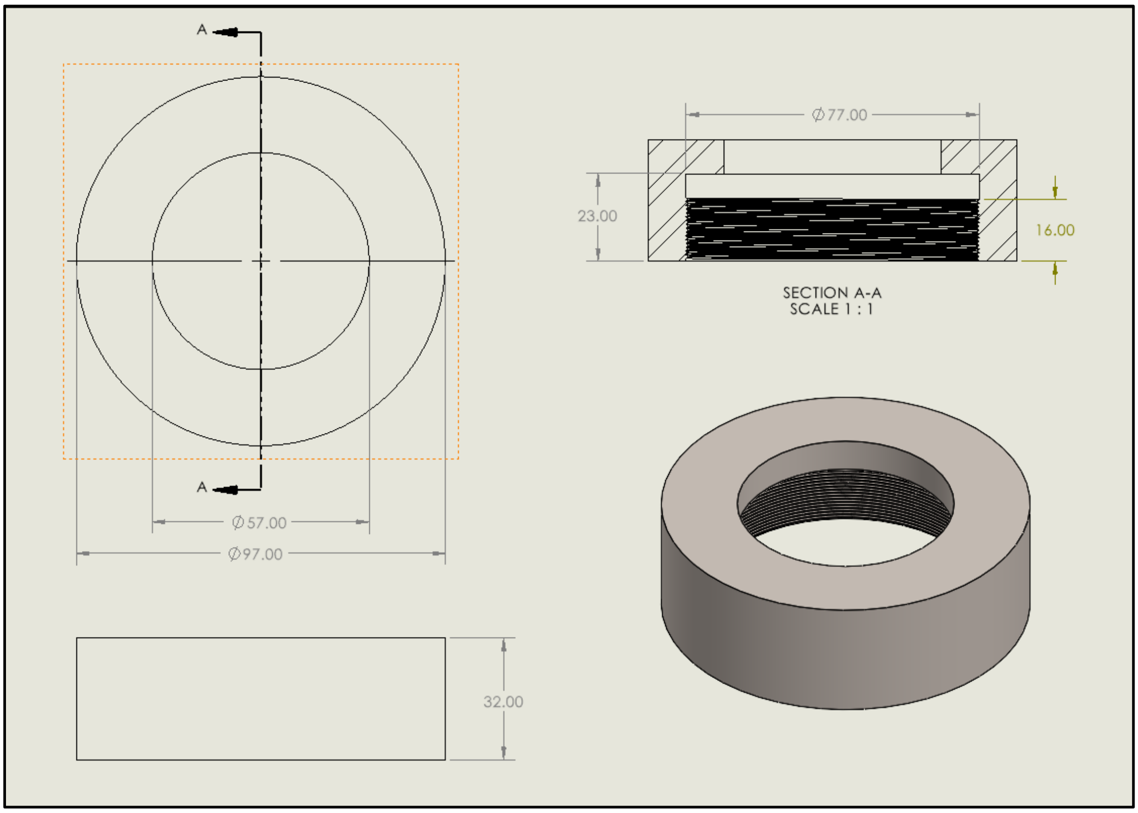

Fig 4.8: Part 3

4.6.4: PART 04- SENSOR CONNECTOR

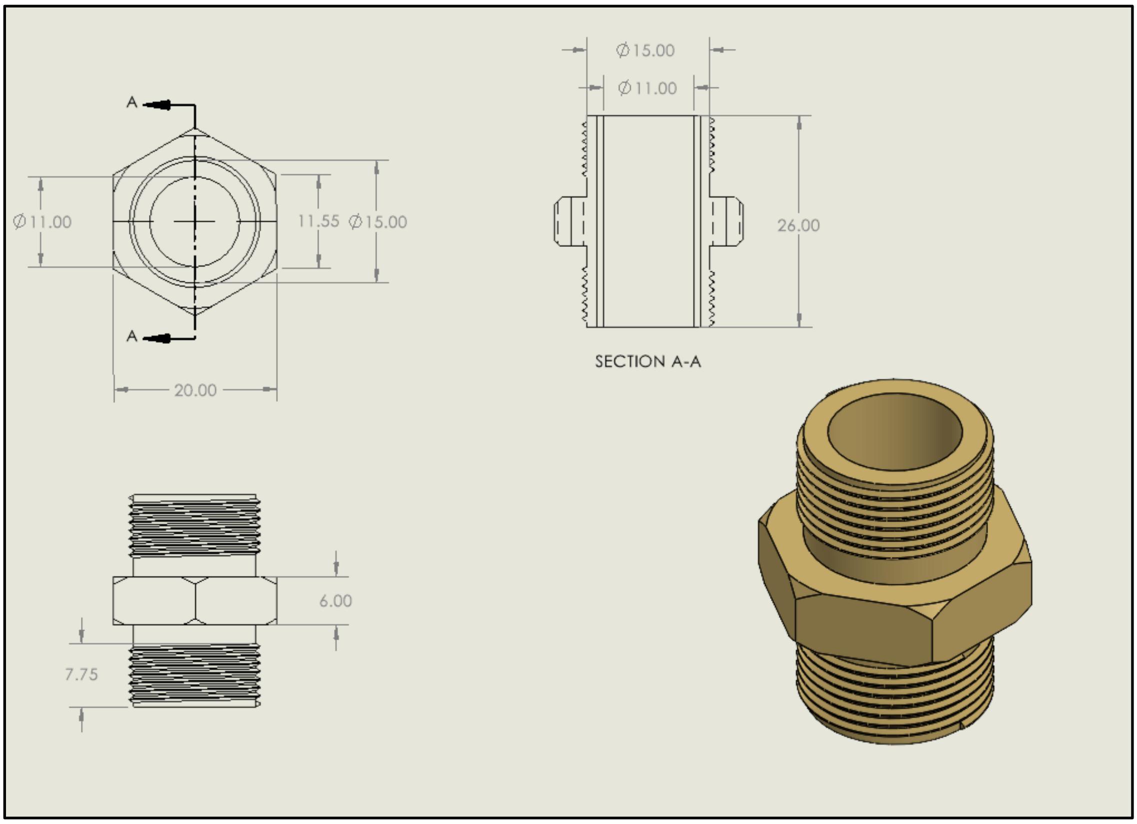

Fig 4.9: Part 4

4.6.5: PART 05- SENSOR CONNECTOR BONDED WASHER

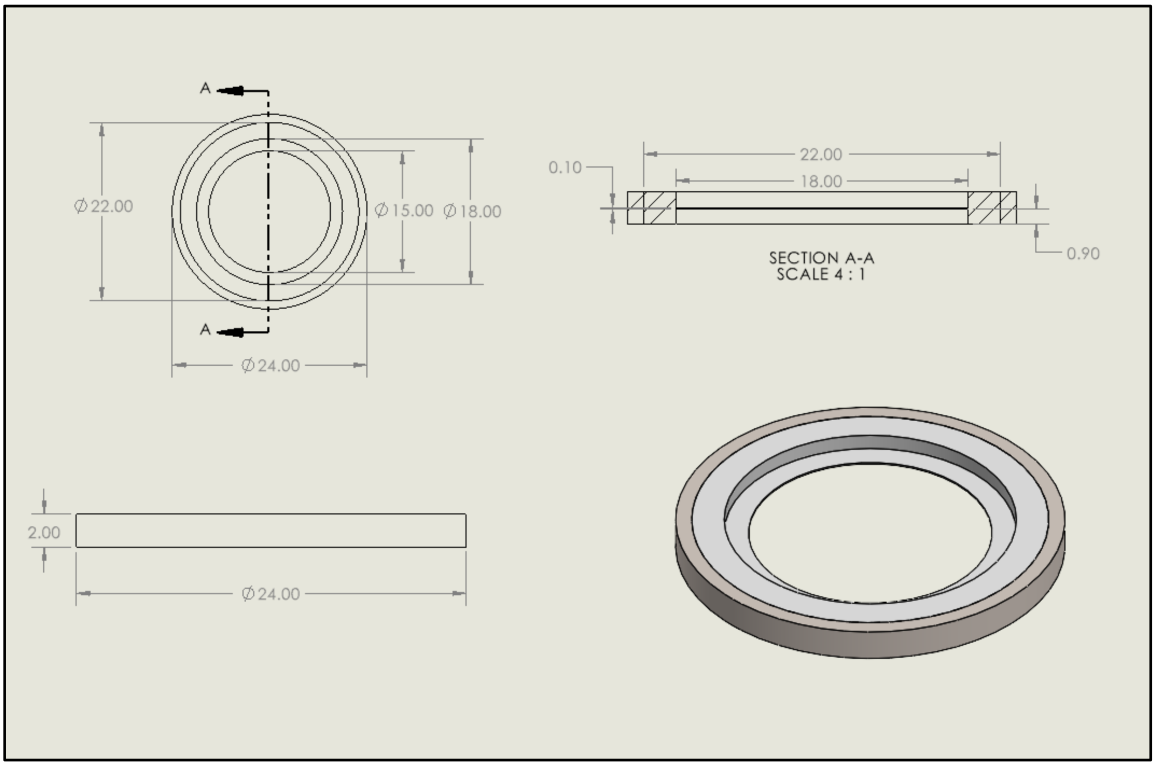

Fig 4.10: Part 5

4.6.6: PART 06- SENSOR RUBBER

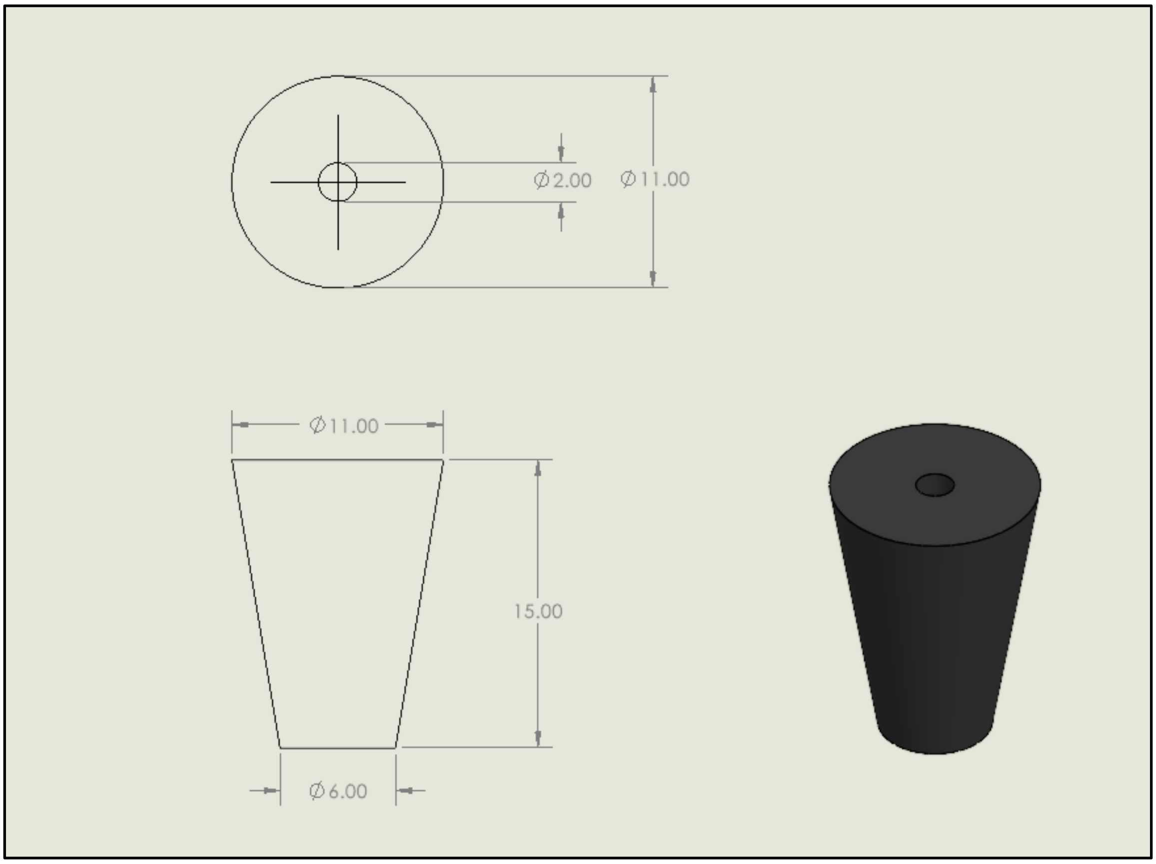

Fig 4.11: Part 6

4.6.7: PART 07- SENSOR CONNECTOR CAP WASHER

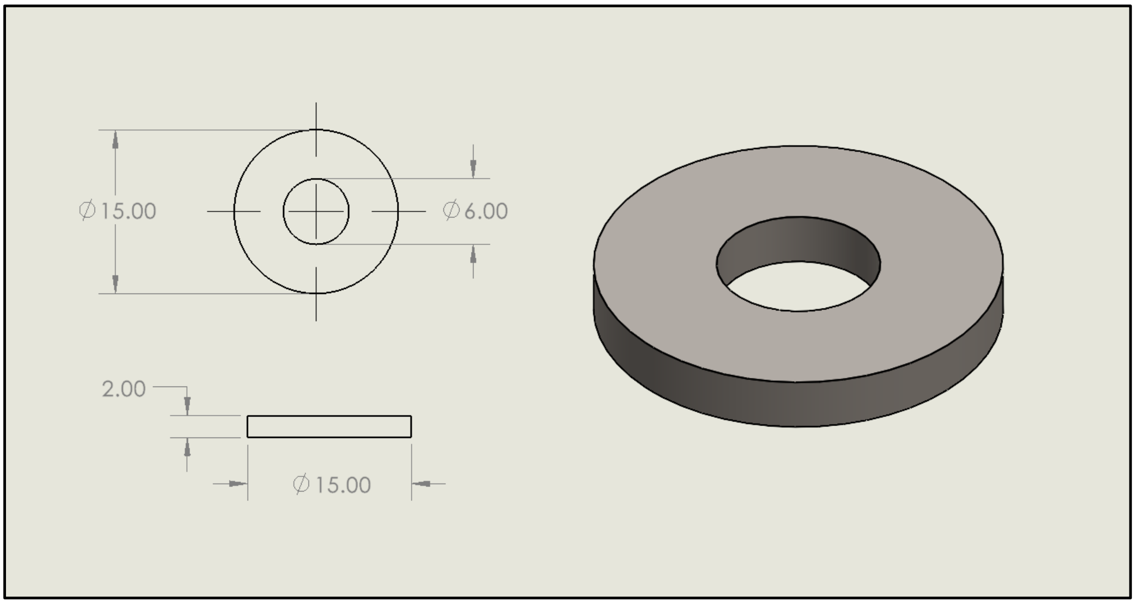

Fig 4.12: Part 7

4.6.8: PART 08- SENSOR CONNECTOR CAP

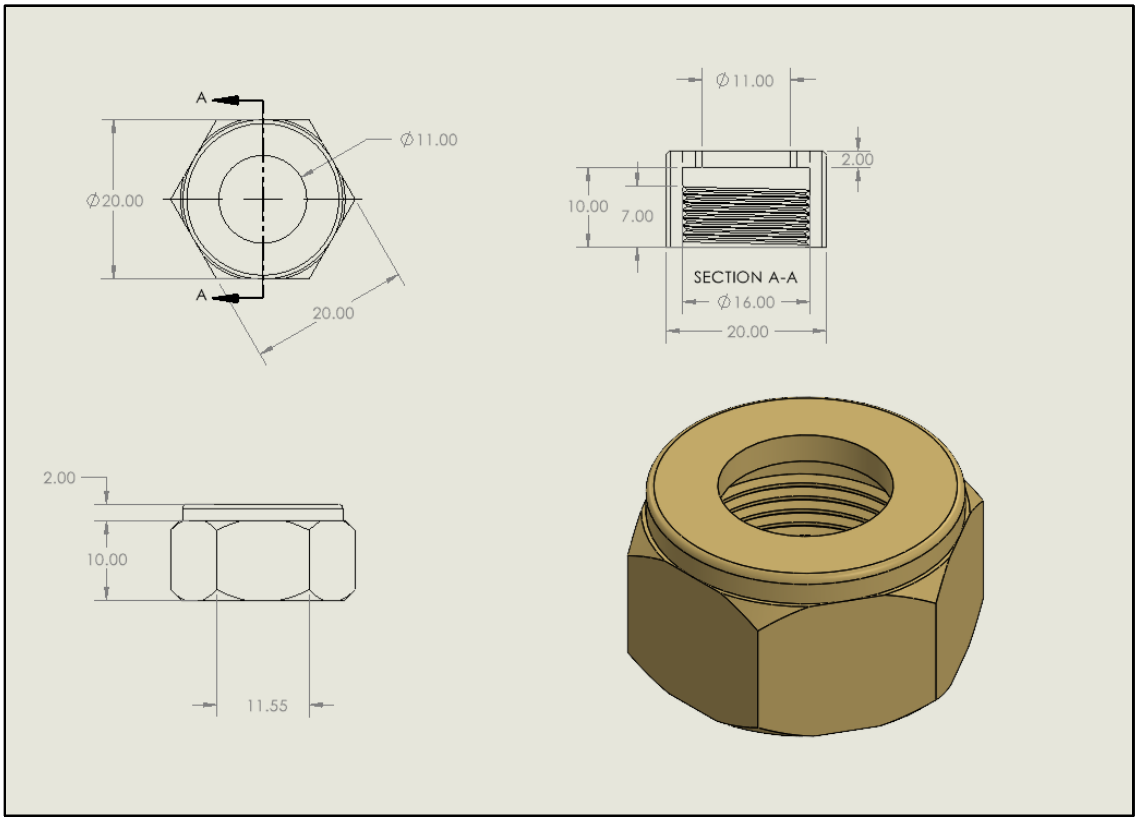

Fig 4.13: Part 8

4.6.9: PART 10- PRESSURE GUAGE

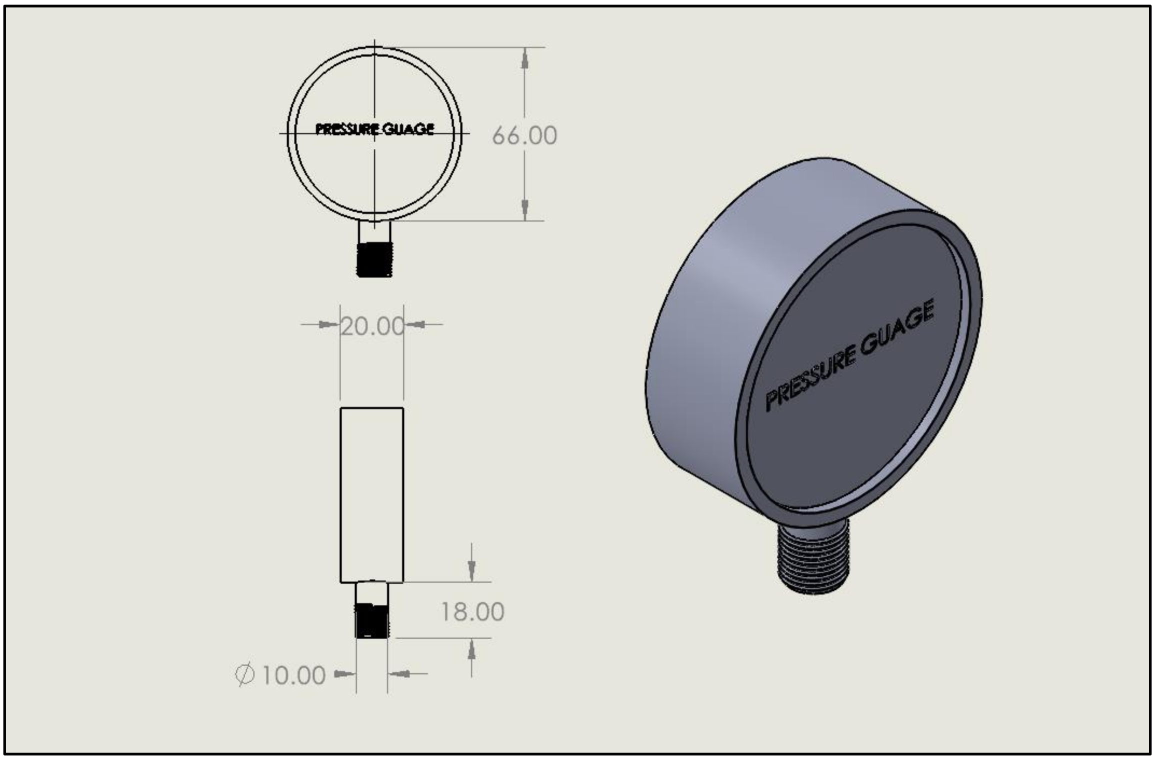

Fig 4.14: Part 10

4.6.10: PART 11- CONTROLLABLE VALVE

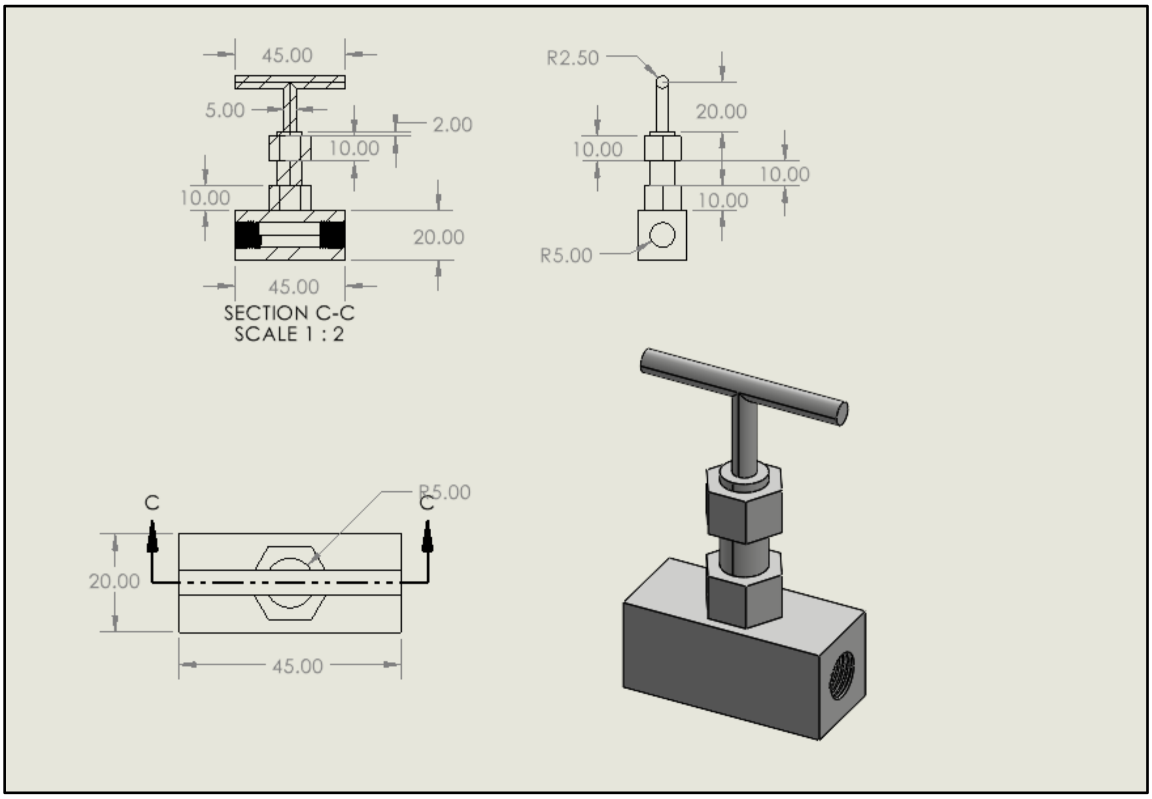

Fig 4.15: Part 11

4.6.11: PART 12- BULL NOSE

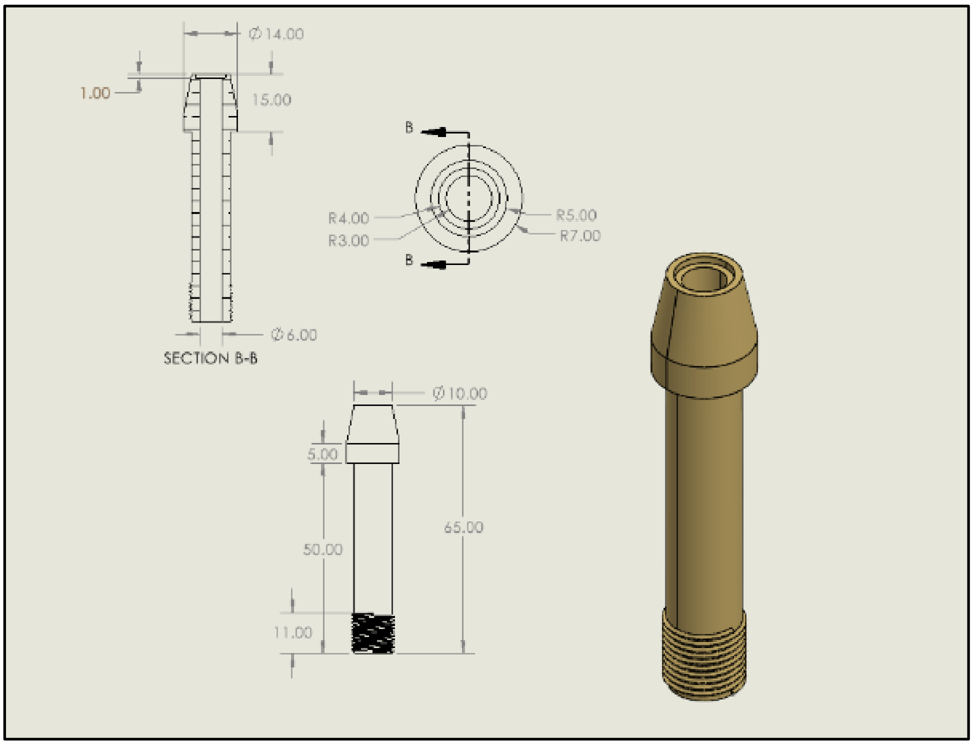

Fig 4.16: Part 12

4.6.12: PART 13- BULL NOSE NUT

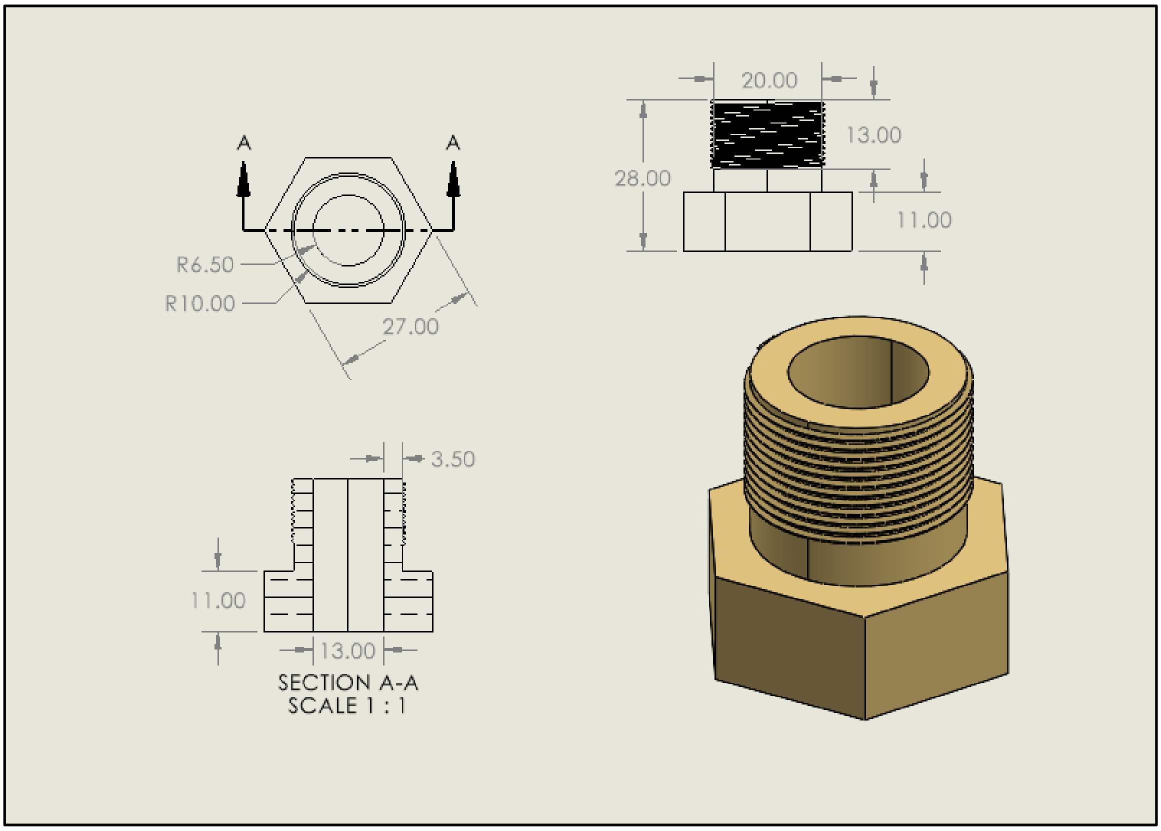

Fig 4.17: Part 13

4.6.13: PART 14- INLET VALVE NUT

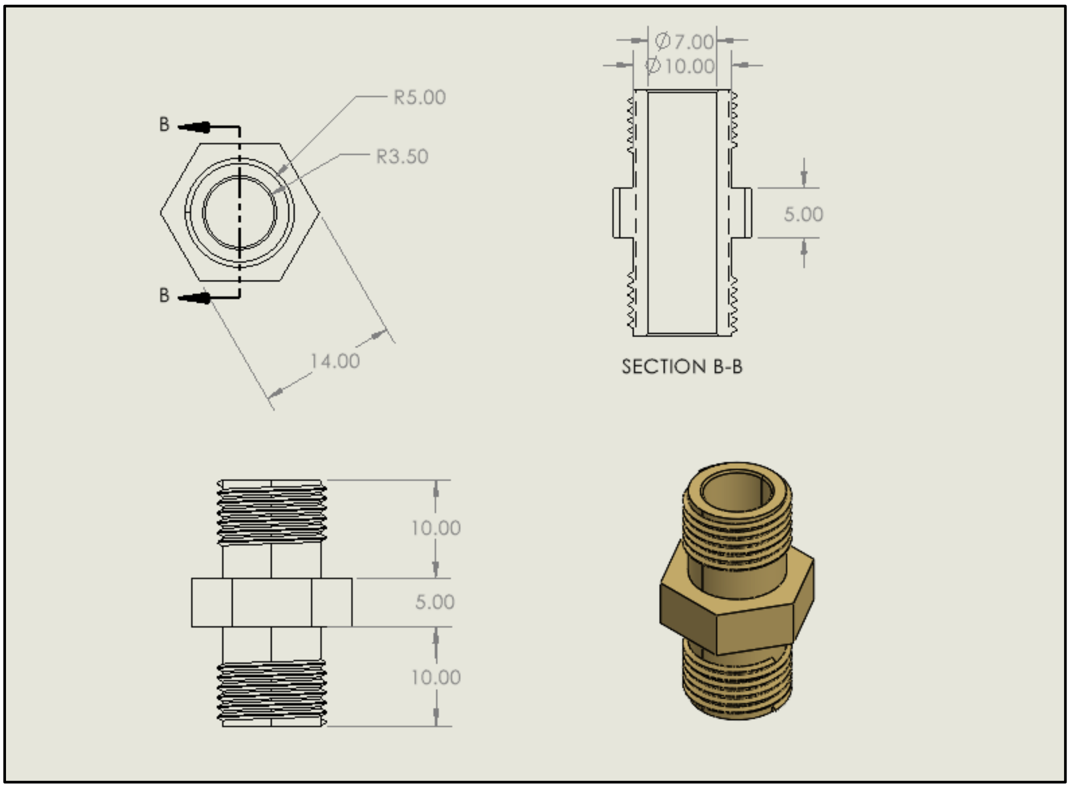

Fig 4.18: Part 14

4.6.14: PART 15- TEE CONNECTOR

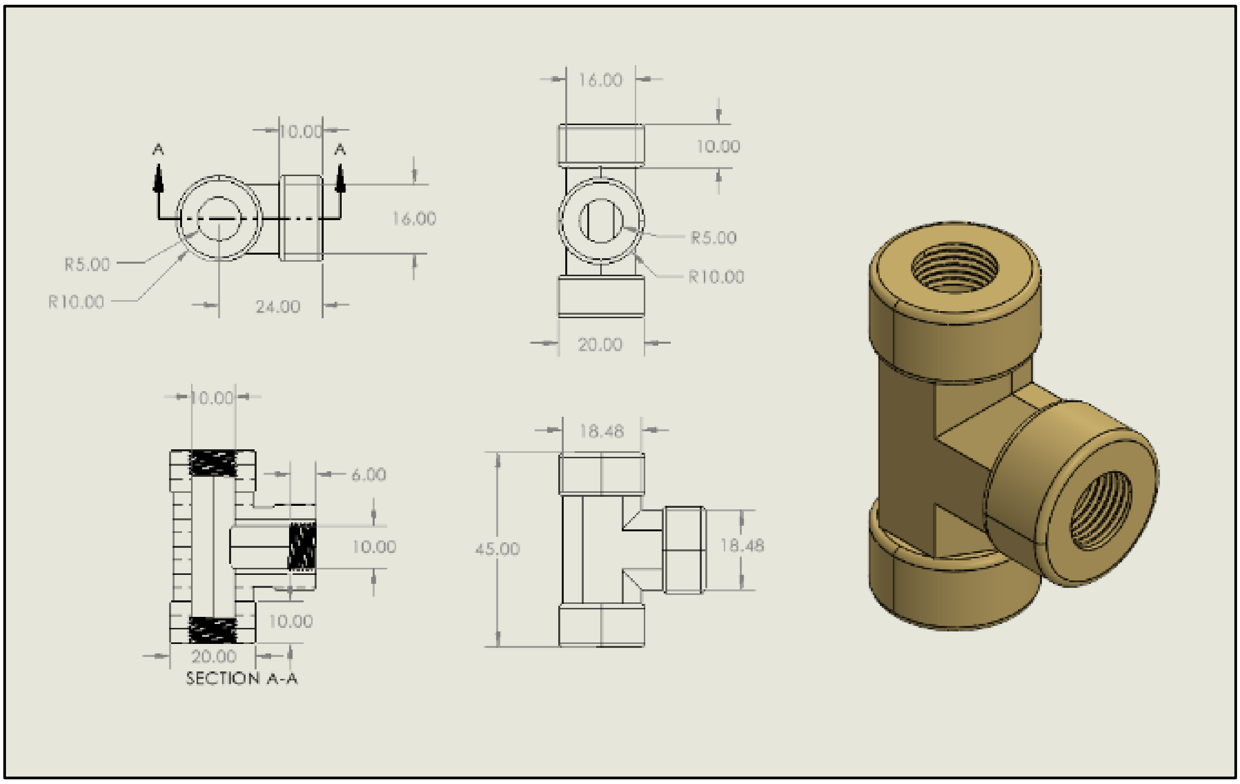

Fig 4.19: Part 15

4.6.16: PART 16- INLET VALVE BONDED WASHER

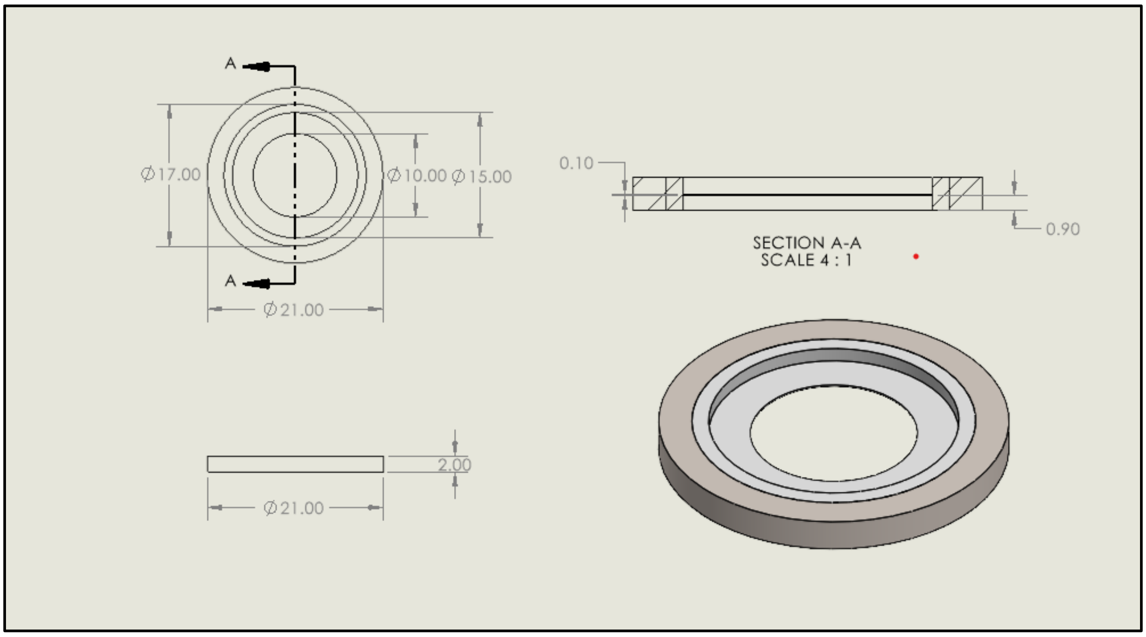

Fig 4.20: Part 16

Chapter 5

FABRICATION OF THE AIR TIGHT CONTAINER

Fabrication is the process of constructing a physical prototype or product based on a specified design.

The material used for parts 1, 2, 3 is stainless steel with a yield strength of 137.9MPa.

The material used for parts 4, 8, 12, 13, 14 and 15 is C280 Brass which has a yield strength of about 124Mpa.

5.1 DEVELOPMENT OF THE AIR TIGHT CONTAINER

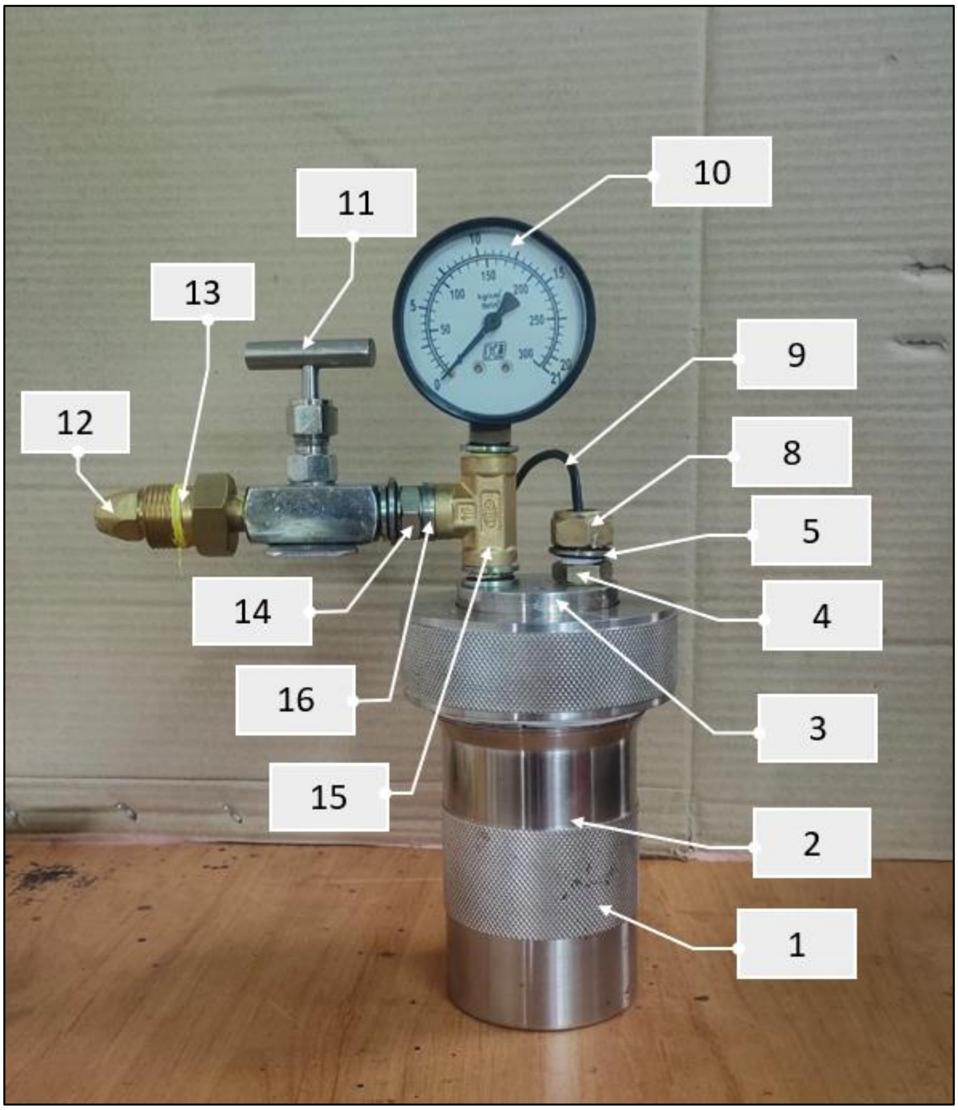

Fig 5.1: Developed air tight container

5.2 FABRICATION PROCESS

1. Procurement of the container.
2. Procurement of pressure gauge, controllable valve, connectors, washers, rubber cork etc.

3. Drilling of 15mm hole on the inner cap.
4. Forming threads inside the 15mm hole by tapping.
5. Assembly of all the components.
6. Testing of the container.

5.4 TESTING

Testing was done at different stages of the development. Fig. 5.2 (a) shows the testing done after the holes were drilled for a pressure of 5-8 bars. Fig. 5.2 (b) shows bubbles coming out from the container due to damage in the inlet valve. So the inlet valve was replaced by a controllable valve connected with a pressure gauge. Fig 5.2 (c) shows bubbles coming out from the sides of rubber due to lack of tightening. The cable was opened at both the ends which resulted in pressure loss. In the final phase of testing, the inlet valve was replaced by a pressure gauge, controllable valve. The wire was sealed at both the ends using heat shrink. A pressure of 12 bar was filled into the container as shown in Fig. 5.2 (d) and no air leak was found in the container when immersed in the water.

Fig 5.2 (a): Testing 1

Fig 5.2 (b): Testing 2

Fig 5.2 (c): Testing 3

Fig 5.2 (d): Testing 4

Chapter 6

THEORETICAL CALCULATIONS

6.1 INTRODUCTION TO THICK AND THIN CYLINDERS

Thick Cylinder: A cylinder where the wall thickness is significant compared to its internal radius, typically more than 1/10th of the internal radius.

Thin Cylinder: A cylinder where the wall thickness is small compared to its internal radius, typically less than 1/10th of the internal radius.

6.2 DETERMINATION IF CONTAINER IS THICK OR THIN CYLINDER

Thickness of the container, t = 6.5mm

Inner radius of the container, R_i = 28.5mm

t/R_i = 6.5/28.5 = 0.228

Hence the container is a thick cylinder. Further calculations will be based on thick cylinders.

6.3 DEFNITIONS

6.3.1 HOOPS STRESS

Hoop stress, also known as circumferential stress, is the stress exerted in the tangential direction on the walls of a cylindrical object due to internal or external pressure. It acts perpendicular to the axis of the cylinder and along the circumference.

For a cylinder under internal pressure, the hoop stress σ can be calculated using the formula:

$$\sigma = \frac{P * Ri}{t} \tag{6.1}$$

6.3.2 LAMES EQUATION

Lame’s equations for a thick-walled cylinder under internal and external pressure are used to calculate the radial and hoop stresses. These equations are derived from the theory of elasticity. For a thick-walled cylinder with internal radius Ri and external radius Ro, subjected to an internal pressure Pi and an external pressure Po, the hoop stress at any radius within the wall are given by:

$$\sigma = \frac{P_i R_i^2}{R_0^2 - R_i^2}\left(\frac{R_i^2 + R_0^2}{R_i^2}\right) \tag{6.2}$$

Chapter 8

CONCLUSION

The primary objective of this project was to design and fabricate an airtight container with a mechanism for a detachable cable and could withstand a pressure of 15-20bar. The 3D CAD modelling of the air tight container was done on SolidWorks software. Multiple design iterations were done for improving the functionality and airtightness of the container. The material used for the main body of the air tight container (parts 1, 2 and 3) is AISI 316 annealed Stainless Steel with a Yield Strength of 137.89MPa. The final assembly of the air tight container contains a total of 16 components.

Calculation of hoop stress acting on the walls of container was done theoretically using Lame’s Equation for different values of the pressure. It was found that for a pressure of 0.2MPa, the stress induced on the walls of the container was 0.98Mpa. The maximum stress that would be applied will be 6.91MPa which is lesser than the yield stress of the container. Hence it was concluded that the design is safe.

Numerical analysis was conducted using ANSYS software to simulate the structural behaviour of the container under various pressure. This analysis provided a detailed understanding of stress distribution at different values of pressure. On application of 0.2MPA of pressure on the walls of container the stress obtained was 0.947. Fig.8.1 shows a graph of variation of stress at different values of pressure.

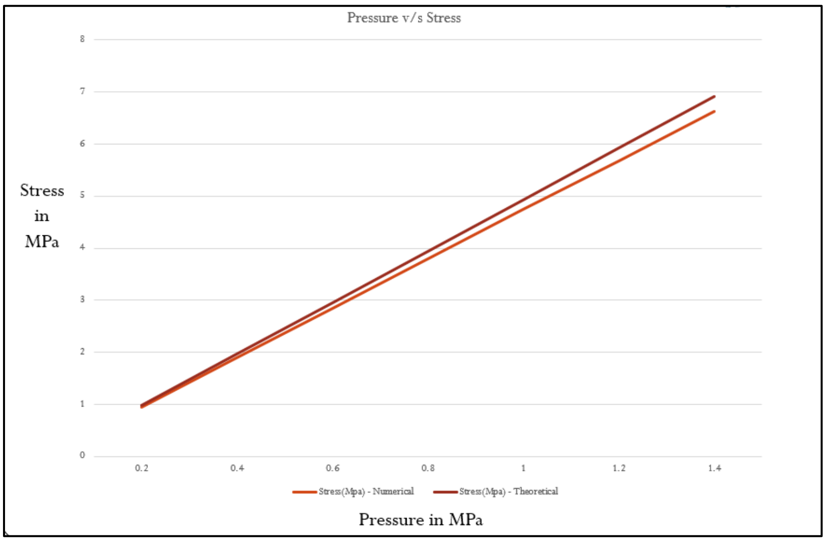

Fig.8.1: Pressure vs stress for theoretical and numerical design

The percentage of error for theoretical and numerical values of stress at 0.2bar pressure is give as,

Percentage of error = $\frac{Theoretical\ value - Numerical\ value}{Theoretical\ Value} * 100\%$

$= \frac{0.987 - 0.947}{0.987} * 100\%$

Percentage of error = 4.052%

Since the percentage of error is less than 15%. The design of the container is valid.

The assembly included integrating a pressure gauge, controllable valve and a detachable sensor cable. Challenges such as ensuring the effective sealing of detachable cable was addressed through a number of rigorous iterative adjustments.

A comprehensive number of leak tests were conducted on the container in which the container was filled with air and was dipped into a bucket filled with water to check if there were bubbles coming out of it were conducted to validate the airtightness of the container. The container was kept was filled with a pressure of 17bar and was kept idle for about an hour. There was no variation in pressure which concluded that the container was completely air tight

The final developed design of the air tight container performed exceptionally well, maintaining airtightness and allowing for the reliable operation of the detachable cable.

In conclusion, the project successfully achieved its objectives of designing and fabricating an airtight container with a detachable cable mechanism and ensuring its structural integrity through rigorous design calculations and numerical analysis using ANSYS. The innovative design feature has resulted in a product that holds significant potential for various applications requiring airtight containment and sensor integration. The insights gained from this project lay a strong foundation for further research and development in the field of airtight containment solutions.