Portable Torque Driver

By

Mohd Hafizal Bin Ramli

Dissertation submitted in partial fulfillment of

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(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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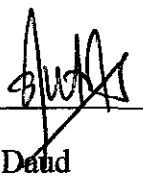

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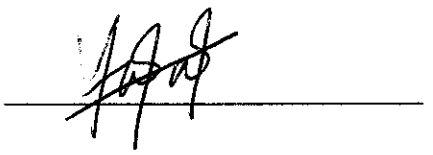
TRONOH, PERAK

December 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



Mohd Hafizal Bin Ramli

ABSTRACT

Portable torque driver or nut remover is a kit for changing a flat tire. It is stored in the case of a small, lightweight and easy to carry anywhere which makes it portable. Torque driver is basically an impact wrench. An impact wrench is a tool used to turn the lug nuts of car's tire in order to lose or tighten them. Among various types of impact wrench, pneumatic type impact wrench is employed here. Pneumatic type impact wrench is using compressed air as a power source to rotate it socket, which is used to fit into lug nut and turn it. In turn, air compressor is used to compress the air into canister. Canister or pressure tank is a small light tank in cylindrical shape used to store the compressed air compress by air compressor before it is used to rotate impact wrench socket. In order to operate air compressor, electrical power source is needed. Here, automobile battery is utilized as an electrical power source to operate air compressor. Portable torque driver help us to change car's flat tire in short time during emergency. Besides that, it does not require a lot of manpower to operate as it is operated pneumatically.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Flat tire is one of the common problems faced by car passengers. A flat tire may cause the passengers to fix it on a dark lonely road or may end up in tragic accidents which cause life. There are 3 major causes that contribute in flat of tires. First is cut on tire tread. In Boston, a lady was involved in a fatal car accident. Based on analysis perform by Harvard chemist, the main factor is the tire when it blow and become flat [1]. Second is incorrect tire pressure. On November 2006, The US National Highway Transport Safety Administration (US NHTSA) has passed a legislation requiring all new cars to be equipped with Tire Pressure Monitors System (TPMS) [2]. However, most of motorists are not aware about the important of correct tire pressure. Over or less pressure on car tires will result in flat of tire itself. Third is flat of car tire can be due to aging. Tire manufacturers have long known that tires more than six years old regardless of tread depth, pose a substantial safety hazard to consumers [3]. Here the focus is on fixing car tire when it blows up or flat.

Changing a flat car's tire is not an easy task either for men or women. It requires skills in order to lose the lug nut and lift the car correctly and safe. Although most of the cars nowadays already equip with car jack and wrench to fix flat car's tires, but those manual tools require a lot of physical effort [4][7]. For those who do not know how or are not capable in fixing a flat tire especially old people and women, it leaves them no choice but to call for help from roadside assistance or mechanics or wait for kind-heart person to stop by and help [5]. However, there are also people who take advantage on this situation. In Florida, a woman changing a flat tire on I-75 was punched and robbed by a man who told her he had stopped to help her [6]. Besides that, calling a roadside assistance or mechanic for just to change a flat tire also cause amount of money.

In order to make sure safety of motorist when changing a flat tire and for better financial plan, people come with a solution to invent a portable electrically operated car jack and wrench. The idea is to have a portable car jack and wrench kit which can be brought anywhere, easy to use and short time taken to change tire. The kit will eliminates the cumbersome use of traditional tire changing equipment and makes changing a flat tire simple for all drivers. Nowadays, there are various types of portable electrically operated car jack and wrench kit available in the market. Each product come with different approach and design like using a pneumatic force to operate car jack and wrench instead of using electrical power directly. However, most of them are still big in size and heavy which make them not so portable.

Basically, this invention relates generally to tire changing devices as mention above, more particularly, to a tire changing kit that simplifies the task of changing a car tire. Besides that, it will improve the kit that already in the market in term of size, weight, design and it approach to perform tire changing.

1.2 Problem statements

A conventional way of fixing a blows or flat tire is using a lug nut wrench and scissor car jack. However, as stated above, this manual tool require the user to have a lot amount of energy in order to lose and tighten the nuts and lift the car. This will cause a problem to women and old folk which mostly incapable when it comes to physical effort. Even worst, there are many car passengers who do not know to use wrench and car jack correctly [5].

Besides that, the portable torque drivers that available in the market nowadays are also in bulky size which requires a lot of space to store them and this make them become not so portable. Beside their bulky size, they are also heavy which result in difficulty to operating them. Most of them have weight around 12 kg to 20 kg.

Present invention in the market is also difficult to maintain. This is because the design is complicated. Some of them also have unnecessary extra features and some of them have no extra features. The availability of the product is also covering certain places only. Most of them are available in United State of America market and China market. There is no portable torque driver that available in Malaysia

market yet, as far as my research. The available Portable torque drivers that available in United State of America and China are also expensive in term of price.

1.3 Objectives

The main objective of this invention is to invent a portable torque driver that can help especially women and old folk car passenger to fix blows or flat tire so that they do not have to use too much physical effort. The portable torque driver kit will have a small size. For a pressure type portable torque driver, a canister size is the main focus here. Canister is very important equipment as it is used to restore the compressed pressure before it is used to operate the wrench. In turn, by resizing it into smaller size, the weight will also decrease. This certainly meets the basic idea of inventing a portable torque driver kit which is easy to carry anywhere. Other objectives:

- To improve the performance of the system in term of time taken to fully restore compressed pressure in the canister
- To add several additional feature which result in increasing the effectiveness of changing a tire using portable torque driver kit
- To improve design of the portable torque driver kit in term of in commercial value

1.4 Scope of study

In order to achieve above objectives, there are several researches and study that need to be done. Firstly is the study about torque itself. By understanding the torque theory, it helps in calculating the right amount of force requires losing and tightening lug nut. Secondly, research on the patent of kit present in the market because each different patent has their individually unique feature. The main focus here is on United State of America market and China market. By knowing the available design in market, it helps in improving the system design in order to benefit user and avoid plagiarism.

Secondly, research on design material of the canister body. The material is very crucial in order to make sure that it can withstand the stress produce by compress air.

Next is designing part. Designing process involve certain calculation on stress and size of the canister. In addition, it also involves designing a system to measure and control the amount of pressure compress in canister and time taken. Well-design canister will be sent to factory for fabrication and tested.

CHAPTER 2

LITERATURE REVIEW

2.1 Available Products in the market

Portable torque driver can be classified into three main categories which are electrical motor, pneumatic and hydraulic. Each of these categories is classified based on their approach in driving the impact wrench. For example, for electrical motor driven impact wrench, its' socket is directly connected to motor. When the motor is rotating clockwise, then the socket will rotate clockwise and vice versa. It goes the same as pneumatic and hydraulic driven impact wrench. The socket is connected to a canister for pneumatic driven and a hydraulic tank for hydraulic driven impact wrench. Each approach has their pros and cons.

Nowadays, there are varieties of portable torque drivers in the market. However, most of them are not very portable. There heavy and bulky sizes make them hard to bring to anywhere. Besides that, some of them have too many extra feature which make the system design and product itself become complex. In addition, there is also a product that has no extra feature at all. Here we will review into three different types of portable torque driver in order to improve them.

2.1.1 Electrically powered automobile Jack and Nut Remover

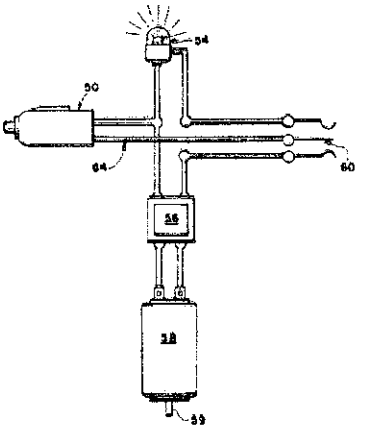

Figure 1: Schematic representation of a jack electrical circuit used in typical embodiment

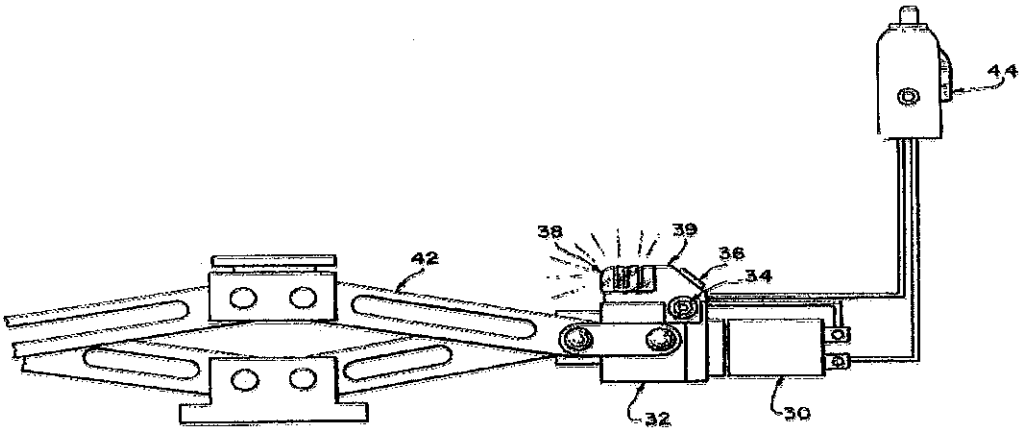

Figure 2 : Cross-sectional schematic representation of a first embodiment of a self contain electric jack system

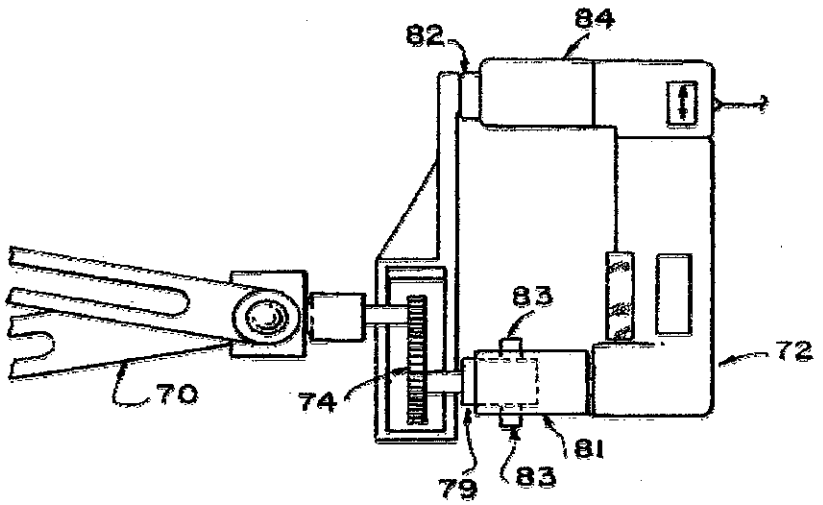

Figure 3 : Schematic representation of the nut remover variation

An electrical circuit for the nut remover is shown in **FIGURE 1**. The nut remover can be plugged into a twelve volt auto lighter socket using a plug **50**. If nut remover system is to be powered through the jack socket **34, FIGURE 2**, the a smaller twelve volt accessory plug **52** can be modified to fit into a standard twelve volt auto lighter socket using a sleeve adapter (not shown) which fits there over. The nut remover can also include the lighting means **54** to help make it easier for the user to see what he or she is doing. A reversing switch **56** can be set to remove a tire nut or to put a tire nut back on. The nut remover is driven by motor **58** acting on driven axle **59** and controlled by a power switch **60** having three settings: power off/light off; power off/light on; and power on/light on [8].

In use, the active socket **81, FIGURE 3,** of the nut remover is placed over the nut to be loosened, while the inactive or non rotating socket **84** is placed over an opposite nut. The switch **60** is activated causing rotation of the socket **81**. Torque normally generated opposite the direction of rotation of the socket **81** is transferred through the handle **62** and opposite leg to the non-rotating socket **84** anchored on an opposite nut. Nut removal and nut tightening is thus facilitated, the generated torque being absorbed by the auto rather than operator [8].

In addition, the invention has numerous of extra features. First is electrically operated car jack. Instead of lifting car using manual car jack, the invention provide user with motorized jack which using a twelve volt auto lighter socket as source of power. In the body of car jack there is an extra lighter socket and lamp. Secondly is mercury switch. If the mercury switch determines the car to be at a precarious angle, it will not permit current to flow to the motor, thereby automatically preventing the lifting of the car. Third is extra lamp which plug into extra lighter socket on jack body.

2.1.2 Tire Changing Kit

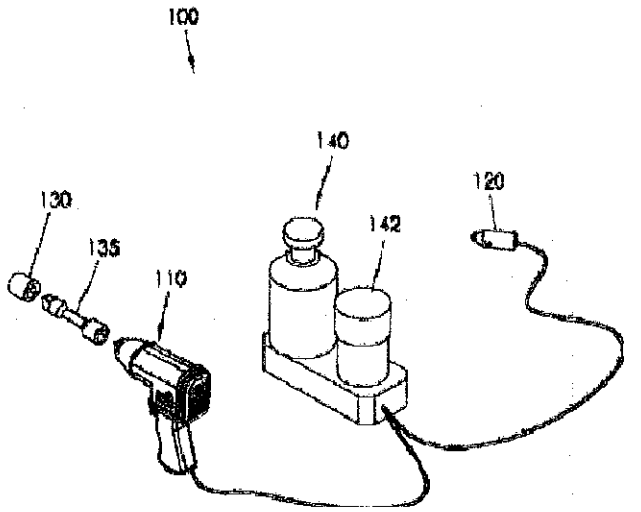

Figure 4 : Perspective view of a tire changing kit according to preferred embodiment

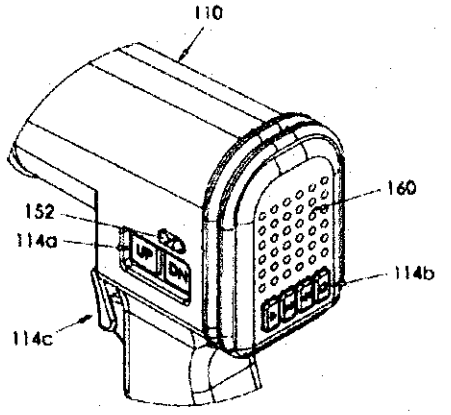

Figure 5: Perspective view of impact wrench back part

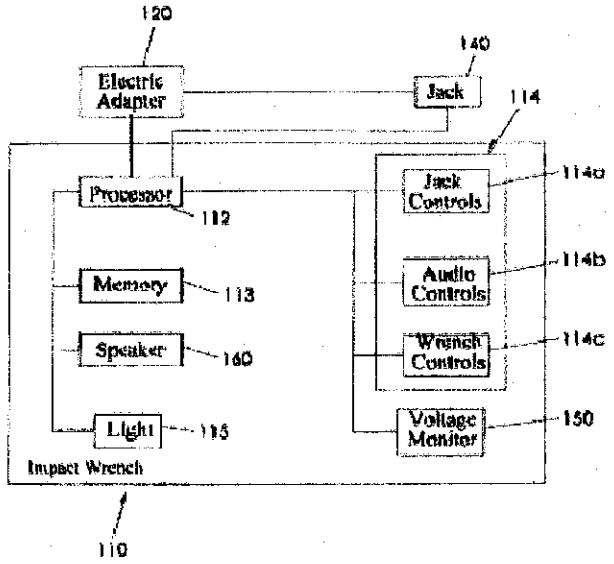

Figure 6: Block diagram of components of the tire changing kit

As shown in **FIGURE 6**, the impact wrench **110** includes a processor **112**, an electrical memory device **113** in data communication with the processor **112**, a user input device **114** in data communication with the processor **112**, and various programming. The user input device **114** include a plurality of input elements, for example input element 114a and **114b**, for providing various instructions to the processor **112** (**FIGURE 5**) [9].

As shown in **FIGURE 4**, an electrical plug **120** is configured for electrical communication with an automobile battery through an automobile outlet, e.g. a cigarette lighter, and the electrical plug **120** is in electrical communication with the impact wrench **110** for powering the impact wrench **110**. At least one socket **130** is configured to be rotated by the impact wrench **110** for turning a lug nut, and a torque

stick **135** may be included between the socket **130** and the impact wrench **110** to limit an amount of torque applied by the impact wrench **110** on the socket **130**. The torque stick **135** is a socket extension that begins to twist and absorb the energy from the impact wrench **110** once the torque stick **135** reaches a predetermined torque setting [9].

On top, the invention also has an extra feature. First is pneumatic operated car jack. Second is a lighting device. It is being coupled to the impact wrench in a position that applies light at a forward end of the impact wrench when the lighting device activated. It is understood that the position of the lighting device enables the light to be directed by the user as needed or desired without having to pause the process of changing a tire in order to reposition an auxiliary light. Third is an audio speaker. It is placed at the back of impact wrench which gives instruction to the user steps on changing a tire. Thus, users do not have to read the manual before begin. Fourth, the invention introduces an electronic system in controlling impact wrench operation. This is done by using a processor and memory. Fifth is voltage monitor. Voltage monitor helps user to alert on voltage level of car battery, if the voltage level is low, then battery need to recharge first.

2.1.3 Emergency Kit having an Air Compressor in Combination with an Impact Wrench and a Tire Jack for Changing a Tire

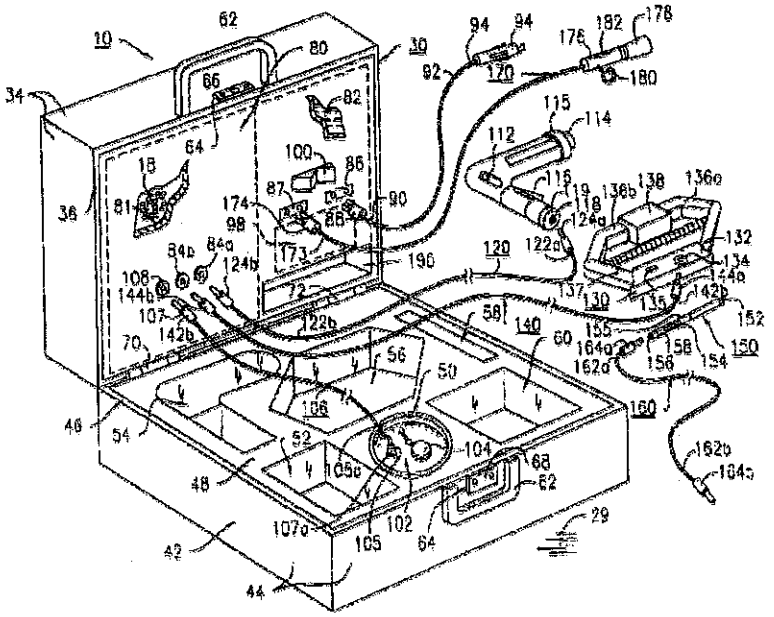

Figure 7 : An exploded front perspective view of the tire changing kit of the present invention

The pneumatic impact wrench **110**, as depicted in **FIGURE 7**, includes a control switch **112** for clockwise and counterclockwise rotation of a detachable lug remover member **114** located at the distal end tip **115** of the impact wrench **110**. The detachable lug remover member **114** may vary in size and configuration depending on the lug nut used with a particular wheel rim of vehicle. The impact wrench **110** also includes an activation trigger **116** connected to a handle member **117**. The handle member**117** includes a quick connect receptacle inlet **118** located at the proximal end **119** of the impact wrench **110**, as depicted in **FIGURE 7**. The impact wrench **110** further includes an impact wrench pneumatic hosing **120**. The impact wrench pneumatic hosing **120** at each of its ends **122a** and **122b** includes a quick release connector member **124a** and **124b**. Quick release connector member **124a** connects to the quick connect opening **84a** on the air holding tank **81** of air compressor assembly **80** and quick release connector member **124b** connects to the quick connector receptacle inlet **118** on the handle member **117** of impact **110**. When the impact wrench **110** is in operational use the activation trigger **116** on handle member **117** allows user to activate the lug remover member **114** on the end tip **115** for rotational movement in order to remove or re-tighten the lug nut [10].

The air compressor assembly is lightweight having an air inflation capacity of 1.0 cubic feet per minute with pressure rating between 100 psig to 250 psig. The air compressor can be powered using cigarette lighter inlet plug. The invention also provide user with car jack. The car jack is motor operated, but user can also use impact wrench to move it between raised or lowered configurations. Besides that, there is also an external lamp. All the features in the invention are placed in a brief case.

2.2 New invention: Portable Torque Driver

In this new invention, pneumatic system is used to control impact wrench. For a pneumatic driven nut remover, there are three main components which are impact wrench itself, compressor and canister or pressure tank. The purpose of new invention is to invent a portable torque driver which is light in weight, easy to bring to anywhere, small in size and user friendly. In order to achieve the goal, all the main components stated above need to be in smaller size and in light weight. Due to that, the approach used is to find a light material which can resist high pressure as a

material used to build canister. The impact wrench and compressor are in standard size and weight which already available in the market.

The main focus here is to design an automobile's nut remover itself. Due to that, some unnecessary features are eliminated. For example, car jack is not included as an extra feature considering most of car nowadays already equipped with car jack. Instead of car jack, new invention is equipped with just a socket which fit on car jack. Here force transfer input mechanically coupled to the jack and a force transfer bit complementary to the force transfer input that is configured to be rotated by the impact wrench. In other words, the impact wrench is operatively connected directly to the jack, especially in the case of a scissor jack, to actuate it between raised and lowered configurations. The space require to allocate car jack is replaced by only allocating sockets which decrease invention space and weight. Besides that, there are other crucial extra features that are put into consideration to be included in this new invention which are pump and lamp. However, this product is still in designing stage. Due to that, the whole focus is directed to design the nut remover first.

2.2.1 Comparison between available invention and new invention

There are three relevant inventions that available in the market nowadays. The comparisons between these three inventions are as shown below in Table 1.

Notes:

A: Electrically Powered Automobile Jack and Nut Remover

B: Tire Changing Kit

C: Emergency Kit having an Air Compressor in Combination with an Impact Wrench and a Tire Jack for Changing a Tire

D: Portable Torque Driver

Y: Yes

N: No

Table 1: Comparison between available invention and new invention

Characteristics	A	B	C	D
Type	Electrical motor driven	Electrical motor driven	Pneumatic driven	Pneumatic driven
Source of power	12 Volt car's battery	12 Volt car's battery	12 Volt car's battery	12 Volt car's battery
Nut remover	Impact wrench	Impact wrench	Impact wrench	Impact wrench
Canister	N	N	Y	Y
Air Compressor	N	N	Y	Y
Case	N	N	Y	Y
Size	Big	Big	Big	Small
Weight	Heavy	Heavy	Heavy	Light
Extra Features	Motorized Car jack ; Mercury switch ; Jack's lamp ; Extra lamp ; Extra plug	Pneumatic car jack ; Audio instruction ; Lamp ; Voltage monitor ; Processor system	Motorized car jack ; Lamp ; Pump	Socket (jack) ; Lamp ; Pump
Availability	United States	United States	United States	Malaysia

Here is a comparison table, **TABLE 1**, which compare main features and extra features of available invention available in the market and new invention. From Table 1, main objective of new invention is accomplished which is to invent a light and small portable torque driver.

2.3 System Design Concept

Beside the three main parts on pneumatic driven nut remover, this invention also consists of system design. In other words, in order to have a right amount of pressure compressed in canister, there must be a system that can measure it. Here a pressure gauge is used to measure the pressure and a timer is used to make sure that right amount of pressure is achieved.

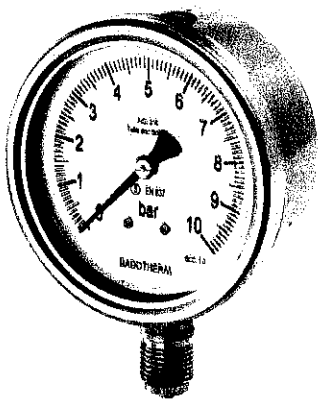

Figure 8 : Pressure Gauge

Before a timer is set, numbers of experiments are done to find an average time to accomplish desired pressure. There is also some also a need to design a circuit that fit the voltage and current rating of the timer.

2.3.1 Timer

Monostable timer is used in the system. Monostable timer means that once the circuit is switched on it will time once and then stop. In order to start it again it must be switched on manually a second time. Here the timer is set to create delay, for example 540 seconds. When the switch is pushed, compressor will start to run until 540 seconds and it will stop. The switch must be pressed again for the compressor to run again. The circuit diagram of monostable timer is as shown in Figure 25.

When a negative (0V) pulse is applied to the trigger input (pin 2) of the Monostable configured 555 Timer oscillator, the internal comparator, (comparator No1) detects this input and "sets" the state of the flip-flop, changing the output from a "LOW" state to a "HIGH" state. This action inturn turns "OFF" the discharge transistor connected to pin 7, thereby removing the short circuit across the external timing capacitor, C1. This allows the timing capacitor to start to charge up through resistor, R1 until the voltage across the capacitor reaches the threshold (pin 6) voltage of 2/3Vcc set up by the internal voltage divider network. At this point the comparators output goes "HIGH" and "resets" the flip-flop back to its original state which inturn turns "ON" the transistor and discharges the capacitor to ground through pin 7. This action also causes the output to change its state back to the original stable "LOW" value awaiting another trigger pulse to start the timing process over again. Then as before, the Monostable Multivibrator has only ONE stable state.

The **Monostable 555 Timer** circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the $R_1.C_1$ network has elapsed.

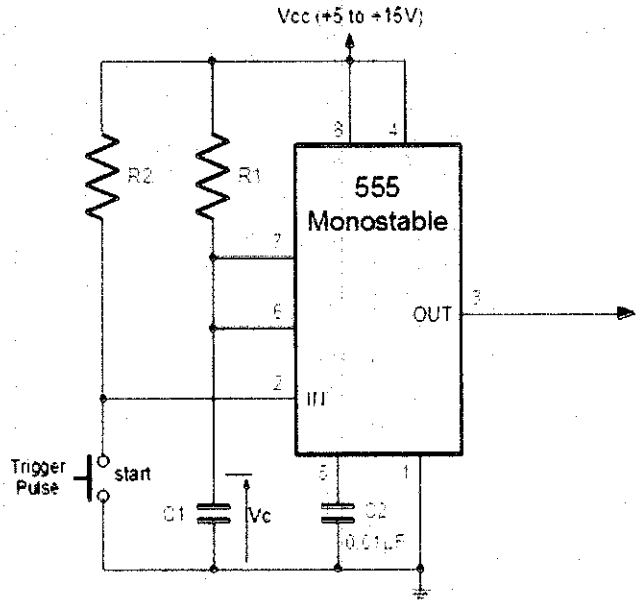

Figure 9: Circuit Diagram of Monostable Timer

2.3.2 Relay

Relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts as shown in the diagram. Relays allow one circuit to switch a second circuit which can be completely separate from the first.

Referring to Figure 24, the first circuit is monostable timer and second one is power supply (car battery). Current for car battery is too high which is 10 A. This will damage the monostable timer. Due to that we separate both circuit using relay. Besides that, BJT is used to to make sure that the relay change when it get significantly amount of current and diode is used to make sure that there is no overflow current from car battery to monostable timer circuit. The circuit diagram is as shown in Figure 26.

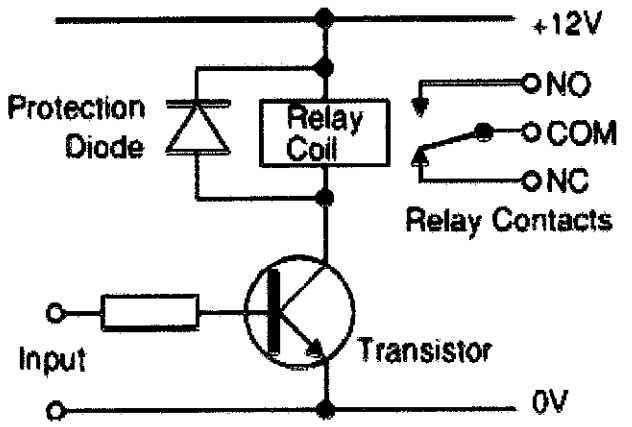

Figure 10: Relay circuit diagram

2.4 Material Selection

In any pressure vessel subjected to internal or external pressure, stresses are set up in the shell wall. The state of stress is trivial and the three principal stresses are longitudinal, circumferential and radial [12].

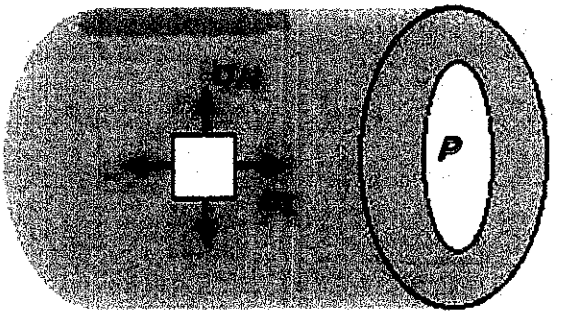

Figure 11: Direction view of stress with respect to cylindrical body

Longitudinal stress, σ_L , is stress acted on x axis of the wall and circumferential stress;σ_H, is acted on y axis of the wall as shown in **FIGURE 9**. Radial stress is often ignored.

Longitudinal stress is a stress that counteract with internal pressure inside the vessel in parallel with cylinder surface. This counteract stress is actually used to create an equilibrium forces in horizontal direction with respect to internal pressure.

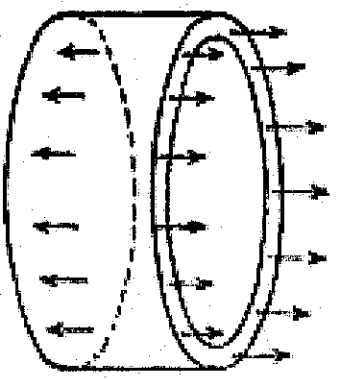

Figure 12: Longitudinal stress's act direction with respect to cylindrical

Hoop stress is a stress that counteract with internal pressure inside the vessel in serial with cylinder surface. This counteract stress is actually used to create an equilibrium forces in vertical direction with respect to internal pressure.

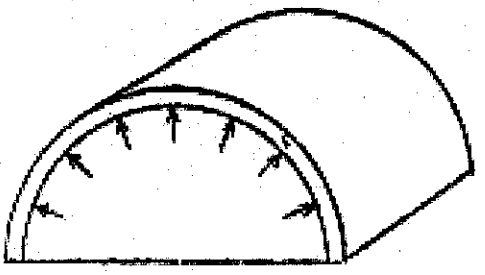

Figure 13: Hoop stress's act direction with respect to cylindrical

Besides that, another theory which is important in designing a pressure vessel is Thin-Walled Pressure Vessel Law. The main concern in this law is ratio between radius of the vessel and it thickness. Based on Thin-Walled Pressure Vessel Law, the ration between radius and thickness for pressure vessel must be greater or equal to 10. In other word, the radius value must be at least ten times greater that thickness value. For example, if the radius is set to be 10 cm, then the thickness of the vessel must be at least 1 cm.

Here, Pugh selection chart is used to select the best material that should be used for body of canister. The purpose of any method of evaluation is to allow design principles to emerge visibly in a context and to be articulated. The method is also known as controlled convergence [11]. The final material is not yet to be decided, but the criteria of material are already identified. It is shown in **TABLE 2.** Besides using Pugh selection chart, stress acted on canister body with respect to desired pressure is also taking into consideration in choosing material. This is actually to check and balance material selected using Pugh selection chart. In other word, it is to avoid over specification of material that chosen.

Table 2: Pugh's Material selection chart

Characteristics	Stain less Steel	Material A	Material B
Manufacturing			
High pressure	D		
Weight	A		
Corrosion	T		
Material Cost	U		
Safety	M		

CHAPTER 3

METHODOLOGY

3.1 Research methodology

Research methodology that has been used on this new invention is in **FIGURE 12.**

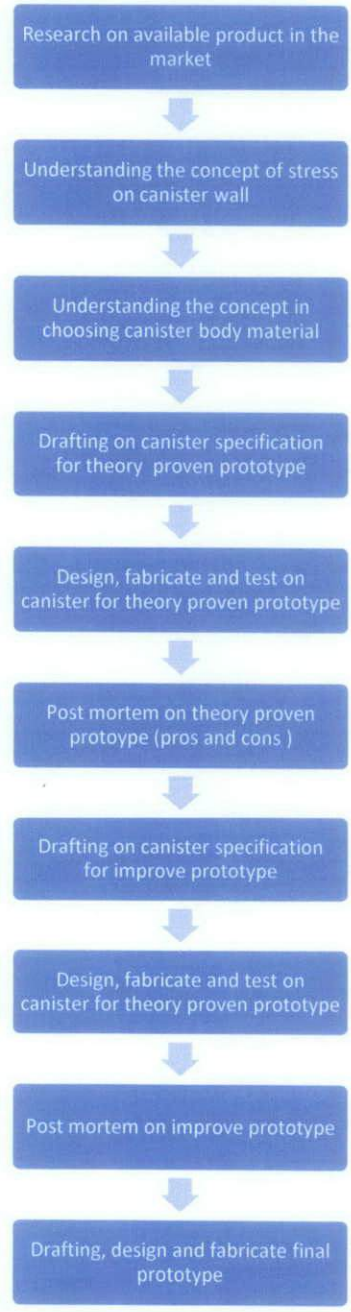

Figure 14: Flow chart of research methodology

3.2 Project activities

Project activities in this invention project are as shown in **TABLE 3.**

Table 3: Description of project activities

Activities	Details
Research on available product in the market	There are two type of product that available in the market nowadays. One is product that has been patent but does not manufacturer and other one is manufactured. There is only one patent that has been manufactured which is simple electrical driven impact wrench.
Understanding the concept of stress on canister wall	For pneumatic driven impact wrench, canister is a crucial part. In order to design a suitable canister for new invention, stress on canister wall should be calculated first. This to avoid designed canister explode during test session.
Understanding the concept in choosing canister body material	Canister design also requires knowledge on material properties. Each material has their unique properties. Each have different agility, yield strength, corrosion resistance and etc.
Drafting on canister specification	After stress acted on canister wall based on desired pressure is calculated, best material that can meet stress specification is chosen. Best material is very important in order to avoid off specification or over specification. Besides focusing on material selection and shape, operating time is also put into consideration. Operating time is very important because it reflex on how long user can used the portable torque driver. The longer portable torque driver can operate, then more and more application can be added on portable torque driver. Application of portable torque driver is based on it criteria.

Design the canister	Based on specification collected, designing a canister is started. Canister is designed in several patents and compared which one is better.
Fabrication of prototype and test	Canister designed is sent to manufacturer in order to fabricate and product performance is tested.
Theory proven prototype	The idea of using portable torque driver, drive by pneumatic air, to lose tire nut had been pattern. Unfortunately the concept has not been put into manufacturing which poses many questions. Due to that, theory proven prototype is design and fabricate in order to verify that this concept can be used in losing tire nuts and commercialize. Besides lose the tire nuts, portable torque driver is also design to perform other application such as lift car jack and clean dust and dirt using air nozzle. It also has long operating time.
Improve prototype	Theory proven prototype proves that portable torque driver, pneumatic driven, can be used to lose tire nuts. However the prototype is not so portable and need to be improved. Improvement is done mainly on canister size. However, the improvement affect on operating time and its application.
Final prototype	Improve prototype managed to reduce canister size and weight. However, there is problem on canister body design as it cannot sustain pressure for a long time and tend to crack. Final prototype is designed to overcome that problem and improve on prototype operation concept. Improvement is done mainly on canister size. However, the improvement affect on operating time and its application. Operating of portable torque driver becomes about 1/10 from theory proven prototype.

Design a project concept	Designing process is extending to system design. Here, designed canister is combining with impact wrench and compressor. Other part of the system that needs to be design is on measuring right amount of pressure into canister.

3.3 Design the canister

In designing the canister, we need to consider five main criteria which are the shape of canister, diameter, length, thickness and internal operating pressure inside canister. Based on these five criteria then we can calculate the stress acted on canister's body, yield strength and type of material that can be chosen in fabricating the canister.

3.3.1 Shape of canister

Canister can be design in several shapes. Common shapes of pressure vessel that available in the market are cylindrical, sphere and cubic. Here cylindrical type of pressure vessel is chosen. This is to make sure that the stress acted on canister's wall is distributed well and to ensure that canister is easy to handle, since it has two flat surfaces.

3.3.2 Diameter and length

Diameter and length is usually decided based on requirement, as small as possible and pneumatic gun can operate at least 30 seconds. Since the fabrication is done using a readymade pipe available in the market, thus diameter of canister is bounded to the size available in the market. However, the range is between 150 mm to 200 mm. Based on diameter ad length, the volume of the canister can be calculated using the following formula:

$$V = \pi r^2 h \quad (1)$$

Where;
r = radius
h = height

The formula to calculate volume in liter is as below:

$$V = V_{in\,mm} \times 1000 \tag{2}$$

3.3.3 Internal pressure

Internal operating pressure inside canister must be higher than seven bar. This is because, seven bar is requires in order to open tire lug nuts. However, it is hard to pressurize the canister with high internal pressure due to limit in compressor used. Here ten bars is set as internal pressure to make sure that pneumatic gun can operate at least 30 seconds.

3.3.4 Thickness

There are two approaches to specify the canister's thickness, first is using a formula and second based on available thickness in market. The first one is more accurate and efficient but it requires the value of stress acted on the canister's body. Due to that, thickness is chosen based on available thickness in market. The formula is used to check and balance whether thickness available can shed with internal pressure. The formula used is as follow:

$$\sigma_L = \frac{Pr}{2SE + 0.4P} \tag{3}$$

Where;
P = Internal pressure
r = radius
S = allowable stress
E = joint efficiency

3.3.5 Stress acted on canister's body

As mention in Chapter 2, there are two type of stress acted on canister's wall, longitudinal and hoop stress. The longitudinal stress formula is as shown below:

$$\sigma_L = \frac{Pr}{2t} \tag{4}$$

Where;
P = Internal pressure
r = radius
t = thickness

The formula to calculate hoop stress is as shown below:

$$\sigma_H = \frac{Pr}{t} \tag{5}$$

Where;
P = Internal pressure
r = radius

3.3.6 Yield strength

A number of terms have been defined for the purpose of identifying the stress at which plastic deformation begin. The value most commonly used for this purpose is the yield strength. The yield strength is defined as the stress at which a predetermined amount of permanent deformation occurs. The graphical portion of the early stages of a tension test is used to evaluate yield strength. To find yield strength, the predetermined amount of permanent strain is set along the strain axis of the graph, to the right of the origin (zero). It is indicated in Figure 15 as Point (D).

A straight line is drawn through Point (D) at the same slope as the initial portion of the stress-strain curve. The point of intersection of the new line and the stress strain curve is projected to the stress axis. The stress value, in pound per square inch, is the yield strength. It is indicated in Figure 15 as Point 3. This method of plotting is done for the purpose of subtracting the elastics strain from the total strain, leaving the predetermined "permanent offset" as a remainder. When yield strength is reported, the amount of offset used in the determination should be stated.

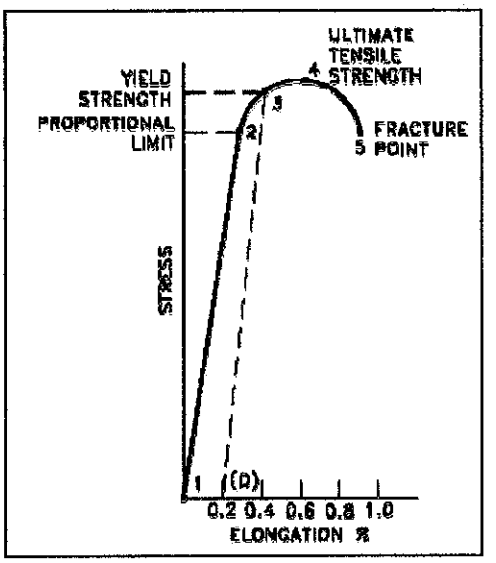

Figure 15: Typical Brittle Material Stress-Strain Curve

Here, in this project, yield strength value is calculated in order to find compatible material that can stand the stress on cylinder wall due to internal pressure. Yield strength calculation is as shown below:

Yield strength calculation, YS:

$$\text{YS} = \text{Safety Factor} \times \text{Maximum Allowable stress} \quad (6)$$

3.4 System Design

Here the focus will be on timer. In order to make sure that the timer stop at desired time, the value of R1 and C1, refer to Figure 25, must be correct. However, value of R1 is usually constant. Formula to calculate value of C1 with respect to desired time is as shown below:

$$t = 1.1\, R_1\, C_1 \quad (7)$$

Where;
t = desired time
R1 = resistor 1
C1 = capacitor 1

3.5 Relationship between volume of air in canister with operating time

The intension here is to make sure that the canister is designed with small size and can operate around 30 seconds. Reducing the size of canister would also reduce volume. With small volume, the operating time will be short. However, here the canister's volume is fixed. Due to that, the only variable left is mass of air in canister. The relationship between mass and volume is as shown below:

$$m = \frac{PV}{RT} \quad (8)$$

Where;
m = mass
P = internal pressure
V = volume of canister
T = temperature
R = universal gas constant

The weight of air can be calculated using following formula:

$$w = m \times 9.81 \quad (9)$$

Where;
m = mass
w = Weight

3.5.1 Weight flow rate

The changing of air's mass inside the canister from time to time can be calculated using weight flow rate. The formula for weight flow rate is as shown below:

$$W = A\sqrt{\left(\frac{2gk}{k-1}\right)(p_1\gamma_1)\left[\left(\frac{p_2}{p_1}\right)^{2/k} - \left(\frac{p_2}{p_1}\right)^{(k+1)/k}\right]} \quad (10)$$

Where;
W = Weight flow rate
A = nozzle's area
g = gravitational force
k = adiabatic exponent
γ = constant
p_1 = Pressure inside canister
p_2 = Pressure at nozzle

3.5.2 Operated time

Operated time is the duration for pneumatic gun to operate properly before it loses power to open tire's lug nut. In other word, operated time is the time for the weight of air in the canister reduces from eight bars to six bars. Operated time can be calculated using formula below:

$$T_n = w_{n-1} - W \quad (11)$$

Where;
W = Weight flow rate
w = weight of air
T = operated time

Operating time has directly affected on the application of portable torque driver. The longer the operating time, then more and more application can be done. In other word, increase of operating time will also increase portable torque driver applications. By reducing operating time, the extra features of portable torque driver

will also reduce. Example of portable torque driver extra features are socket to lift scissor car jack and clean dust and dirt using air nozzle.

3.5 Key milestone

Key milestone for Final Year Project 1 (FYP 1) is as shown in **FIGURE 16** is referred to Gantt chart in Appendices.

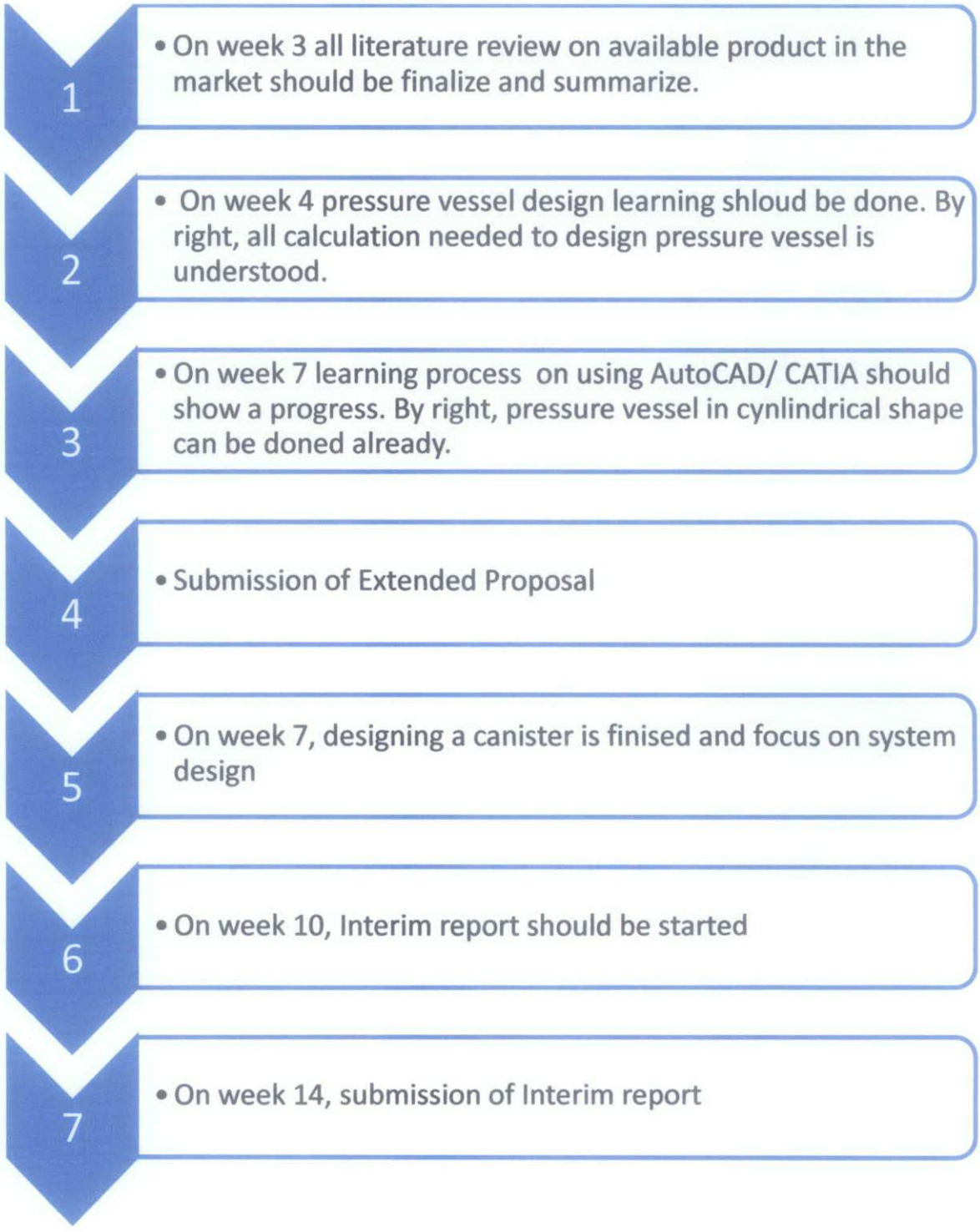

Figure 16: Key milestone for FYP 1

Key milestone for Final Year Project 2 (FYP 2) is as shown in **FIGURE 17** is referred to Gantt chart in Appendices.

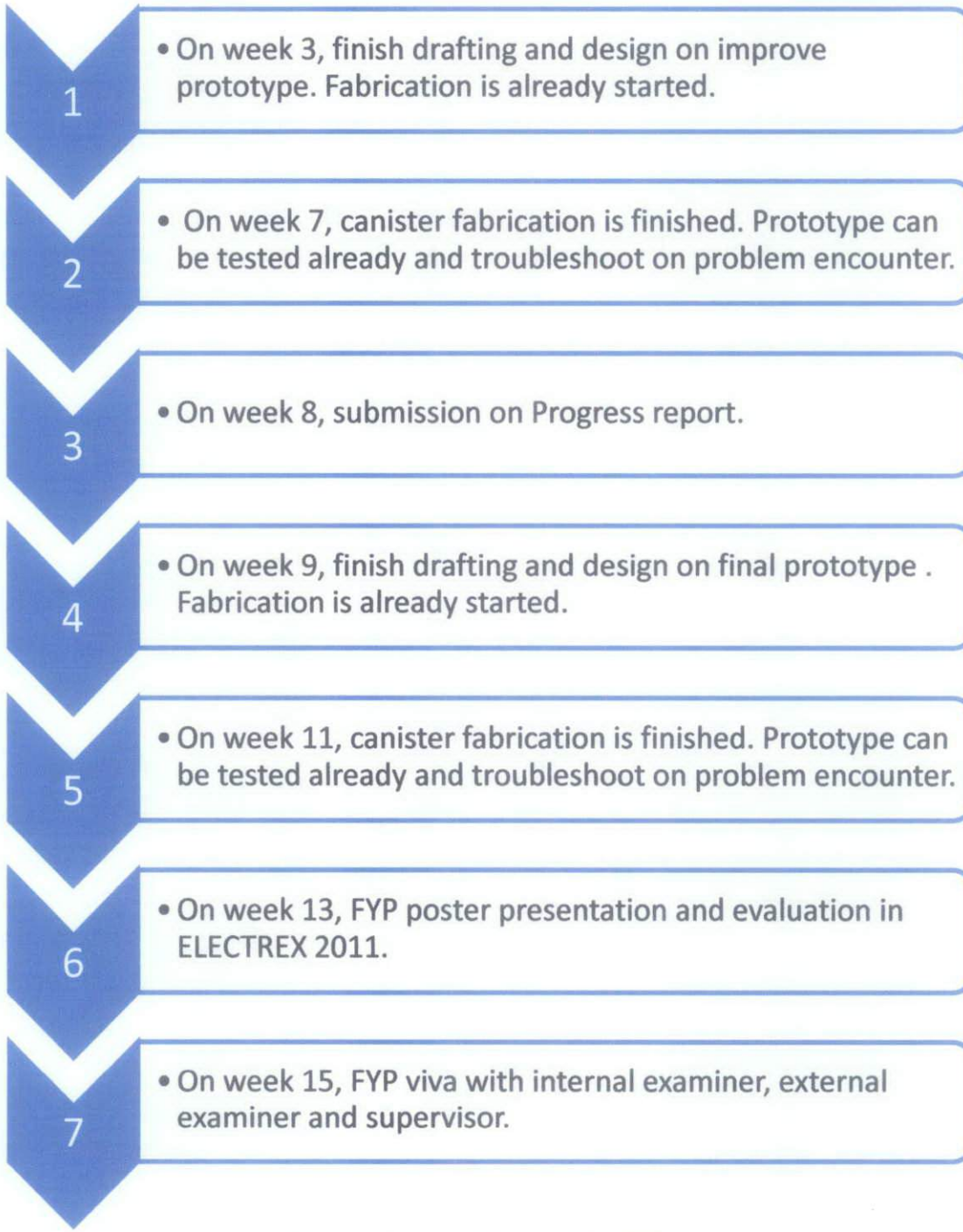

Figure 17: Key milestone for FYP 2

3.5 Tools

Tools used to invent portable torque driver is as shown in **TABLE 4.**

Table 4: List of tools

No	Name	Details
1	AutoCAD	Used for draw the model with scale in 3D and 2D
2	Microsoft Office	Used for writing a report
3	Adams Views	Used for calculation of the volume because it contain a tool to make analysis and to draw the graph
4	Torque meter	Used to measure the torque required to open and tighten the nut
5	Spanner	To tighten connection of hose and body
6	Screw driver	To tighten ring on the hose

CHAPTER 4

RESULT AND DISCUSSION

4.1 Canister specification:

Canister or pressure vessel is used to hold a pressurize air feed from the compressor. The cross-sectional diagram of cylinder is as shown in Figure 14:

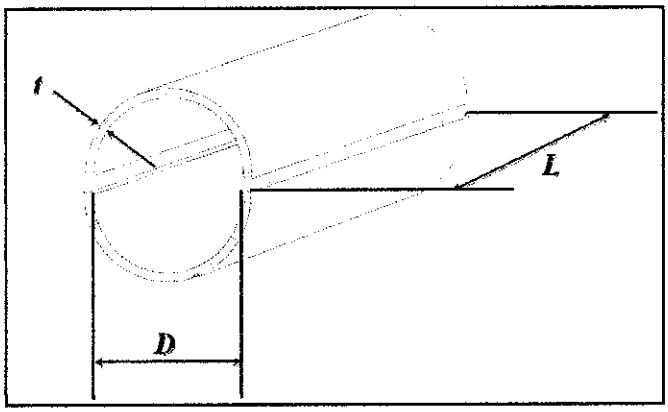

Figure 18: Cross-sectional diagram of cylinder

4.1.1 Canister specification for final prototype

Canister specification for final prototype is as shown in Table 7:

Table 5: Canister specification for final prototype

Criteria	Details
Shape	Cylindrical
Thickness, t	2 mm
Outer diameter, d	90 mm
Length/ Height, h	290 mm
Internal pressure, P	8 bars / 800000 N/m^2

Based on specification given above, the volume of canister was calculated using equation (1). The calculation is as shown below:

$$V = \pi(0.045)^2 0.29$$
$$= 1.845\ mm^3$$

By using equation (2), volume of canister in liter is:

$$V = 1.845 \times 1000$$
$$= 1.845\ L$$

4.1.2 Comparison on specification between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 6:

Table 6: Canister specification of prototypes

Prototype Criteria	Theory proven	Improve	Final
Shape	Cylindrical	Cylindrical	Cylindrical
Thickness, t	9 mm	6 mm	2 mm
Outer diameter, d	190 mm	200 mm	90 mm
Length/ Height, h	300 mm	100 mm	290 mm
Internal pressure, P	8 bars / 800000 N/m^2	8 bars / 800000 N/m^2	8 bars / 800000 N/m^2
Volume, L	8.5058 L	3.142 L	1.845 L

As shown in Table 6, the shape for each prototype is the same as cylinder is an ideal shape in pressure vessel fabrication. This is because, pressure acted on pressure vessel or canister body is well distributed in cylindrical shape container. The thickness of canister is reduced as the improvements are made. This is because thickness affect directly on canister weight. Thick container would have heavy weight compare to thin container. In order to make the portable torque driver really portable, it must have a light weight. Due to that, the canister thickness is being

reduced. Outer diameter and length affect directly on canister volume. However, diameter has larger effect on volume compare to length. Here, volume of canister is drastically reduced from 8 liters to approximately 2 liters only. This is because the scope of portable torque driver application has been reduced to lose and tighten tire nut only. The operating pressure of portable torque driver is 8 bars for each prototype.

4.2 Stresses acted on canister's wall

There are two types of stress that acted on cylindrical canister which is hoop stress and longitudinal stress. The calculation of both stresses for each of prototype is as shown:

4.2.1 Final prototype stresses

Based on specification given in Table 5, longitudinal stress is calculated using equation (4). The longitudinal stress is as shown below:

$$\sigma_L = \frac{800000(0.045)}{2(0.002)}$$
$$= 9MN/m^2$$

The hoop stress is calculated using equation (5). The hoop stress is as shown below:

$$\sigma_H = \frac{800000(0.045)}{(0.002)}$$
$$= 18MN/m^2$$

Based on calculation above, longitudinal stress acted on cylinder wall due to internal pressure is 9 MN/m^2 and hoop stress acted on the wall is 18 MN/m^2. Hoop stress is greater than longitudinal stress by half. Due to that, hoop stress is the maximum allowable stress acted on the wall of canister for theory proven prototype. The maximum allowable stress acted on the wall of canister for final prototype 18 MN/m^2.

4.2.2 Comparison on stresses acted canister body between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 7:

Table 7: Stresses act on Canister body of prototypes

Prototype Criteria	Theory proven	Improve	Final
Longitudinal stress	$4.2MN/m^2$	$6.7MN/m^2$	$9MN/m^2$
Hoop stress	$8.4MN/m^2$	$13.3MN/m^2$	$18MN/m^2$
Maximum allowable stress	$8.4MN/m^2$	$13.3MN/m^2$	$18MN/m^2$

As shown in Table 7, the longitudinal stress, hoop stress and maximum allowable stress is increase as improvements is made on canister design. This is because, as improvements are made, the thickness is reduced. Stress is indirectly proportional to thickness, when thickness is reduced, stress will increase and vice versa. Maximum allowable stress affect on material selection process.

4.3 Material selection

Material selection is very important in order to avoid the canister from burst out when it is been pressurized. Material selection is done based on yield strength and Pugh's selection table. Yield strength and Pugh's selection table result is as shown below:

4.3.1 Yield Strength

The yield strength is defined as the stress at which a predetermined amount of permanent deformation occurs. The yield strength need for material selection for each prototype is as shown below:

4.3.1.1 Final prototype yield strength

Based on allowable strength value, yield strength is calculated using equation (6). Safety factor is chosen to be 2. Yield strength is as shown below:

$$YS = 2 \times 18\ M$$

$$= 36MN/m^2$$

Based on yield strength calculated above, the material selected should have greater or at least equal yield strength of 36 MN/m^2. However, if the yield strength different between material selected and calculated, or in other word material selected yield strength is too big compare to calculate, the canister will be over design.

4.3.1.2 Comparison on yield strength between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 8:

Table 8: Stresses act on Canister body of prototypes

Prototype Criteria	Theory proven	Improve	Final
Yield strength	16.8 MN/m^2	26.6 MN/m^2	36 MN/m^2

As shown in Table 8, yield strength required for material selection is increased as improvements are made. This is because, maximum allowable is increase. Yield strength is directly proportional with maximum allowable strength. In selecting body material for final prototype, material should have yield strength above 36 MN/m^2 . It is assume, the maximum pressure that would break and deform the canister wall is 36 MN/m^2. However, no pressure test have been done it order to practical maximum allowable pressure before canister body break and deform. Based on theoretical, material with yield strength higher than 36 MN/m^2 is enough to make sure that canister would not break during operating pressure.

4.3.2 Pugh's Selection Chart

There a vast material which have yield strength equal or greater than 16.8 MN/m^2 or 26.6 MN/m^2 or 36 MN/m^2. Due to that, Pugh's selection chart is used in order to compare all these materials based on other criteria.

Table 9: Pugh's selection Chart

Characteristics	Stainless steel	PVC	Aluminum	Ceramic
Manufacturing		+	+	+
High pressure	D	-	S	-
Weight	A	+	+	+
Elasticity	T	-	S	-
Material cost	U	+	+	+
Safety level	M	-	S	-
∑+		3	3	3
∑-		3	0	3
∑S		0	3	0

Notes:

(+) : Material has better characteristic compare to DATUM

(-) : Material has lack characteristic compare to DATUM

(S) : Material has same characteristic compare to DATUM

Five criteria were added in material selection which are, manufacturing, high pressure, weight, elasticity, material cost and safety level. Here, stainless steel is chosen to be the datum. Datum is a minimum limit for each criterion. Supposedly, material that would be selected should have criteria better than stainless steel or at

least the same. Manufacturing is referring to the difficulty the material to be manufactured, handled and obtained. High pressure is ability of the material to with stand high pressure. Weight is the weight of the raw material. Elasticity is ability of the material to with stand force before it starts deform. Material cost is the total cost for material and safety level is safety in term of corrosion. Based on analysis above, aluminum is the better choice. Due to that, aluminum 6061 has been chosen as the material for canister body for theory proven and improve prototype. Furthermore, aluminum 6061 has yield strength 34 MN/m^2 which is greater than yield strength for both of them.

For final prototype, cold rolled steel is used. This is because yield strength for final prototype is larger than 34 MN/m^2 . However, the back draw of steel is it is heavy.

4.5 Mass of air inside the canister

Mass of air is the only variable left which can be related to operating time. In order to calculate operating time, there are two mass of air is calculated which are mass of air for operating pressure (internal pressure) and regulating pressure.

4.5.1 Final prototype mass of air

The mass of air for operating pressure is calculate using equation (9) with internal pressure, 8 bar, volume, $3.142\,mm^3$, universal constant gas, 0.2870 kJ/kg.K and temperature, 300 K. The operating pressure's mass of air, m_1 is as shown below:

$$m_1 = \frac{800000\ (1.845m)}{0.287\ (300)}$$

$$= 17.14\,kg = 168.2\,N$$

The mass of air for regulating pressure is calculate using internal pressure, 7 bar, volume, $3.142\,mm^3$, universal constant gas, 0.2870 kJ/kg.K and temperature, 300 K. The regulating pressure's mass of air, m_2 is as shown below:

$$m_2 = \frac{600000\ (1.845m)}{0.287\ (300)}$$

$$= 12.9\ kg = 126.1\ N$$

4.5.2 Comparison on mass of air between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 10:

Table 10: Mass of air in prototypes canister

Prototype Criteria	Theory proven	Improve	Final
Mass of air of operating pressure, m	79.04 kg	32.11 kg	17.14 kg
Mass of air of regulating pressure, m	59.28 kg	24.09 kg	12.9 kg

As shown in Table 10, mass of air for both operating and regulating pressure is reduced as improvements are made. This is due to decrease of volume of canister from theory proven to final prototype. Mass of air is directly proportional to volume of container. Huge mass of container have capability to restore high mass of air and vice versa.

4.6 Weight flow rate

Weight flow rate is the number of air's weight that flow out from canister with respect to time. Weight flow rate for each prototype is as shown below:

4.6.1 Final prototype weight flow rate

Weight flow rate is calculated using equation (10) with nozzle' area, $0.02m^2$,gravitational force, 9.81N, adiabatic exponent, 1.4, constant, 182.8 Nm^{-3} , internal pressure, 801.3 KPa and pressure at nozzle, 101.3 KPa. Weight flow rate is as shown below:

$$W= (572.56 \times 10^{-6}) \sqrt{\left(\frac{2(9.81)(1.4)}{(1.4\text{-}1)}\right)} (1001.3k \times 182.8)[(0.126)^{1.43}\text{-}(0.126)^{1.71}]$$

$$W= 3.399\ Ns^{-1}$$

4.6.2 Comparison of weight flow rate between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 11:

Table 11: Mass of air in prototypes canister

Prototype Criteria	Theory proven	Improve	Final
Weight flow rate, W	$3.399\ Ns^{-1}$	$3.399\ Ns^{-1}$	$3.399\ Ns^{-1}$

As shown in Table 11, weight flow rate for each prototype is the same. This is because all prototypes have the same operating pressure which is 8 bars and same regulating pressure which is 6 bars.

4.7 Operated time

Operated time is calculated using formula (11).

4.7.1 Weight of air versus time

Operated time from weight of for each prototype is as shown in Table 11:

Table 12: Weight of air versus time

Time	Theory proven	Improve	Final
1	775.4083777	315.0320279	168.184144
2	772.0096027	311.6332529	164.785369
3	768.6108277	308.2344779	161.386594
4	765.2120527	304.8357029	157.987819
5	761.8132777	301.4369279	154.589044
6	758.4145027	298.0381529	151.190269
7	755.0157277	294.6393779	147.791494
8	751.6169527	291.2406029	144.392719
9	748.2181777	287.8418279	140.993944
10	744.8194027	284.4430529	137.595169
11	741.4206277	281.0442779	134.196394
12	738.0218527	277.6455029	130.797619
13	734.6230777	274.2467279	127.398844
14	731.2243027	270.8479529	124.000069
15	727.8255277	267.4491779	120.601294
16	724.4267527	264.0504029	117.202519
17	721.0279777	260.6516279	113.803744
18	717.6292027	257.2528529	110.404969
19	714.2304277	253.8540779	107.006194
20	710.8316527	250.4553029	103.607419
21	707.4328777	247.0565279	100.208644
22	704.0341027	243.6577529	96.80986897
23	700.6353277	240.2589779	93.41109397
24	697.2365527	236.8602029	90.01231897

25	693.8377777	233.4614279	86.61354397
26	690.4390027	230.0626529	83.21476897
27	687.0402277	226.6638779	79.81599397
28	683.6414527	223.2651029	76.41721897
29	680.2426777	219.8663279	73.01844397
30	676.8439027	216.4675529	69.61966897
31	673.4451277	213.0687779	66.22089397
32	670.0463527	209.6700029	62.82211897
33	666.6475777	206.2712279	59.42334397
34	663.2488027	202.8724529	56.02456897
35	659.8500277	199.4736779	52.62579397
36	656.4512527	196.0749029	49.22701897
37	653.0524777	192.6761279	45.82824397
38	649.6537027	189.2773529	42.42946897
39	646.2549277	185.8785779	39.03069397
40	642.8561527	182.4798029	35.63191897
41	639.4573777	179.0810279	32.23314397
42	636.0586027	175.6822529	28.83436897
43	632.6598277	172.2834779	25.43559397
44	629.2610527	168.8847029	22.03681897
45	625.8622777	165.4859279	18.63804397
46	622.4635027	162.0871529	15.23926897
47	619.0647277	158.6883779	11.84049397
48	615.6659527	155.2896029	8.441718972
49	612.2671777	151.8908279	5.042943972
50	608.8684027	148.4920529	1.644168972

51	605.4696277	145.0932779	-1.754606028
52	602.0708527	141.6945029	-5.153381028
53	598.6720777	138.2957279	-8.552156028
54	595.2733027	134.8969529	-11.95093103
55	591.8745277	131.4981779	-15.34970603
56	588.4757527	128.0994029	-18.74848103
57	585.0769777	124.7006279	-22.14725603
58	581.6782027	121.3018529	-25.54603103
59	578.2794277	117.9030779	-28.94480603
60	574.8806527	114.5043029	-32.34358103

4.7.2 Comparison of operating time between prototypes

The comparison table for theory proven prototype, improve and final prototype is as shown in Table 13:

Table 13: Operating time of prototypes

Prototype Criteria	Theory proven	Improve	Final
Operating time, s	58 s	24 s	13 s

As shown in Table 13, the operating time of each prototype is decreasing. This is because operating time is directly proportional to canister volume. The volume of canister is being reduced as improvements are made.

The comparison of operating time is illustrated in Figure 23:

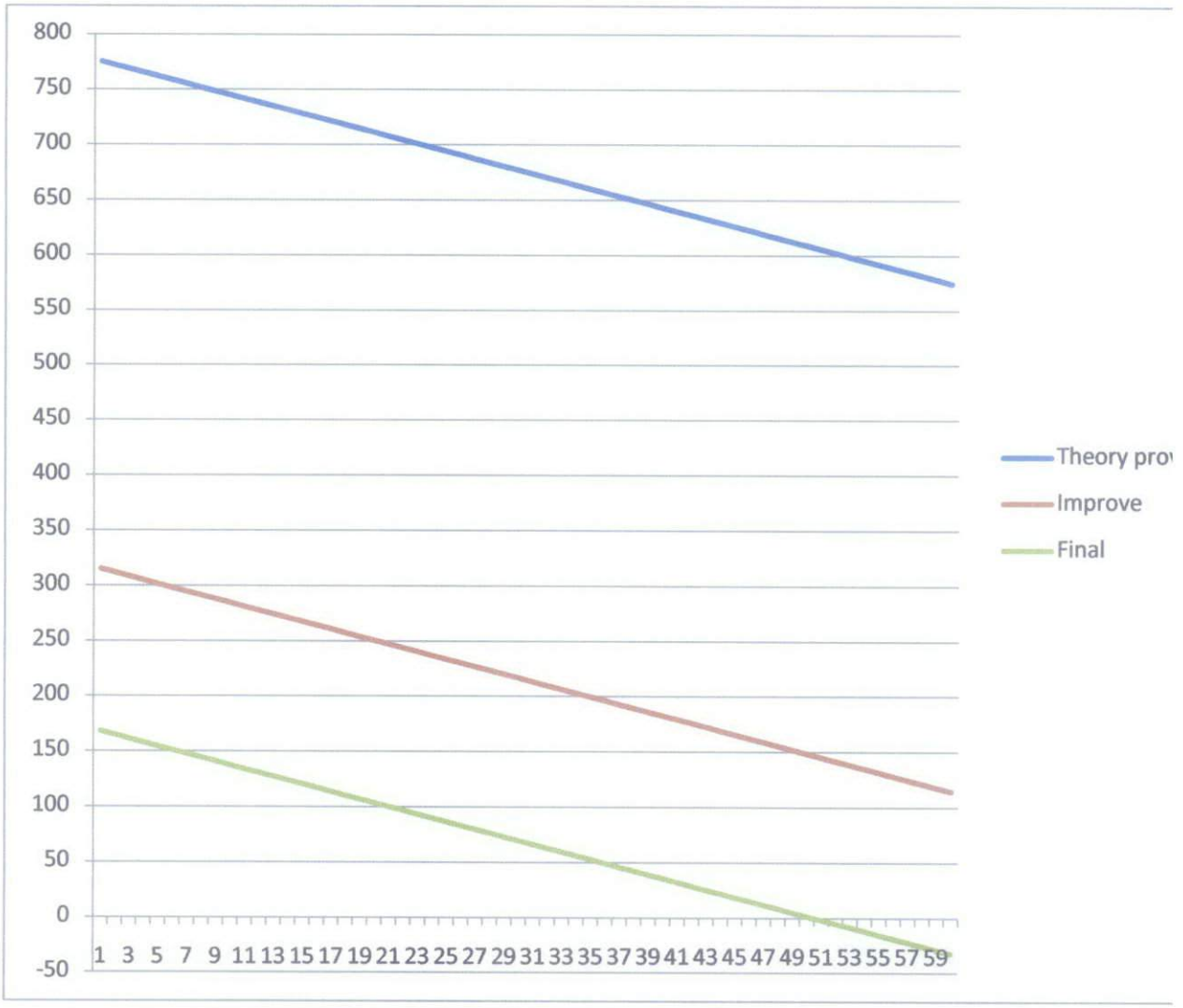

Figure 19: Weight of air versus time

4.8 System design

Figure below shows the schematic diagram of portable torque driver system from source of power which is car's battery to pneumatic gun. It also shows the controlling system implemented which is using timer and relay.

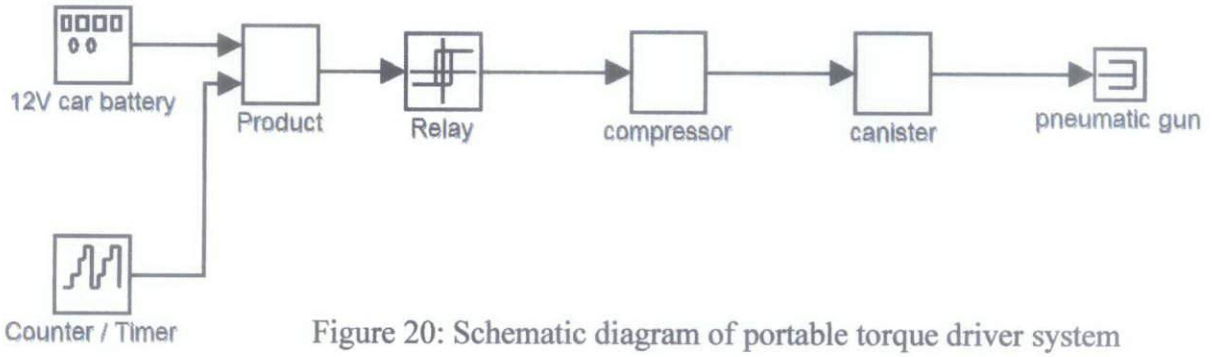

Figure 20: Schematic diagram of portable torque driver system

Portable torque driver system consists of 6 main components, as shown in Figure 24.

4.8.1 Timer

Based on experiment, it needs 517 seconds to reach from zero to 8 bars. Due to that, the value of capacitor 1 is calculated using formula (7) with resistor 1 value, 1MΩ. The calculation is as shown below:

$$517 = 1.1\ (1M)\ C_1$$

$$C_1 = 470\mu F$$

4.9 Canister design

Canister design is as shown below:

4.9.1 Initial Canister design

The initial design concept for the canister that would be fabricated is as shown below:

4.9.1.1 Canister body cylinder

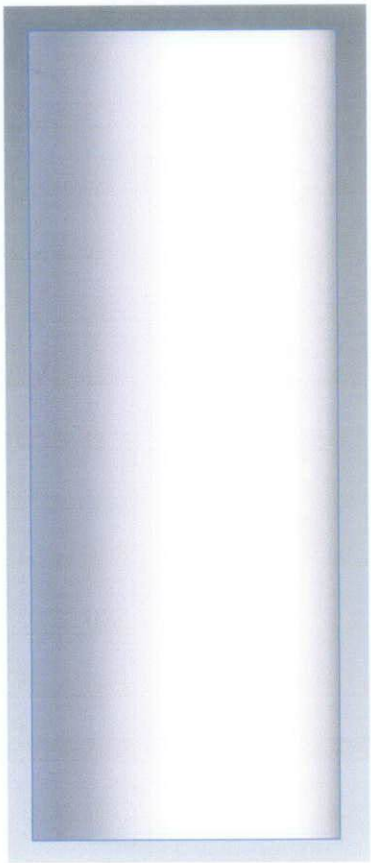

Figure 21: Side view of Canister

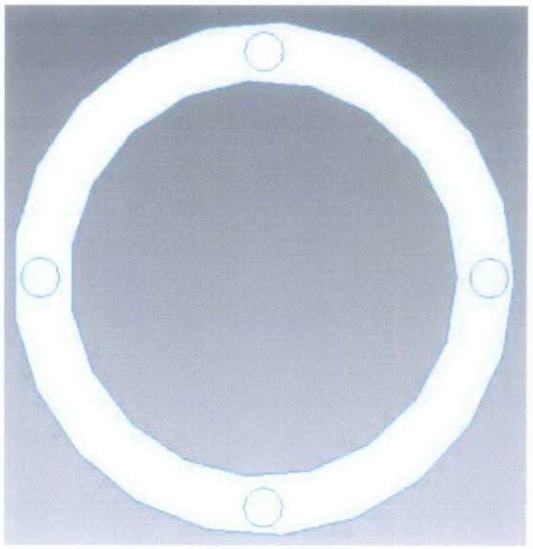

Figure 22: Top view of Canister

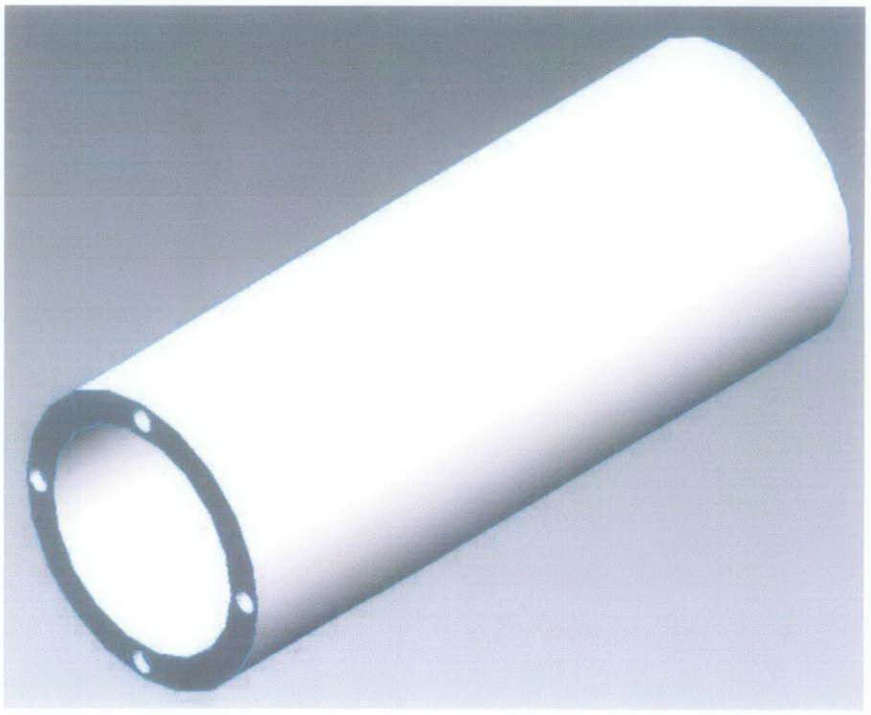

Figure 23: Isometric view of Canister

4.9.1.2 The Canister Cap

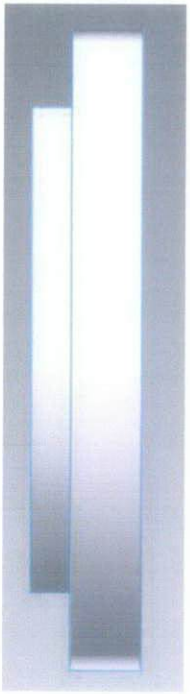

Figure 24: Side view of Canister cap

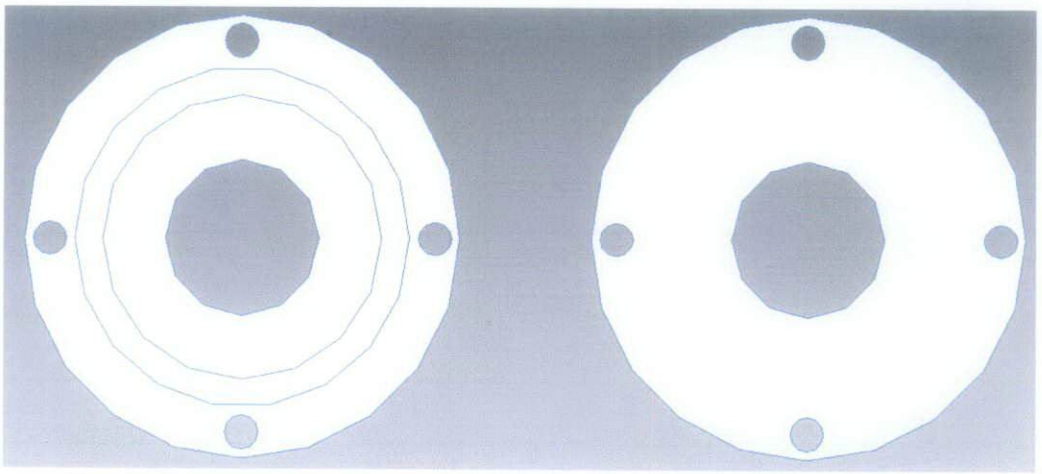

Figure 25: Top view of Canister cap

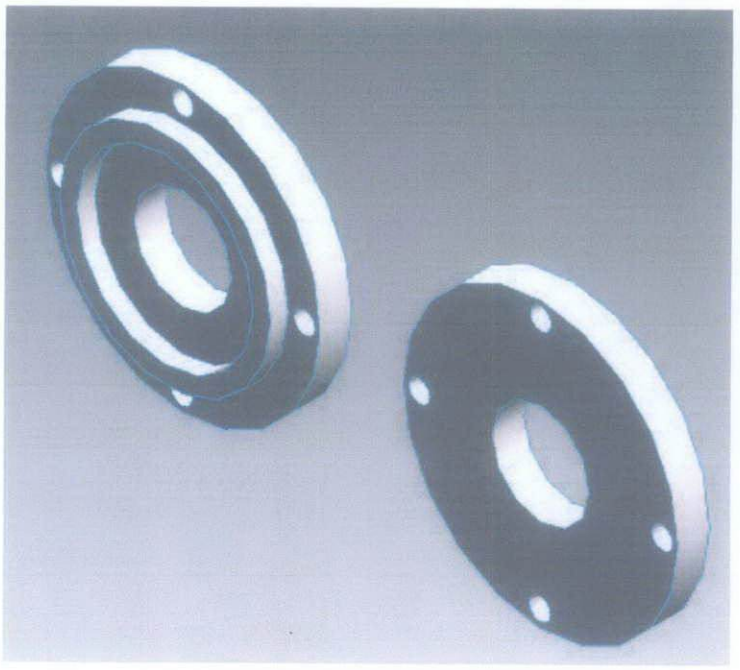

Figure 26: Isometric view of Canister cap

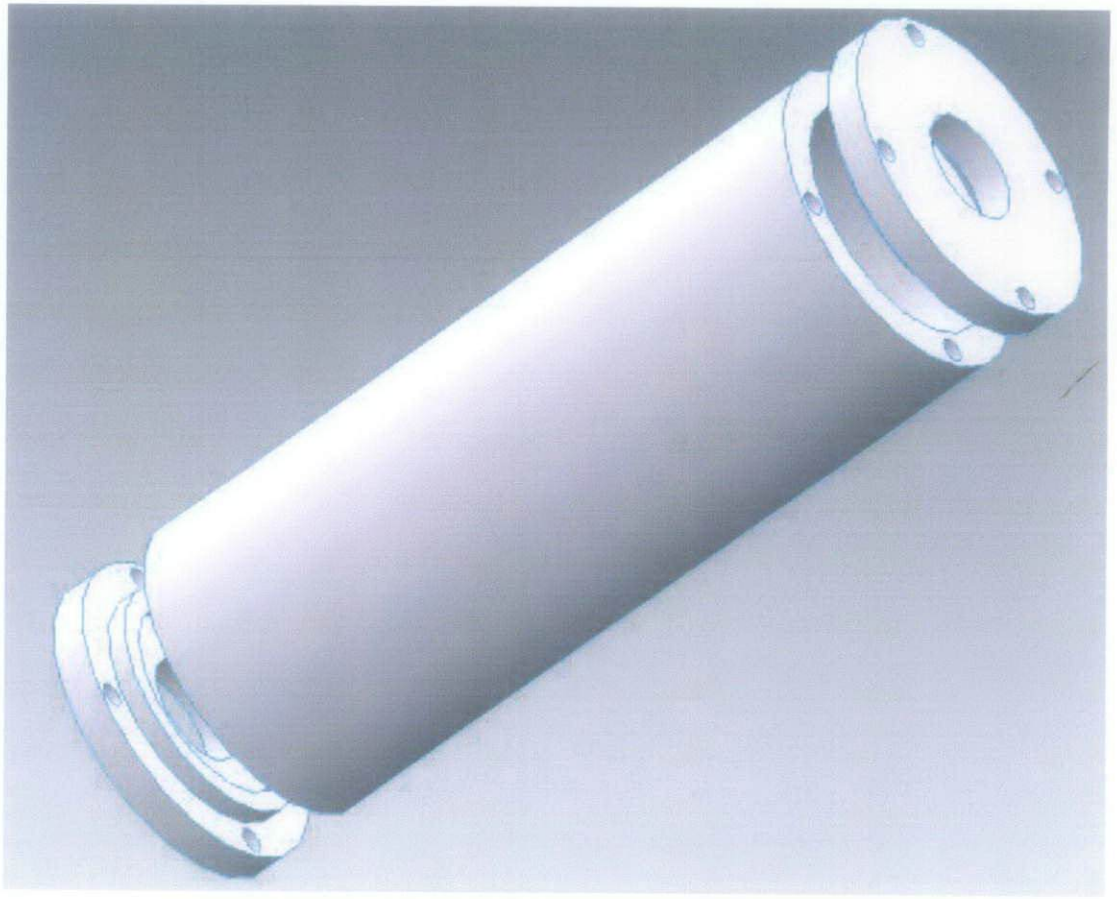

Figure 27: Exploded view of the assembled canister

4.9.2 Improve Canister Design

The improve design concept for the canister that would be fabricated is as shown below:

4.9.2.1 Canister body cylinder

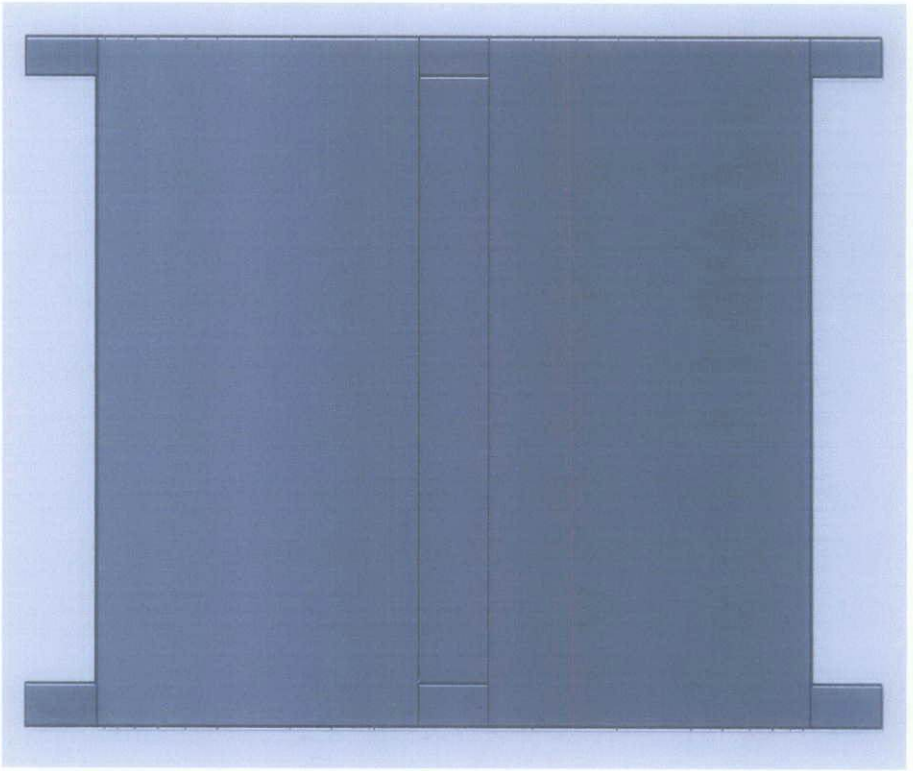

Figure 28: Side view of Canister

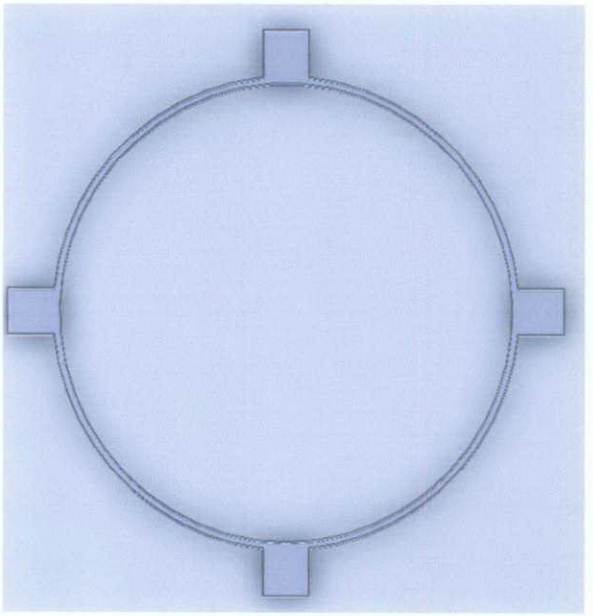

Figure 29: Top view of Canister

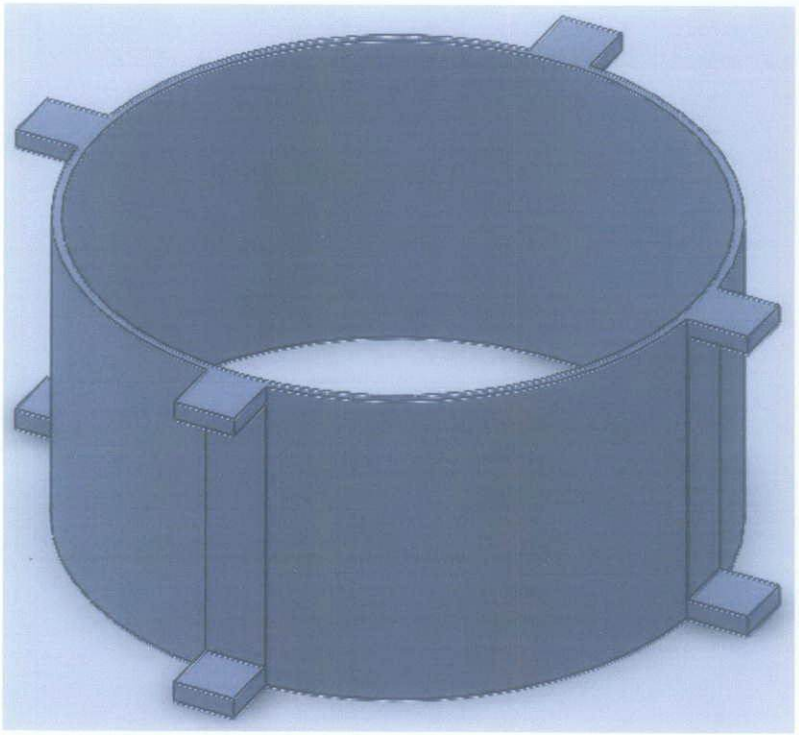

Figure 30: Isometric view of Canister

4.9.2.2 The Canister Cap

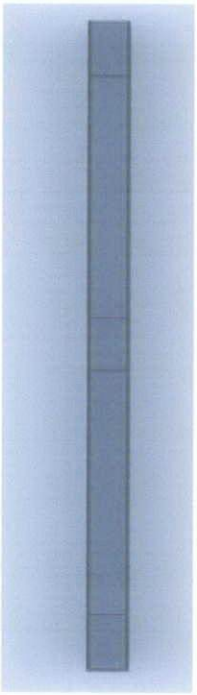

Figure 31: Side view of Canister cap

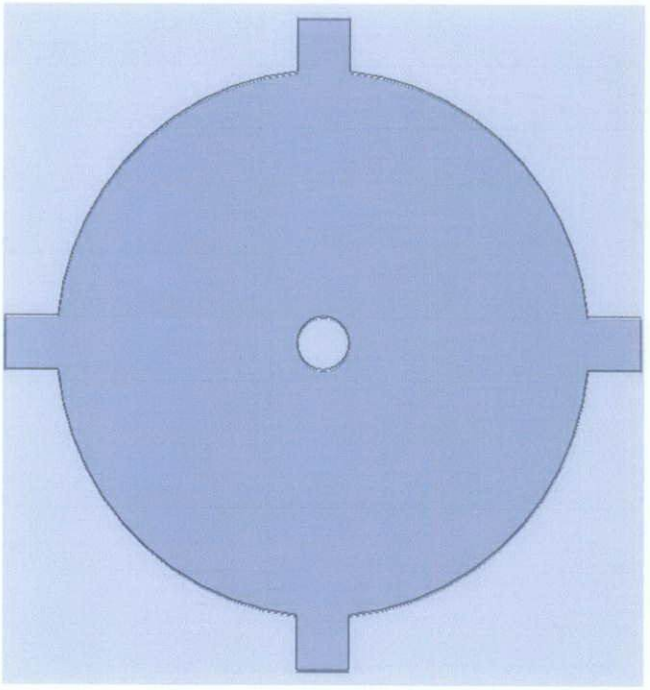

Figure 32: Top view of Canister cap

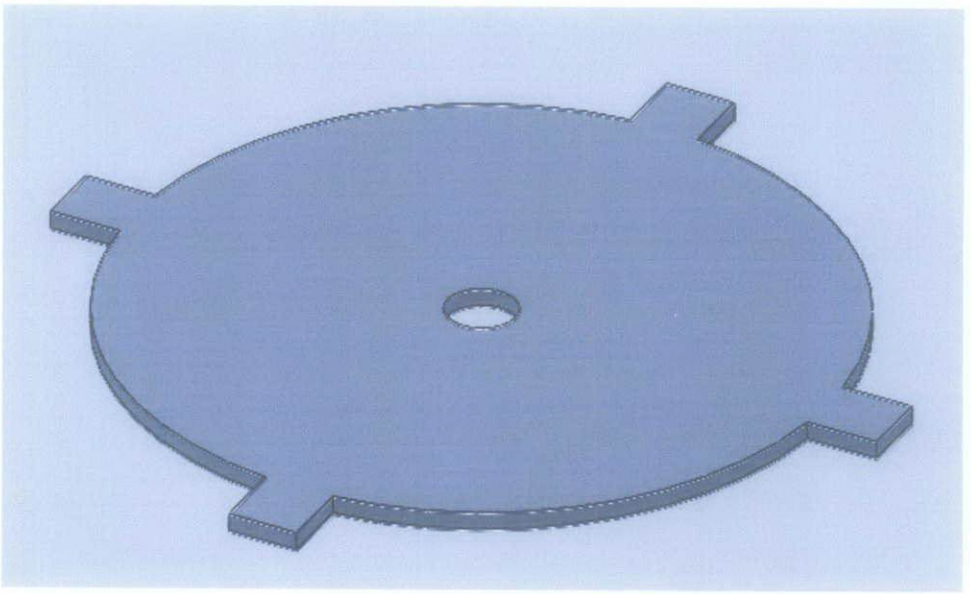

Figure 33: Isometric view of Canister cap

4.9.3 Final Canister Design

The final design concept for the canister that would be fabricated is as shown below:

4.9.3.1 Canister body cylinder

Figure 34: Side view of Canister

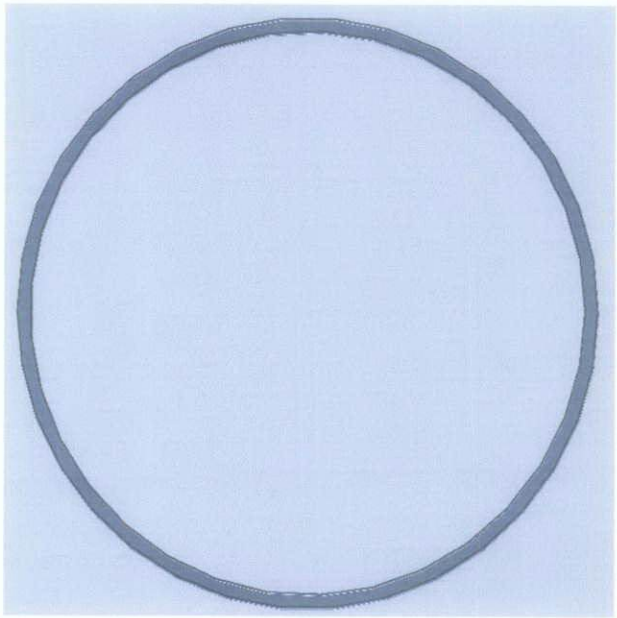

Figure 35: Top view of Canister

Figure 36: Isometric view of Canister

4.9.3.2 The Canister Cap

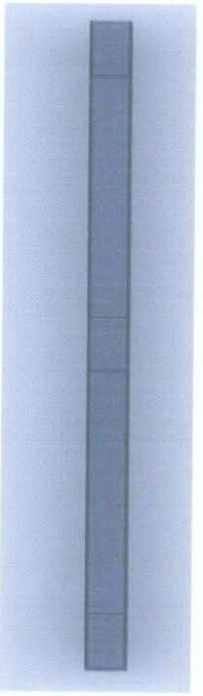

Figure 37: Side view of Canister cap

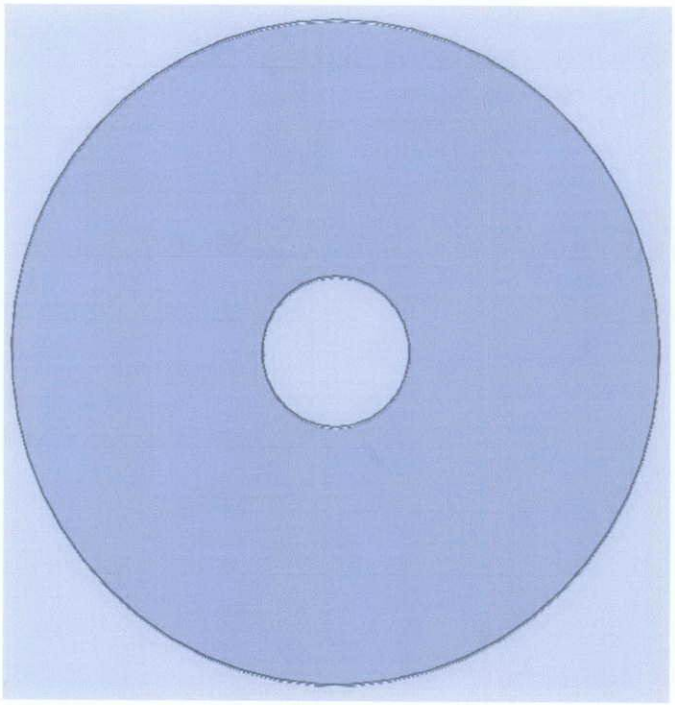

Figure 38: Top view of Canister cap

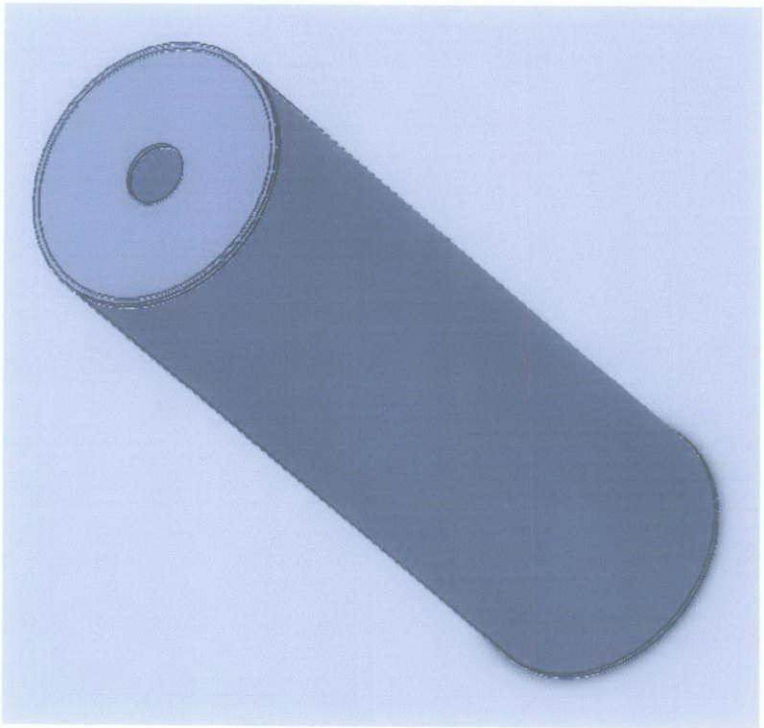

Figure 39: Full view of canister

CHAPTER 5

CONCLUSION AND RECEMMENDATION

Based on research and analysis, the suitable material to be used as a canister's body material is aluminum. However, some market surveys have to be made in order to check the availability of the material and total cost to manufacture the canister itself.

The current volume of canister manages to open lug nut within continuous 13 seconds, operate in 6 Bars, before it loses the power to rotate. Based on surveys done and experiment, 8 seconds, discontinuous, manage to open 4 lug nuts by using existing pneumatic nut remover.

Here, electronic controller is used, combination with relay and timer. However, the controller prone to error due to high capacity power source. Due to that, better solution is by using check valve. Check valve will operate compressor when pressure is lower than 8 bars. When pressure is above 8 bars, check valve will cut off compressor.

Compressor used in this project is not really suitable as it cannot withstand long operation time and easily to be burn. Due to that, new special compressor needs to be design to meet project standard of air compressor which is can operate in long operating time.

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