Designing and Developing Leak Detection Tool Prototype for Liquefied Petroleum Gas Cylinders

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Abstract

Frequent fire incidents from three kilograms Liquefied Petroleum Gas (LPG) cylinder leaks have raised concerns and criticism of the government's gas conversion program, highlighting the need to prevent leaks caused by excessive pressure or damaged components. This study aims to design and develop a prototype tool to detect leaks in 3 kg LPG cylinders, enhancing operational safety and efficiency. The research employed an observational approach, involving direct field observations at PT Agra Budi Gas Utama SPBE. The study examined the operational processes, the application of LPG leak detection tools, and the interaction between operators and existing equipment. The research reveals that Nordic Body Map (NBM) analysis identifies moderate injury risks, with workers experiencing pain in the shoulders, hands, back, and legs due to repetitive movements, prolonged standing, and non-ergonomic workstations. Using anthropometric data of the Indonesian population (50^{th}–95^{th} percentiles), the design introduced key features such as a height-adjustable hydraulic jack, a conveyor system to reduce manual labor, a 60.75-liter water container for leak detection, and safety locks for improved stability. These innovations aim to minimize musculoskeletal injuries, optimize posture, and enhance productivity, with ongoing evaluation recommended for sustained workplace safety and efficiency. Indeed, the trial implementation of the prototype demonstrated its effectiveness in facilitating the detection of leaks, significantly improving the efficiency and accuracy of leak checks performed by operators.

Keywords: LPG Cylinder Leaks, Leak Detection Tool, Operational Safety, Anthropometric Data, Musculoskeletal Injuries

I. Introduction

Liquefied Petroleum Gas (LPG) is a gas formed from the production of oil refineries and gas refineries. LPG is widely used for various purposes such as industry, commercial and household. The use of LPG among the community is currently increasingly widespread. Almost all Indonesian people use LPG, especially 3 kg LPG or commonly known as *melon* gas. Generally, people choose to use 3 kg LPG because the price is much cheaper. [1] There are 2 types of LPG, namely general LPG and special LPG. General LPG comprises the 5.5 kg and 12 kg gas tanks, and it is not subsidized. Specific LPG refers to the 3 kg gas tank, which is subsidized. [2] . In the context of national resilience, it is important to find various forms of energy so that the country does not depend on LPG. The difference can be in the form of developing alternative energy sources, using energy-saving technology, or policies that encourage the use of various forms of energy. It is important for the country to have strong policies and plans to overcome the scarcity of LPG. It includes effective supply, distribution management, and infrastructure development [3] . Another problem that often arises is the scarcity of 3 kg (three kilogram) LPG because the stock is limited, and not all retailers get a share. This scarcity is caused by sales price cheating conducted by the sub agents (bases) through selling over the HET (Highest Retail Price) set by the authority [4].

The use of LPG as an energy source has become a basic need in society. The increasing number of irresponsible people who mix the contents of LPG cylinders makes consumers feel disadvantaged because the contents of the LPG cylinders do not match the specifications. Consumers who use LPG sometimes also forget to check the available gas level so that what happens is that they run out of gas before the due time. Likewise, if there is a leak in the gas stove system and the consumer who uses it is not aware, the level of gas that leaks can cause explosions and fires. Because of these various problems, a warning system is needed that can provide information of what is happening to solve the gas tank leak problems that occur in the house. This information must also be accessible anywhere by utilizing the Internet of Things. The tool that is made will utilize internet connectivity that is connected continuously. The device used is a Wemos microcontroller that is connected to the internet as a data processor and data sender to the database [5]. Load cell sensor is to detect gas levels in LPG cylinders, MQ6 gas sensor is to detect gas levels in the air, servo is used to control the regulator knob, and buzzer is used to give a warning. Next, the android smartphone that has the application installed is used for real-time monitoring. By using internet of things technology, the leak and the level of the gas content can be monitored.

The creation of this tool is to have an error value of 0.5% in reading the weight of a 3 Kg LPG cylinder. This tool has been tested and it can provide warnings to consumers regarding the gas level in the LPG cylinder and the gas leaks that are occurring. This tool also provides an immediate response if a leak occurs. Communication with objects can be done via the internet known as the Internet of Things (IoT) making a prototype of a gas leak detector with the smallest possible shape and size, using an Arduino nano microcontroller, MQ-2 gas sensor and GSM SIM800L Module. This LPG Gas Leak Detector works to detect leaking gas and provide information via SMS (Short Message Service). This tool is expected to be used as a safety tool that is quite cheap and easy to make and use by the public [6].

The increasing frequency of fires and accidents caused by leaks and explosions of LPG cylinders has become a significant concern for users and policymakers. These incidents have not only sparked public controversy but also heightened criticism toward the government's gas transition policy. A decline in LPG cylinder quality, often linked to inadequate supervision during manufacturing, particularly in quality control, is a key contributing factor. Notably, issues with the rubber seals of LPG cylinders have been identified as a critical risk, underscoring the need for stricter safety standards and regulatory oversight. This problem can occur during filling or when the user replaces the LPG cylinder [6]. In addition, this rubber seal also functions to prevent gas leaks when filling or using the LPG cylinder [7]. One of the very important things to pay attention to and be aware of is gas leaks. Under certain conditions, gas leaks can be caused by several factors, namely the gas pressure that exceeds the maximum specifications and the presence of damaged equipment (Gas Seal/Repair Kit) [8]. To find out if there is a gas leak that occurs at the work station, each gas facility is equipped with a gas leak handling system [9]. LPG is in second place with 246 points as the cause of fire due to gas cylinder leaks [10]. Therefore, gas cylinders that often leak cause operators to experience fatigue due to gas cylinder leaks. Thus, this research aimms to design a prototype of a 3 kg LPG cylinder leak checking tool to reduce operator fatigue.

II. METHOD

The observational method is a data collection technique in research where researchers observe and record behavior, events, or phenomena directly without any intervention or manipulation of the research subjects [11]. This research method was conducted by direct observation in the field by distributing questionnaires containing data on the Nordic Body Map, that contains complaints of pain in each part of the operator's body. There are 12 operators consisting of 2 teams. Each team consists of 6 people at SPBE PT Agra Budi Gas Utama to observe the operational process, conduct anthropometric measurements of employees' bodies so that they can be compared with the groundwater level, the use of LPG cylinder leak detectors, and interactions between operators and the tools provided by the company where the tools there will be checked every month so that they are maintained and do not experience damage when in the working position.

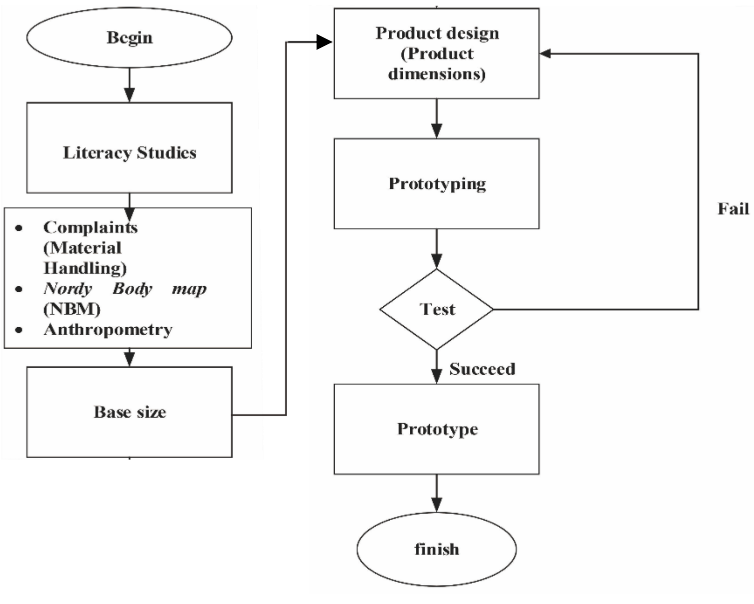


Figure 1Research Flow

The literature study focuses on looking for journals related to gas cylinder leak detectors. After that we can determine the material handling where we directly observe what behavior they do while working, if we already know the results from before, then immediately distribute a questionnaire containing the Nordic Body Map, and if the data of 12 people has been collected, then immediately do the calculation using the formula that already exists in Anthropometry. After getting the calculation from the Anthropometry data, we can then determine the basic size for the prototype to be made, then if the basic size is in accordance with the previous data, then immediately make a design product that is already in the form of a Prototype. Then when it is finished, a test of the tool will be carried out if it is successful, it will be in accordance with the calculation results from the Anthropometry data and vice versa if the test is unsuccessful, the calculation will be carried out again.

III. Results and Discussion

A. Designing and Developing Leak Detection Tool for Liquefied Petroleum Gas Cylinders

1. Nordic Body Map (NBM) Analysis

Nordic Body Map is one of the measurement methods to measure muscle pain in workers. Nordic Body Map assesses and identifies the pain experienced by the workers. This questionnaire is most frequently used to determine discomfort in workers because it is standardized and neatly arranged. The Nordic Body Map questionnaire uses a “Likert scale 5” with a scale of 1 to 5. The respondents are assessed to show which part of their bodies that feel pain during work activities according to the specified Likert scale ranging from No Pain (A), Somewhat Painful (B), Painful (C), and Very Painful (D) [12] .

Calculation of Gas Operator Complaint Level

The calculation of the pain level aims to determine how many complaints are felt by each gas operator while working.

Table 1Recapitulation of Individual Operator Total Score Results

No	Type of Complaint	Complaint Level							
		Operator 1				Operator 2			
		TS	US	S	SS	TS	US	S	SS
0	Pain/stiffness in upper neck	1					2		
1	Pain/stiffness in lower neck		2				2		
2	Pain in the left shoulder				4				4
3	Pain in the right shoulder				4				4
4	Pain in the upper left arm				4	1			
5	Pain in the back		2					3	
6	Pain in the upper right arm			3					4
7	Pain in the waist			3				3	
8	Pain in the buttocks	1				1			
9	Pain in the buttocks	1				1			
10	Pain in the left elbow		2				2		
11	Pain in the right elbow		2				2		
12	Pain in the left lower arm			3				3	
13	Pain in the right lower arm			3				3	
14	Pain in the left wrist			3				3	
15	Pain in the right wrist			3					4
16	Pain in the left hand			3		1			
17	Pain in the right hand			3			2		
8	Pain in the left thigh	1				1			
19	Pain in the right thigh	1				1			
20	Pain in the left knee	1				1			

No	Type of Complaint	Complaint Level							
		Operator 1				Operator 2			
		TS	US	S	SS	TS	US	S	SS
21	Pain in the right knee	1				1			
22	Pain in the left calf	1					2		
23	Pain in the right calf	1					2		
24	Pain in the left ankle			3				3	
25	Pain in the right ankle			3				3	
26	Pain in the left leg			3				3	
27	Pain in the right leg			3				3	
		9	8	36	12	9	14	27	16
	Total	65				67			

Field operator is a term commonly used to refer to individuals or groups who work directly at operational locations, such as in factories, construction sites, mines, oil fields, or other areas where physical or technical work is carried out. They are responsible for the operation, maintenance, and supervision of equipment, machines, or systems in the workplace [13]. Based on the results of table 1, the risk of injury to the body are in the muscles, left shoulder, right shoulder, waist, and back. And the level of complaints of the two operators is slightly painful. The muscle section is on a scale of two with complaints (slightly painful). This can be the basis for the company to take preventive actions.

Table 2Classification of Risk Level Based on Individual Total Score

Likert Scale	Total Individual Score	Risk Level	Corrective Action
1	28-49	Low	No corrective action is required yet
2	50-70	At the moment	Action may be required at a later date
3	71-90	Tall	Immediate action is required
4	92-122	Very high	Comprehensive action must be taken immediately

The results shows that operator one scores 65, and operator two scores 67. It can be included in the current category. This means that action is likely to be needed in the future [14] .

Table 3Summary of Causes of Complaints

No	Parts of Body	Data Results
1	Shoulder	T feels Pain emphasizes the process of putting gas into the truck in Indonesian .
2	Hand	Pain due to repetitive movementsin the process of dismantling .
3	Return	which is painful to be a supporting burden when gas builds up in the truck .
4	Foot	Pain due to being a support when taking LPG from leak check

Working in a standing position for a long time continuously can cause leg pain, swelling in the legs, varicose veins, muscle fatigue, pain in the waist, and stiffness in the neck and shoulders. This is caused by the body being affected by the arrangement of the work area that is not ergonomic so that the position of the worker's body in activities feels limited, causing problems in the body such as the worker's body being too bent which causes pain in the worker's back. Standing too long makes the muscles stiff so that it can reduce the blood supply to the muscles. This causes the blood flow that should be received by the muscles to decrease and causes fatigue and pain in certain parts of the body [15]. Table 3 explains the causes of pain felt by both operators such as pain in the shoulder when pressing in the process of inserting gas into the truck, pain in the hands due to repetitive movements in the unloading process, back pain due to being the support of the load when adjusting the gas in the truck, and pain in the legs due to being the support of the load when adjusting the gas cylinder on the *filling ramp* .

2. Anthropometry

The term anthropometry comes from the word “anthro” which means human and “metron” which means size. Anthropometry is definitively stated as a science that studies the measurement of the dimensions of the human body and its application in design concerning physical geometry, mass, strength and characteristics of the human body in the form of shape and size. Humans basically have different shapes, heights, and weights from one another. Anthropometry will be widely used as ergonomic considerations in interacting with humans. Thus, anthropometry will determine the appropriate shape with the right size and dimensions of the designed product.

In relation to this, product design must be able to accommodate the body dimensions of the largest population that will be used in designing the overall product results with a level of conformity of at least 90% to 95% with the target population. A product usage group must be able to be used as intended. Basically, the work equipment that is carried out can take the reference dimensions of the human body with certainty in a period of time that can accommodate the full range of body sizes of the population that will use it. The ability to adjust or adjustability of a product is one of the very strict requirements that is important in the design process, especially for products that are oriented towards natural exploration [16].

Results of Anthropometric Matrix Selection

Anthropometric data of the Indonesian population used for LPG gas leak detection tools are shown in the following Table 4.

Table 4 Results of Indonesian Anthropometry

Size	Information	P50	P95
D1	Height	152	187
D3	Shoulder Height	126	157
D22	Upper arm length	32	42
D23	Lower arm length	40	54

Table 4, the height of the lower hand grip in the standing position (TGTBB) is calculated using the 50th and 95th percentiles. It can be concluded that the position of the cylinder on the 3 Kg LPG leak detector ranges from 54-61 cm.

3. 3 Kg LPG Cylinder

LPG (Liquefied Petroleum Gas) Cylinders are pressurized containers made of heated carbon steel sheets and used to store LPG. The filling capacity varies between 3 kg (equivalent to 7.3 liters) to 50 kg (equivalent to 108 liters), with a minimum design pressure of 18.6 kg/cm². LPG steel cylinders are categorized into two types, namely a two-part model used for capacities between 3 kg and a maximum of 15 kg, and a three-part model used for capacities above 15 kg and a maximum of 50 kg [17] . Tube Body is the cylinder body material that must meet the SNI 07-3018-2006 standard, using sheet steel plates and hot rolled coils for gas cylinders (Bj TG), or meet the JIS G 3116 standard with class SG 26 (SG 255) or SG 30 (SG 295) [18] . Neck Ring is the material for the neck ring part that must meet the JIS G 4051 standard with quality S17C to S45C. Foot Protectors and Hand Protectors; the material for the foot ring and handrail must meet the SNI 07-0722-1989 standard, using hot rolled steel for general construction, or in accordance with the material used for the related pipe body, namely according to the JIS G 3101 standard with class SS400.

4. Dimensions of 3 Kg LPG Gas Cylinder

The dimensions of the 3 Kg LPG cylinder which is used as the basis for the 3 Kg LPG leak detector can be explained in Figure 2 as follows:

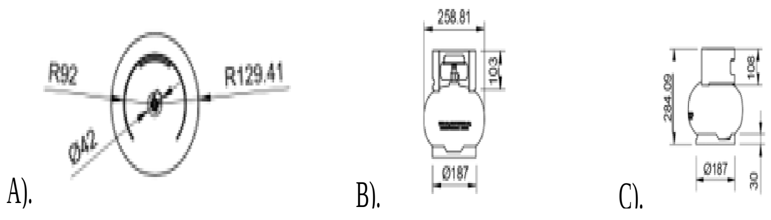
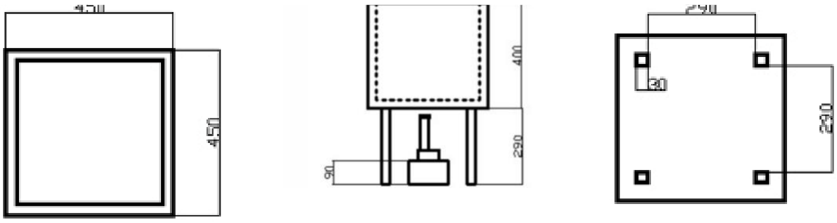


Figure 2 3 Kg LPG Cylinders

Figure 2 explains that in figure A the bottom of the tube called the foot ring has a diameter of 187 cm and a radius of 129.41 cm. While the top of the tube has a diameter of 181.6 cm and a radius of 129.41 cm. In figure B there is a tube with other parts such as a hand grip with a width of 258.81 cm and a height of 103 cm, while in figure C the diameter of the tube body is 42 cm and the height of the 3 kg LPG tube is 284.09 cm.

5. 3 Kg LPG Cylinder Water Container

The water container for a leak test on a 3 kg LPG cylinder is figured out in the following Figure 3:



A) Side views illustration B) Top views illustration A) Below views illustration

Figure 3 LPG Cylinders 3 kg Water Container

Figure 3 explains that the height of the cylinder from the floor is 54 - 61 cm, then the height of the cylinder is 28.409 cm so that it becomes 29 cm, the thickness of the handrail on the cylinder = 4 cm, the height of the cylinder in the water container is 29 4.25 cm. It can be seen that the water container is square in shape, having four pillars supporting the four corners. This water container can adjust the height of the LPG cylinder, and every pillar is assisted by a safety lock (Lock). The inside part of the square container is recoated with *No-drop* paint to avoid leaking when filled with 60.75 liters water. The amount of the water is based on the water volume formula calculation.

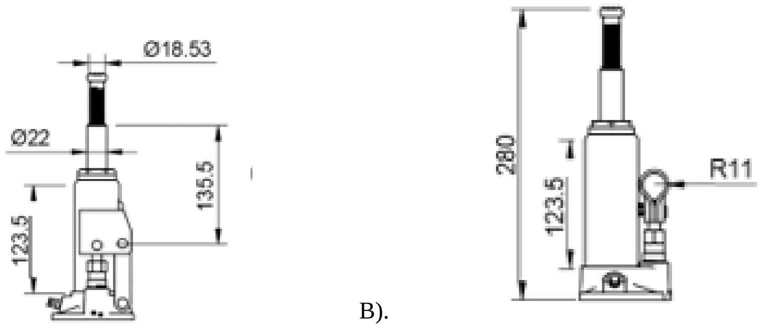
6. Water Capacity

Water capacity refers to the maximum amount of water that a container or system can hold. The term is often used in various contexts, such as the capacity of a water tank or reservoir, to describe how much water can be loaded before overflowing or before reaching its maximum limit [19]. The water container has a volume that can completely submerge a 3 kg gas cylinder in water. The purpose of completely submerging the gas cylinder in water is to find out if there is a leak in the LPG cylinder.

7. Hydraulic Jack

Hydraulic comes from the Greek word " *hydor* " which means water and consists of all objects or substances related to water, so it is known as a hydraulic system. A hydraulic jack is one simple application of Pascal's law. The pressure applied to a fluid in a closed space will be transmitted in all directions equally. Pascal's principle states that pressure is transferred through the fluid without changing its magnitude. When a small plunger is given a pressing force, the force will be transmitted by the oil fluid in the pump. As a result, the oil in the jack will produce a lifting force on the large plunger and can lift the load above it.

The basic principle of hydraulics is based on the simple nature of liquid. They can easily adjust their shape, allowing the transfer of power and force in various directions and various sizes and shapes. Thus, a hydraulic system is a system for transferring and regulating force and movement using liquid, in this case oil. In order to function optimally, hydraulic fluids must meet a number of requirements such as adequate viscosity, good viscosity index, fire resistance, anti-foam, cold resistance, and corrosion resistance. Hydraulic systems are generally used to produce a force greater than the initial output power. In this system, fluid such as mineral oil is pressurized by a pump and then flowed through pipes and valves to the working cylinder. The translational movement of the piston rod in the working cylinder caused by the fluid pressure in the cylinder space is used to perform forward, backward, upward or downward movements, according to the placement of the cylinder, either horizontally or vertically [20] .



A). B).

Figure 4. Hydraulic Jack

Figure 4 explains that in figure A there are several parts of the hydraulic jack, namely a saddle with a diameter of 18.53 mm, a ram plugger with a diameter of 135.5 mm, an oil filler plug with a diameter of 22 mm, and a pump body height of 123.5 mm. Figure B presents the part from the height of the screw to the valve section with a height of 280 mm, and the width of the pump rod with a radius of 11 mm. Based on the measurement results, the height of the jack reaches 20cm. The position of the jack must be able to touch the bottom of the water reservoir at least 29 cm, therefore a block with a size of 9 cm is needed. By raising the jack on the base of the water reservoir by 7 cm, a maximally designed height of 36 cm will be obtained.

8. Conveyors

A conveyor is a mechanical device or system used to move goods, materials, or products from one place to another continuously. Conveyors are used in a variety of industries, including manufacturing, mining, food processing, and logistics to increase efficiency and productivity by moving materials automatically and in a controlled manner. Conveyors help speed up production and logistics processes by reducing the need for human labor and minimizing errors, thereby increasing operational efficiency [23].

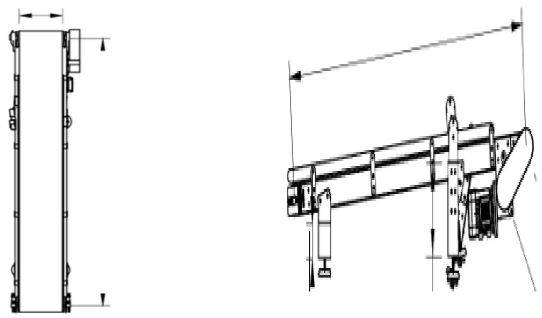
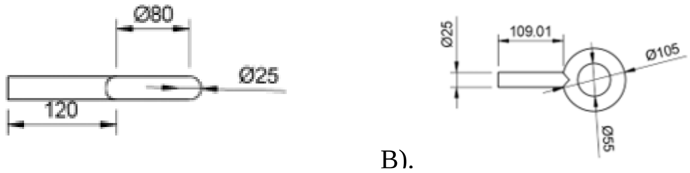


Figure 5 Conveyors

Figure 5 explains that a conveyor is a mechanical system used to move materials from one place to another continuously. The main function of a conveyor is to move goods efficiently, reduce manual labor, and increase productivity in the production process.

9. Security Lock

A safety lock is a mechanism designed to prevent accidental or unauthorized use or operation of equipment, machinery, or devices. These safety locks are used in a variety of industries and applications to protect users, prevent accidents, and ensure that devices or machines can only be operated by authorized persons and under safe conditions. The primary purpose of a safety lock is to enhance safety by ensuring that only authorized persons and under proper conditions can access or operate a particular piece of equipment or device [24].



A). B).

Figure 6 Safety Keys

Figure 6 explains that there are 4 safety locks. The dimensions of the lock and supporting leg components are detailed as follows. In Figure A, each leg lock is designed with a leg width of 80 cm, a bottom width of 120 cm, and a lock height of 25 cm. Meanwhile, Figure B illustrates the supporting leg with a width of 109.01 cm, extending from the bottom base to the top of the support with a diameter of 55 cm. Additionally, the rear, side, and front legs in Figure B are uniformly designed with a width of 105 cm.

B. Prototype of Leak Detection Tool for Liquefied Petroleum Gas Cylinders

Product design is the totality of features that affect the appearance, feel, and function of a product based on customer needs. However, because it is demanded by the ever-changing fashion needs, some people only think about the model (shape), but many also forget the quality side of the product [25]. Based on the dimensions of the gas cylinder, the dimensions of the water container are designed. The water container can make a 3 kg LPG cylinder completely submerged in water. The purpose of the gas cylinder being completely submerged in water is to find out if there is a gas cylinder leak. The diameter of the gas cylinder is 258.81 mm, and the height of the gas cylinder is 284.09 cm. The depth of the container is 40cm, and the surfaace level of the water is 30cm to completely sink the gas tank. To completely contain a 3 kg LPG tank, the water container is in a rectangular shape with 45cm length of each side.

Based on anthropometric data in table 4, the position of the 3 kg LPG cylinder on the 3 kg LPG leak detector ranges from 54 - 61 cm. In this design, a distance of 61 cm was taken considering that people with the 50th and 95th percentiles will not bend to pick up and put the 3 kg LPG cylinder. People with the 50th percentile will also not bend but will bend their hands when picking up and putting the 3 kg LPG cylinder. Based on anthropometric calculations, the height of the handgrip in a standing position ranges from 54 to 61, so that operators/employees can perform gas cylinder leak testing more ergonomically, with a body position that does not need to bend, based on anthropometric data and dimensions of the 3 kg LPG cylinder. Based on measurements, the height of the jack as an aid for going up and down is 20 cm. The position of the jack must be able to touch the bottom of the water container at least 29 cm, therefore a block with a size of 9 cm is needed. By raising the jack on the bottom of the water container by 7 cm, the maximum design height will be 36 cm. The engineering drawing of the tool design is shown in table 5.

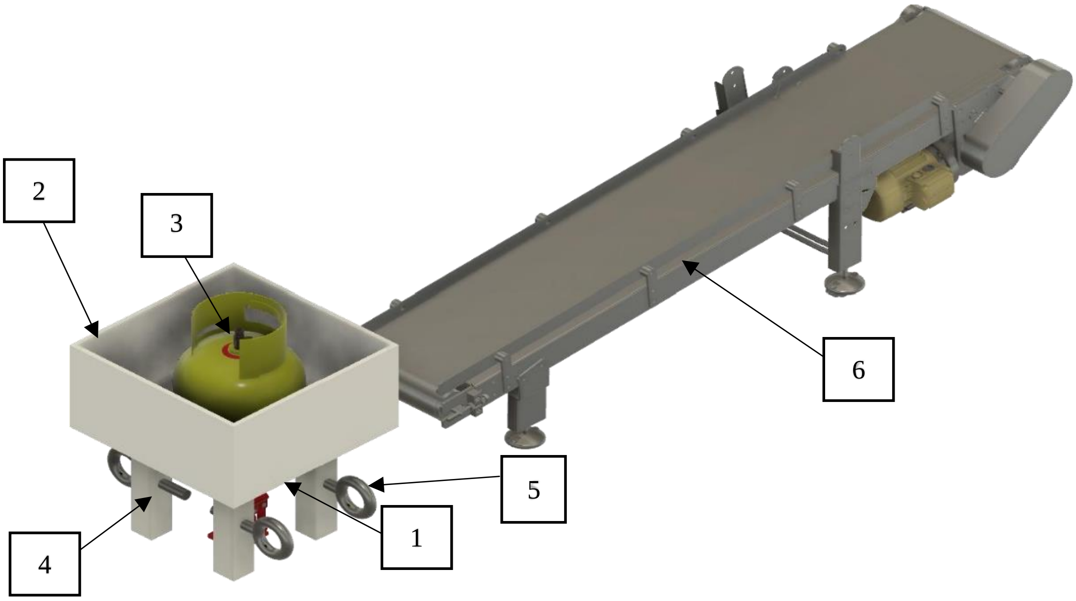


Figure 7 Prototype of Leak Detection Tool for Liquefied Petroleum Gas Cylinders

Table 5 Names of Parts of the Prototype of 3 Kg LPG Gas Leak Detector

Goods	Amount	Part Name
1	1	Jack Up
2	1	Water container
3	1	LPG Gas
4	1	Water container feet
5	4	Locking the legs
6	1	Conveyor

IV. CONCLUSION

This study has developed and tested a prototype for detecting gas leaks in 3 kg LPG cylinders. The design was carefully informed by anthropometric data, ensuring that the leak detector's cylinder placement was ergonomically optimized for users within the 50th to 95th percentiles. The final height of 61 cm was selected to accommodate both ease of use and safe handling, reducing the need for excessive bending or physical strain. The study also established the key dimensions of the gas cylinder, with a diameter of 258.81 mm and a height of 284.09 mm. The container, with a height of 40 cm and a water level of 30 cm, was tailored to ensure effective submersion without spillage, while the rectangular shape (45 × 45 cm) provided ample space for the cylinder. Testing of the prototype demonstrated its effectiveness in simplifying the process of checking gas leaks, showing that the system enhances both safety and operational efficiency. This study not only contributes to the current understanding of LPG leak detection but also highlights the potential for future developments in gas safety technology. Further refinement of the prototype could lead to wider applications, improving.

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