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Smart Gas Leakage Auto-Shutoff Electrical Clip

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Abstract : *Liquefied Petroleum Gas (LPG) is extensively used in residential buildings, hotels, restaurants, or other cooking places due to its convenience and efficiency. However, gas leakage might occur from the cylinder, regulator, or connected pipes accidentally, which causes fire accidents, explosions, and even property damage. The situation becomes dangerous when the leakage is not detected on time or nobody was present to manually turn OFF the regulator. Common practices of gas leakage detection systems generally detect gas sensor presence and raise an alarm but do not physically shut OFF the gas regulator. This project aims to propose a Smart Gas Leakage Auto-Shutoff Electrical Clip, which detects LPG leakage automatically and operates an external clip to move the regulator to the OFF position. The project implements an MQ-6 gas sensor and Arduino UNO microcontroller to control a high-torque MG996R servo motor, which rotates the specially adapted retrofit clip to demonstrate the auto-shutoff mechanism. A similar buzzer circuit is designed for emergency alert purposes. In contrast to the common practice of the IoT-based remote-controlled gas leakage detection system, the proposed concept concentrates on direct detection and automated external clip operation, which physically moves the regulator to the OFF position via an embedded system. The electrical clip can be placed externally to the current regulator and does not require a complete redesign of the existing structure. The compatibility can be achieved conditionally depending on the shape and size of the existing regulator. The proposed concept can be further validated by testing the sensor, clip mechanism, and servo motor, followed by multiple repetitive tests for desired result accuracy. The project aims to propose a cost-effective and reliable concept for the improved safety of LPG and reduced human intervention. However, additional mechanical and safety tests need to be done for the concept to be applicable to the actual LPG cylinder.*

Keywords: LPG Gas Leakage, Arduino UNO, MQ-6 Gas Sensor, MG996R Servo Motor, Electrical Retrofit Clip, Automatic Gas Shut-Off, Embedded System, Gas Safety

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) is one of the most commonly used fuels in residential and commercial environments due to its convenience in meeting the energy needs for cooking purposes. It is mostly used in homes, hotels, restaurants, hostels, and college canteens. However, the leakage of this gas from a cylinder, regulator, or connecting pipe can cause severe safety hazards if not detected and addressed promptly. When such a gas leak occurs, the accumulated leaked gas presents an elevated risk of fire, explosion, and damage to property. Hence, it is essential to detect and localize gas leakage and take appropriate action. In most common gas-leakage detection systems, a gas sensor determines the presence of LPG and triggers an alarm to notify the owner of the system. Unfortunately, the alarm signal from such systems does not necessarily shut off the gas supply, and a person must manually operate the regulator to turn it OFF. This factor can be a primary cause of major safety hazards in case of unattended or inaccessible gas connections and regulators. The proposed project is aimed at developing a Smart Gas Leakage Auto-Shutoff Electrical Clip that enables automatic mechanical regulator control in case of gas leakage.

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The gas leakage auto-shutoff electrical clip, which is the main idea of the proposed project, was implemented by using an MQ-6 gas sensor, Arduino UNO, and MG996R high-torque servo motor. The selected components were necessary to demonstrate the principle of the automatic shutoff concept. MQ-6 gas sensor was employed to obtain information about the environment by sensing the level of gas concentration. Arduino UNO was programmed to compare the obtained information with a preset threshold and respond accordingly by controlling the servo motor. MG996R high-torque servo motor was utilized to drive a specially designed retrofit external clip, which was supposed to contact the regulator control and turn it OFF automatically. In addition, a buzzer could be implemented to inform an operator of the detected gas leakage by means of an audio signal. In contrast to solutions that mostly rely on alarms, the proposed design was conceptually intended to mechanically control the gas regulator by means of an external clip instead of a built-in electronically controlled valve. A prototype of the system was developed to verify the idea by using a dummy regulator model. The main purpose of the developed prototype was to demonstrate the general concept of the gas-leakage auto-shutoff system. It is assumed that the proposed solution could serve as a robust basis for the development of an affordable embedded system concept that would minimize the necessity for human-machine interaction. The described design could be further improved by implementing a reliable mechanism for the verification of the regulator position and a robust clip engagement and adding a backup power supply. Prior to the use of the developed prototype with a real gas cylinder, the developed concept should undergo a thorough safety inspection and testing to ensure that the designed mechanism is capable of reliably shutting off the gas supply without causing any additional safety concerns.

II. RELATED WORK

LPG is used in most homes, hotels, and other institutions as a cooking fuel. While it may seem convenient, gas leakage from the gas cylinder, regulator, or pipe can cause severe danger if not detected early enough. Most people rely on their sense of smell or a gas alarm to detect a leak. However, an alarm can only alert a person of the leak; it cannot physically disable the gas supply. This limitation has motivated the search for a solution that can detect a gas leak and simultaneously disable the gas supply. Gas sensors and controllers can be used to achieve this objective. This project uses an MQ6 gas sensor and an Arduino UNO controller to detect and disable gas supply through a servo motor. The Arduino takes the sensor input and compares it to a preset value. If the value is greater than the preset value, the controller activates the MG996R servo motor to move a specially designed external clip to the OFF position of a dummy regulator. An alarm (buzzer) can also be added to the circuit to inform people of the leak. One of the reasons for this design is to ensure that it is easy to make and does not require internet connectivity, cloud platform integration, or a companion mobile application.

Another objective of this project is to determine if a clip mechanism can be used to open or close a regulator without replacing the existing regulator. The design process involved identifying the shape of the regulator, the grip of the clip on the regulator, and the force required to open or close the regulator. If the clip does not grip the regulator properly, the motor might rotate but fail to open the regulator. Thus, the final prototype must be tested to confirm that the clip fits the regulator, opens it smoothly and consistently. The prototype can be tested using a dummy gas cylinder and regulator. However, the sensor calibration should be done separately in a safe environment. The value at which the sensor triggers the motor should also be calibrated. For example, one should not assume that the sensor value of 500ppm is an accurate representation of the gas concentration in the environment. This project's main objective was to develop a gas leak detection system that can detect gas leaks and disable the supply locally using easily accessible hardware. The effectiveness of the proposed solution relies on the accuracy of the sensor, the grip of the clip, and the motor's ability to consistently move the clip to the OFF position. The system must go through more rigorous testing before it can be used with a gas cylinder.

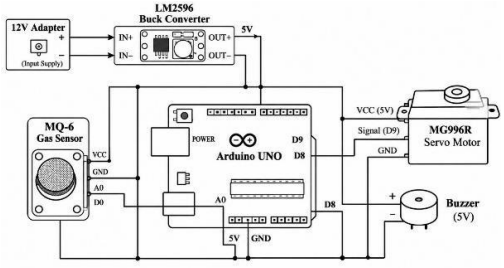
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III. SYSTEM ARCHITECTURE

3.1 Overview of the Proposed System

The proposed Smart Gas Leakage Auto-Shutoff Electrical Clip will be able to sense possible LPG Leakage and exhibit an automatic response mechanism by virtue of a motorized external clip. Gas sensor and a rudimentary mechanical linkage to effect a change in the position of a regulator control towards the OFF position. It is common in several home setups to rely on either a gas alarm or human observation to sense gas leakage. While the alarm can provide an audible alert, it is necessary for the operator to manually effect a shutoff in case of gas leakage. This project aims to explore the possibility of using a sensor-based approach to achieve this function. The circuit basically involves the MQ-6 gas sensor, an Arduino UNO, and an MG996R Servo Motor with an externally designed clip. A buzzer can also be integrated with the setup to provide an audible alarm in case the gas level sensed crosses a threshold level. The analog output of the MQ6 gas sensor is read by the Arduino UNO, against a reference threshold level set as a part of the design process.

In case the gas is leaked, the Arduino is programmed to energize the Servo Motor, which in turn moves the external clip towards the OFF position of the regulator. It is notable that the external clip linkage is designed to hold on to the regulator control and maneuver it to the OFF position. It is essential to design this linkage with respect to the geometry of the regulator control, the holding force, torque requirement, and location of the servo motor. The mechanical linkage is therefore a part of the design exploration and is not available off the shelf. The prototype developed as a part of this project is designed only for laboratory demonstration and uses a dummy gas cylinder and regulator. The performance of the prototype cannot be generalized to actual implementations without further explorations and professional certification.



3.2 Major Components of the System

The architecture comprises four major components, gas sensing, decision-making, mechanical actuation, and optional warning; the functions of each component contribute to the response of the prototype to a potential gas leak condition.

• MQ-6 Gas Sensor: The MQ-6 combustible gas sensor detects the presence of LPGs and other gases and provides an electrical signal as an output, which varies depending on the ambient conditions. The sensor output connects to the Arduino UNO controller, which reads the value during operation. The sensor needs some time to warm up before testing, and its readings should be calibrated under the conditions in which the system is used. Therefore, the sensor output should not be considered a direct indicator of the gas concentration but instead indicates the calibrated value.

• Arduino UNO Microcontroller: The Arduino UNO microcontroller represents the primary controller of the proposed system. The controller reads the sensor output and compares it to the designated threshold value; subsequently, it triggers the servo motor and optional buzzer depending on the outcome of the comparison. Moreover, the controller ensures that the servo command follows the specified movement profile by implementing the clip actuation to the designated demonstration position. The microcontroller offers an appropriate level of complexity for the described application, as it is relatively straightforward to program and compatible with the sensor and actuator.

• MG996R Servo Motor: The MG996R servo motor provides the mechanical actuation of the clip, which engages the control of the dummy regulator model. When triggered by the controller, the motor rotates to the designated position, which moves the clip to the OFF position of the dummy regulator model. The mechanical engagement should be

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designed and tested during the development of the proof-of-concept prototype because the final rotation angle depends on the characteristics of the prototype. The motor needs an appropriate power supply, which can provide the required current; therefore, the 5 V voltage rating of the Arduino UNO should not be considered sufficient.

• External Clip Mechanism: The clip mechanism engages the control of the dummy regulator model. The clip is a separate mechanical component, which should be designed or modified to fit the target regulators. The mechanism should be compatible with the torque provided by the servo motor; therefore, a sufficient level of friction and rotational motion should be ensured during the development. Moreover, the engagement procedure should be consistent, and the motion range should correspond to the rotation of the dummy regulator model.

• Optional Buzzer: An external buzzer can be connected to the controller to provide an audible warning when the sensor output exceeds the designated threshold. Connecting the buzzer to the controller provides an additional warning about the potential gas leak by indicating the condition with an audible signal. However, the buzzer only serves as an optional indicator, and the mechanical actuation of the clip mechanism remains the primary function of the prototype.

3.3 Functional Architecture

Stage 1 – Gas Detection: The MQ-6 sensor monitors the surrounding air and produces an electrical output according to the characteristics of the encountered gases. The sensor should be allowed to warm up as recommended for the module and should be tested under controlled conditions prior to testing.

Stage 2 – Signal Reading: The Arduino UNO reads the sensor output through an appropriate input pin. This value is then used by the program to establish whether the value is below or above the selected threshold. The threshold should be selected on the basis of calibration and the actual test arrangement.

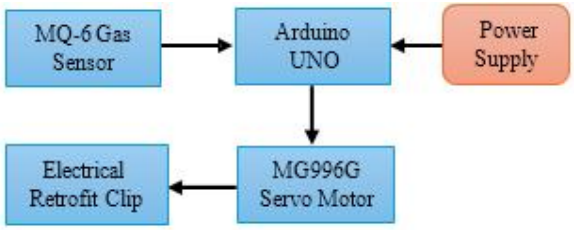
Stage 3 – Decision-Making: The controller then compares the current reading with the programmed threshold. It must activate the selected response if the reading crosses the threshold. If the reading remains below the threshold, then the controller must follow the normal operating logic. Appropriate filtering or a short confirmation period may be effective in reducing unnecessary activation due to short-term fluctuations, provided that the behaviour has been tested and documented.

Stage 4 – Servo Activation: The Arduino UNO then sends a control signal to the MG996R servo motor. The motor then rotates towards a predefined angle. The required angle will depend upon the mechanical arrangement and must be established during prototype testing.

Stage 5 – Clip Movement: The movement of the servo is transferred to the external clip. The clip then attempts to move the control of the dummy regulator towards the OFF position. Success will be dependent upon the adequacy of grip, correct alignment, the provision of sufficient torque, and the absence of mechanical obstruction.

Stage 6 – Warning Indication: If the optional buzzer is included, then the controller must activate it when the selected threshold is crossed. The sound indicates that the sensor reading has reached the programmed trigger level, but must not be taken to represent a certified measurement of the gas concentration.

3.4 Block Diagram



The block diagram starts with the MQ-6 gas sensor, which supplies the input to the Arduino UNO. The Arduino UNO can be considered as the central processing unit, which manages the operation of the outputs based on the set

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conditions. The MG996R Servo Motor constitutes the actuator part of the system, and a buzzer is used to indicate the triggered state of the system.

The signal path and the mechanical path are two separate functions. The former is realized by the signal from the sensor, which is transferred to the controller and further to the motor. The latter begins at the motor's shaft encoder, which connects the clip to the dummy regulator model. This separation of clip position and motor rotation allows for better understanding of the work principle, easier troubleshooting, and simple testing of the system's operation. For this reason, all these aspects should be taken under the special observation during the evaluation of the prototype work.

3.5 Operating Sequence

The system is started by providing power to the Arduino UNO, the gas sensor, and other components. Once the sensor is ready, the Arduino starts reading its output. The program compares the acquired value with the selected threshold. Once the value is higher than the threshold according to the program's condition, the controller opens the clip by rotating the servo motor to the defined OFF position of the dummy regulator model. If the value is below the threshold, the system runs its defined normal state. The program should specifically state what should happen to the servo after its movement. For instance, if a return clip movement is required, it should be defined. However, it should not be assumed that the system will actuate to a safe position on its own accord unless there is a specific command for it. Similarly, the system should not be confirmed to have shut off the gas unless it has a designated command or sensor for it.

3.6 Power Supply and Electrical Connections

The Arduino UNO will require a suitable power source, and the MQ-6 sensor module needs to be connected to the correct voltage and interface. The MG996R servo motor can draw considerably more current on start-up or when running under load, and should normally be powered using a suitable separate regulated supply. The grounds of the Arduino and servo supply should be connected together where required for the control signal reference, following the correct wiring arrangement. The servo signal wire connects to a suitable Arduino digital pin, and its power connections must follow the motor manufacturer's specifications.

The sensor output must also be compatible with the selected Arduino input. The wiring should be checked before applying power to avoid any short circuits, incorrect polarity, or damage to the controller. Servo should be run without a mechanical load initially to confirm its direction and programmed angle. The clip can be fitted to the dummy regulator model and tested at low mechanical risk.

3.7 Safety and Design Considerations

Overall the reliability of the system will be determined by both the electrical and mechanical components. The MQ-6 sensor may not be reliable as it can be affected by environmental factors and other combustible gases. The trigger level must be chosen and recorded based on the testing method. The sensor must be positioned properly within the system and left in operation for an appropriate time period. The clip section can cause problems as there is no guarantee that the regulator will move into the OFF position after the servo command is given. There may be slipping, misalignment or issues with overcoming the mechanical resistance.

The design must be tested multiple times to ensure that the clip can grip and move the dummy regulator model. The servo must provide enough torque but not too much force applied to the mechanism. It is important that when demonstrating the prototype that the dummy cylinder and regulator are used. The sensor should be tested separately using an appropriate method. The DIY mechanism should not be attached to a live LPG cylinder unless it has been professionally assessed by an engineer. This project is to demonstrate the concept of a local gas detection and servo activation system and is not a certified gas safety device.

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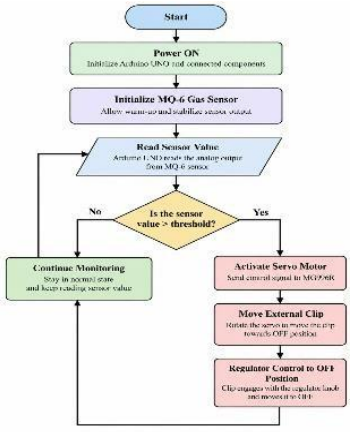
IV. CORE CONCEPT

The aim of this project is to detect if there is a leak of LPG. This is achieved by using a motorised clip which when the LPG detection system detects a leak will place the regulator control into the OFF position. Traditional leak detection systems will alert the user that there is a leak but further actions need to be taken to stop the gas leaking. This project investigates the use of a gas sensor and microcontroller.

An MQ-6 gas sensor has been used. The output from the gas sensor has been connected to an Arduino UNO. This compares the gas sensor data against a set threshold value in the code. If the sensor reading is above or below the threshold value then an output signal is sent from the Arduino to the MG996R Servo Motor. The Servo will rotate to a pre-set angle and therefore cause the external clip connected to the Servo to move. The clip will then lock into place with the control on the dummy regulator model placing it into the OFF position. This investigation looks at how the external attachment can be used to place the regulator into the correct position. This project uses a local simple embedded system. This means there are no Wi-Fi or cloud connections needed and no mobile application. This means the system is simple in terms of hardware making it easier to demonstrate in the lab. The performance of the system will be dependent on the calibration of the sensor, threshold value, torque of the servo motor and clip design. The prototype will be used to show how the concept will work with the dummy regulator model.

V. OPERATIONAL WORKFLOW

The Smart Gas Leakage Auto-Shutoff Electrical Clip works based on the gas sensor detecting a gas leakage. This involves the MQ-6 gas sensor detecting the gas level, the Arduino UNO taking in the information and the MG996R Servo Motor being controlled. The aim of this system is to show that the device will automatically complete an action if there is a gas leakage. Power is supplied to the components and the following steps are completed.



5.1 Powering Up the Components

Power is supplied to all the components. The MQ-6 Gas Sensor warms up. The Servo Motor is set back to its default position. The power is connected and the Servo Motor should respond. The controller will start collecting data from the sensor.

5.2 Gas Sensor

The MQ-6 Gas Sensor will detect any combustible gases within the surroundings. As the gas level in the environment varies, the levels of electricity coming from the sensor will vary. This is collected from the input pin in the Arduino UNO. The threshold should be decided after some controlled testing.

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5.3 Threshold Comparison

After the controller has collected the data, it will compare it with the threshold. If the data is above the threshold, the controller will start the process of turning on the Servo Motor. This provides a simple way of linking the sensor to an action. The threshold must be chosen correctly after calibrations.

5.4 Turning on the Servo Motor

Once the condition has been met in the program, the Arduino will send a signal to the MG996R Servo Motor. The Servo Motor will turn to the pre-set angle. The angle will need to be decided during testing of the prototype as it will depend on how big the clip is, where it is and how it is designed. The Servo Motor should have a correct power.

5.5 External Clip

The Servo Motor will transfer the rotation to the external clip. This clip has been designed to connect to the dummy regulator model control and turn it off. Depending on how well the clip grips and its correct position, it will turn to the correct position. If it does not grip very well or there is not enough torque from the Servo Motor then the regulator may not turn to the correct position. The final position should be checked during testing.

5.6 Constant Checking

Whilst the system is being used, the Arduino will constantly be collecting data from the sensor. If the data collected is less than the threshold it will keep checking. If the data collected is higher than the threshold then the Servo Motor will turn on. The actions to be completed once the Servo Motor turns on should be decided during programming. The prototype should show the clip turning on the dummy regulator model. The sensor should also work correctly during testing.

5.7 Testing

The system can be tested throughout and fully. The MQ-6 Sensor can be checked to see how it reacts. The Arduino can be checked to see if it is correctly comparing the threshold and sending a signal to the Servo Motor. The Servo Motor can be tested with the external clip connected to the dummy regulator model. Important points to note would be if the sensor is giving constant readings, how quickly the controller reacted, how the Servo Motor acted, if the clip had a good grip and if the dummy regulator turned. Multiple tests can be carried out to check if there are any issues with the clip not acting consistently, not being in the correct position or not turning on. This can be noted and improvements can be made to the prototype.

VI. IMPLEMENTATION AND RESULTS

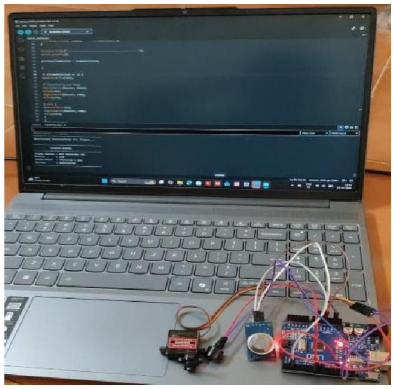
A. Prototype Development

The prototype of the Smart Gas Leakage Auto-Shutoff Electrical Clip was made by combining a gas sensor, microcontroller and servo motor. The main aim was to show a proof of concept for automatically detecting a gas leak and performing a mechanical action. It uses an MQ-6 gas sensor, Arduino UNO, MG996R servo motor and custom clip. This is a simple design that is also inexpensive and can be used in a lab setting without any internet connection. The first step was connecting the MQ-6 sensor to the Arduino UNO board. The sensor was also let warm up. A programme was written on the Arduino to constantly read the data from the sensor and if it went above the defined threshold, it would send a signal to the MG996R servo motor. The threshold and angle of the servo motor was chosen based on the set up of the prototype. This would need to be tested.

The mechanical part of the project was made using the clip outside. This was to connect to the control of the dummy gas regulator model. The servo motor was positioned so that when it rotated it would cause the clip to move. When the servo received the signal to activate, the clip would move to turn the regulator control to the OFF position. The clip needs to be lined up properly to ensure good contact and movement. The servo was tested first to ensure it moved in the

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correct direction. This was done in stages, firstly the sensor data, secondly the Arduino reacting, thirdly the servo moving and finally the clip moving. This helped determine if there was a problem with the gas sensor, the programme or the mechanical aspect. The prototype was to be used in a controlled environment with the dummy regulator model. The sensor was tested separately in a safe environment. More testing would be required to determine if the mechanism is reliable and could work with different regulator designs. This shows a simple concept of how gas sensing could be combined with automatic mechanical movement. However, this cannot be considered a certified LPG shut-off device without proper engineering analysis and safety validation.



B. System Performance

The performance of the Smart Gas Leakage Auto-Shutoff Electrical Clip relies upon the functionality of the MQ-6 Gas Sensor. The Arduino UNO interprets the data provided by the sensor and causes the MG996R Servo Motor to rotate. This enables us to showcase how a gas leak can cause the clip to move. The system continuously reads from the sensor and compares this to a set threshold. If the value is higher than what we have selected it will cause a signal to be sent to the servo motor. The MQ-6 Gas Sensor is an important part of this system. Depending on how long the sensors been warmed up, calibrated, and the surrounding conditions, the values can change. For this reason it is important to test the sensor in a controlled environment before choosing a threshold. The Arduino will interpret the data based on the programming, then the servo will move. As long as the electronic components work correctly and the physical attachment works, the system will function as intended. How well the clip works is an important aspect of this system. Even if the servo rotates to the correct angle, the clip must be strong enough to push the dummy regulator control. If the clip does not line up correctly, there isn't enough torque, or there is some slippage during rotation, this could cause issues. Testing multiple times can help us identify any issues with the clip and improve the design. We need to consider how well the sensor works, threshold is detected, the servo activates, the clip engages, and how consistent it is.

This system does not require an internet connection, cloud and mobile application. This makes the prototype quite simple to implement. We need to make sure we evaluate the system based on our observations and not assumptions. Due to the fact that we are using a dummy regulator model in our prototype, we cannot confirm that it can safely turn off the gas in a real LPG installation. We would need further engineering and professional validation to ensure it is safe to use.

VIII. CONCLUSION

The Smart Gas Leakage Auto-Shutoff Electrical Clip will detect potential LPG Leaks within the system. This uses an MQ-6 gas sensor to detect any gas, along with an Arduino UNO. An MG996R Servo Motor is used to control the external clip. Once the gas sensor has detected a certain threshold of gas then the controller will cause the servo motor to move the clip to the OFF position of the dummy regulator.

A key feature of this system is that it is very simple to operate. The external clip gives potential to control your regulator without replacing the original regulator. However, the success of this system will rely on correct calibrations

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of the sensor. Choosing the correct threshold values and making sure the servo has enough torque to work properly, along with ensuring everything is in place securely. Testing will need to be carried out to understand how these factors affect the overall system.

This project will give a base for developing an automatic gas leak response. Improvements could be made by adjusting the design of the clip, making sure the sensor is well calibrated, considering the response time and how repeatable the system is with different dummy regulators. The prototype is for demonstration purposes only in a lab environment and should not be seen as a gas safety device. More engineering developments and professional safety testing is needed to ensure it can be used with a real LPG Cylinder..

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