GasProbe: An Intelligent Automated Gas Leak Detection and Shut-Off System for Enhanced Domestic and Institutional Safety

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Abstract: ***Gas leakage remains a significant safety concern in residential and institutional environments because combustible gases can accumulate unnoticed and cause fires or explosions. This paper presents GasProbe, an automated gas leak mitigation system that integrates occupancy monitoring, a temperature-responsive mechanism, an electromechanical gas shut-off device, and an audible alarm. Unlike conventional detectors that only generate alerts, the proposed system is designed to interrupt gas flow automatically during hazardous conditions, thereby reducing reliance on immediate human intervention. The concept emphasizes affordability, modularity, and future scalability through the integration of dedicated gas sensors, IoT connectivity, and remote monitoring. Experimental validation has not yet been completed and is proposed as future work.***

Keywords: Gas leak detection; LPG safety; Electromechanical automation; Smart safety system; Ultrasonic sensor; Automatic gas shut-off; Domestic safety

1. Introduction

Liquefied Petroleum Gas (LPG) is widely used in homes, restaurants, laboratories, and institutions because of its high energy efficiency, affordability, and clean-burning characteristics (NFPA, 2021; BIS, 2020). Despite these advantages, accidental gas leakage remains a major safety concern due to faulty regulators, damaged pipelines, improper installation, equipment aging, and human negligence. Undetected gas accumulation can lead to fires, explosions, property damage, and loss of life (WHO, 2021).

Conventional gas leak detectors primarily generate audible alarms and rely on occupants to manually close the gas supply. Such systems become ineffective when occupants are absent, asleep, or unable to respond quickly. GasProbe has been conceived to bridge this gap by combining gas hazard detection with automatic mitigation through an electromechanical shut-off mechanism. The proposed system emphasizes affordability, ease of construction, modularity, and practical applicability while providing a foundation for future smart gas safety solutions.

2. Background and Literature Review

Modern gas leak detection systems commonly employ semiconductor or catalytic gas sensors to identify combustible gases and activate warning alarms (Sedra & Smith, 2021). Recent developments have integrated Internet of Things (IoT) technology, wireless communication, and cloud-based monitoring to provide remote notifications and improved safety management (Zhang et al., 2023).

Although commercial systems effectively notify users about gas leakage, many remain passive devices that depend on human intervention to stop gas flow. Recent research has increasingly focused on combining sensing technologies with automated shut-off mechanisms to minimize the duration of gas leakage and reduce accident severity (Kumar et al., 2022).

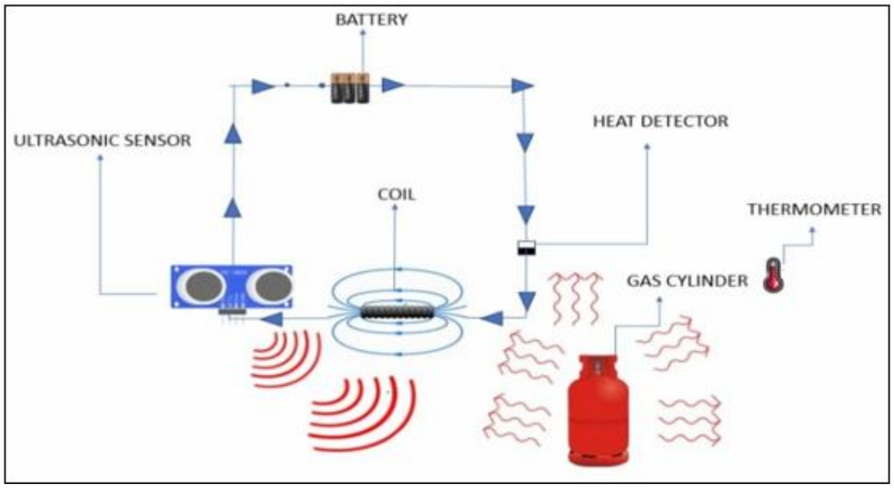
GasProbe follows this engineering approach by integrating occupancy monitoring, thermal sensing, electromechanical actuation, and an audible alarm into a low-cost conceptual safety system capable of automatically interrupting gas flow during hazardous conditions.

3. Problem Statement and Objectives

Current alarm-based systems become less effective when occupants are absent or unable to respond. GasProbe aims to reduce this dependence by providing autonomous intervention. Objectives include improving domestic safety, reducing accident risk, minimizing gas wastage, providing timely warnings, and creating a scalable low-cost prototype suitable for homes and institutions.

4. Proposed System

The proposed architecture integrates an ultrasonic sensor, battery, conducting wires, switch, temperature-sensitive metallic strip, insulator, electromagnet, and buzzer. These components function together to monitor environmental conditions and initiate an emergency response. The modular architecture enables straightforward maintenance and offers flexibility for future upgrades. The proposed architecture follows current trends in intelligent embedded safety systems that combine sensing, automation, and electromechanical actuation **(Zhang et al., 2023).**



5. Methodology

The proposed GasProbe system consists of an ultrasonic sensor, a temperature-sensitive metallic strip, an electromagnet, an alarm buzzer, a battery-powered electrical circuit, and a mechanical gas regulator shut-off mechanism.

The ultrasonic sensor continuously monitors occupancy within a detection range of approximately **2–4 m**. The temperature-sensitive metallic strip functions as a thermal switch and is designed to activate when the surrounding temperature exceeds approximately **55–60°C**, indicating potentially hazardous conditions.

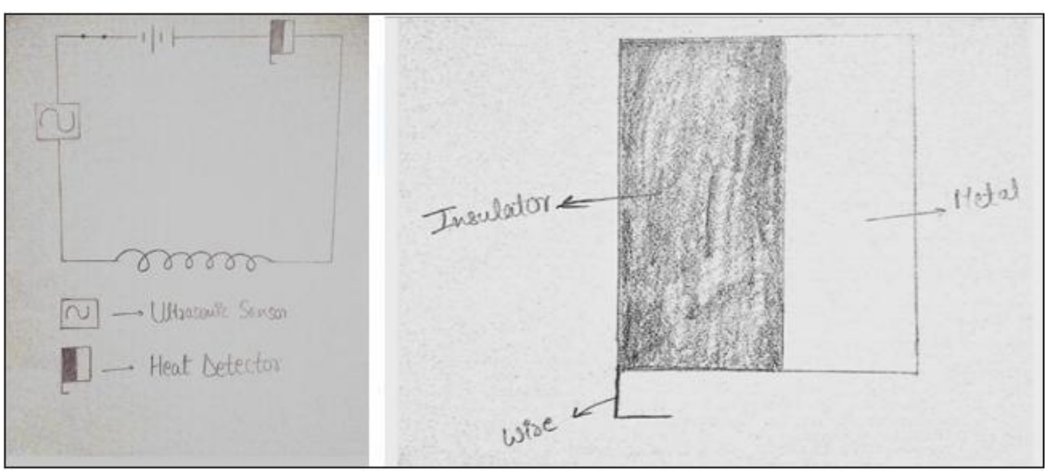
When both monitoring conditions are satisfied, thermal expansion causes the metallic strip to complete the electrical circuit. The energized electromagnet produces sufficient torque to rotate the gas regulator knob and interrupt the gas supply automatically. Simultaneously, the buzzer activates to alert nearby occupants.

The operating sequence is summarized below:
- Monitor occupancy using the ultrasonic sensor.
- Continuously monitor ambient temperature.
- Detect abnormal operating conditions.
- Complete the electrical circuit through thermal activation.
- Energize the electromagnet.
- Rotate the regulator to stop gas flow.
- Activate the audible alarm.

Since the present study is conceptual, prototype fabrication and laboratory testing remain future work. Future validation will evaluate response time, shut-off reliability, activation temperature, false triggering, power consumption, and overall system effectiveness under controlled operating conditions. The proposed operational sequence is consistent with the automation principles commonly adopted in smart safety systems **(Kumar et al., 2022).**

6. Working Principle

The system continuously evaluates its surroundings through integrated sensing mechanisms. The metallic strip expands when exposed to elevated temperatures, completing the electrical circuit. The resulting electromagnetic actuation produces rotational movement capable of turning the regulator knob and stopping the gas supply. By reducing the duration of uncontrolled leakage, the design seeks to minimize the likelihood of gas accumulation reaching dangerous concentrations. Although experimental validation remains future work, the engineering concept demonstrates how simple electromechanical principles can improve safety.



Comparative Analysis

Compared with traditional alarm-only detectors, GasProbe introduces automated hazard mitigation. Instead of merely notifying occupants, the proposed design attempts to isolate the source of leakage. This approach may reduce dependence on immediate human intervention, particularly in unattended buildings, while providing a scalable platform for future integration of IoT monitoring, GSM alerts, and advanced gas sensing technologies**.** particularly in unattended buildings, and provides a modular platform for integrating IoT monitoring, GSM alerts, and advanced gas sensors in future iterations.

Advantages

The proposed system offers affordability, simple construction, modular design, reduced dependence on manual intervention, ease of maintenance, and suitability for residential and institutional environments. Its architecture is intentionally designed so additional sensing technologies can be incorporated without redesigning the entire system.

7. Limitations and Future Scope

The current concept requires laboratory validation and presently relies on a thermal response mechanism rather than dedicated gas concentration sensing. Future work may incorporate MQ-series sensors, IoT connectivity, GSM communication, cloud monitoring, AI-assisted diagnostics, and renewable backup power, transforming the prototype into a comprehensive smart safety platform.

8. Conclusion

GasProbe presents a conceptual approach to automated gas leak mitigation by combining environmental sensing, electromechanical shut-off, and audible warning functions within a low-cost architecture. Unlike conventional alarm-only systems, the proposed design actively interrupts gas flow during hazardous conditions, thereby reducing dependence on immediate human intervention. The proposed concept offers a practical foundation for improving residential and institutional safety while remaining affordable and modular. Future work should focus on prototype implementation, laboratory validation, response-time analysis, reliability testing, and integration of dedicated gas sensors, IoT connectivity, and remote monitoring to demonstrate the practical effectiveness of the proposed system.

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