Engineering Design and Practice Challenge II

Final Report

NEWGIZA UNIVERSITY

NGU.

Team: Ra3d

Contents

1 Introduction

Team Members

Donia Elanany

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Nouran Eldessouky

Team Vision

To revolutionize the way buildings interact with their environment by creating innovative smart surfaces that seamlessly integrate technology, sustainability, and aesthetics.

Team Mission

Our mission is to design, develop, and deploy cutting-edge smart surfaces that enhance the functionality, efficiency, and user experience of buildings. Through continuous innovation and collaboration, we aim to create intelligent surfaces that adapt to the needs of occupants, optimize energy usage, and contribute to a more sustainable future. By pushing the boundaries of technology and design, we strive to transform the way buildings are constructed and operated, making them smarter, more responsive, and environmentally conscious.

Team Goals

- Incorporate the concepts acquired from our current and past courses.
- Take into account the ideas and contributions of all members in our team.
- Create a product that is feasible for production in the near future.
- Enhance our individual and group creative thinking and adaptability.
- Prioritize the safety, physical, and mental well-being of our users.

Golden Rules

1. Always consult the rest of the team before starting a task.
2. Task list to be discussed in advance before being assigned.
3. In case of an emergency, keep your team informed.
4. Always be honest, even with unpleasant news.
5. Be kind and compassionate to each other, no matter the circumstances.

Roles and Responsibilities

- Donia Abdelaziz: Team portfolio manager
- Hana Nabil: Deadline manager
- Malak Amr: Team video lead
- Nouran Tarek: AE research manager
- Omar Tawfik: CCAS research manager
- Zeina El Naggar: Meeting manager

2 Problem Statement, Design Brief and Stakeholder Analysis

Problem Statement

Gas leakages can occur at any given moment, posing a constant threat to the safety of buildings and human lives. If left undetected, these leaks have the potential to cause extensive damage, resulting in severe financial losses and endangering the well-being of individuals. It is crucial to acknowledge that several toxic gases, often lacking any distinct odor or color, can easily evade detection. Their inconspicuous nature increases the risk of inhalation, which can have dire consequences such as cardiac issues and, in the worst cases, fatal suffocation.

Moreover, the long-term effects of exposure to these hazardous gases should not be underestimated. Chronic headaches, persistent shortness of breath, and a noticeable decrease in brain activity are just a few examples of the lasting impact they can have on human health. Beyond the harm caused through inhalation, it is important to recognize the inherent danger posed by flammable gases such as butane, propane, or methane. These substances, if ignited by a heat source, have the potential to trigger catastrophic explosions, leading to widespread property destruction, severe injuries, and the loss of precious lives.

Given the multifaceted risks associated with gas leakages, it becomes imperative to develop robust detection and prevention measures to safeguard both the physical and financial well-being of individuals and communities.

Design Brief

We are designing a smart gas exhaust system that can detect gas leakages, and properly discard potentially harmful gases through shutter valves to vents. The aim is to minimize the risk of dangerous gas leaks, which can lead to explosions or severe health issues when inhaled. This especially targets homeowners, workers in kitchens, and employees exposed to gas fuels regularly.

Stakeholder Analysis

Stakeholder	**Interest**
Building Owners	Ensuring safety, minimizing financial losses
Gas Distribution Companies	Preventing reputation damage, maintaining customer trust
Government	Public welfare
Environmental Agencies	Environmental conservation and preventing pollution
Restaurants	Ensuring a safe working environment, preserving reputation and preventing business disruptions
Laboratories	Safety, compliance with regulatory standards
Industries	Safety, continuity of operations
Insurance Companies	Risk mitigation, minimizing financial losses

Table 1: Interests of Stakeholders

3 Impact

We need to develop a comprehensive solution that effectively detects the concentrations of multiple gases, acts swiftly to eliminate gas leaks, and ensures safety and minimal risk, thereby safeguarding users from any potential harm. The well-being of employees in restaurants, manufacturing facilities, chemistry labs, and universities, as well as the safety of students and homeowners, is compromised due to regular exposure to toxic gases. Our project aims to mitigate these risks by reducing the likelihood of injuries and health issues. It is crucial to exercise extreme caution while designing the system, considering the flammability of the leaking gas. Additionally, the varying densities of the different gases present a challenge, with some gases settling at the bottom of the space and others, less dense than air, accumulating near the ceiling. Therefore, the design of our system must accommodate installation in multiple areas to effectively address this issue.

4 Benchmarking

While there are several gas exhaustion systems available in the market, none of them currently integrate detection, exhaustion, and user notification. Ongoing research in this area has yielded promising outcomes, but no commercially available products have been developed as of yet. Below is a list of the currently ongoing research in this area:

1. The GasSense project, which is a collaboration between several European universities and companies to develop a portable and low-cost gas sensor system for detecting gas leaks.

2. The Smart Gas Sensor project, which is a research effort led by the University of Warwick to develop a wireless sensor network for detecting gas leaks in industrial environments.

3. The GasLeak project, which is a joint effort between the University of California, Berkeley and the Lawrence Berkeley National Laboratory to develop a system for detecting gas leaks using distributed optical sensors.

4. The Gas Sentinel project, which is a startup company that has developed a gas detector for detecting multiple gases, including odorless and colorless gases.

5 Design Criteria

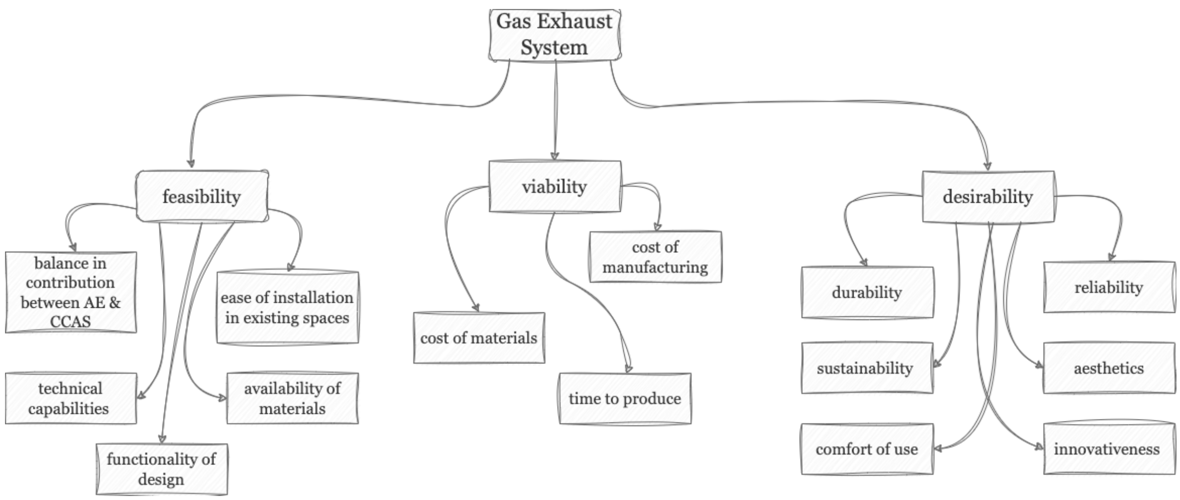


Figure 1: Design Criteria

Solution 1 - Motorized Windows

Opportunities	Challenges
• More sustainable because it uses a passive ventilation method • Less noise than the mechanical exhaust system	• Might be expensive as sliding windows need to be replaced • Will not work in a windowless room (ex: basement)

Table 2: Solution 1 opportunities and challenges

Solution 2 - Shutter Exhaust Mechanism

Opportunities	Challenges
• Aesthetically pleasing • Can be a large single unit or repeated smaller units	• If exhaust system is not installed one will need to be – might be expensive • Will require drilling into the floor/ceiling

Table 3: Solution 2 opportunities and challenges

Solution 3 - Grate on Sliding Panel Exhaust Mechanism.

Opportunities	Challenges
• Aesthetically pleasing • Can be almost any shape, colour or material – very customisable	• If exhaust system is not installed one will need to be – might be expensive • Will require drilling into the floor/ceiling

Table 4: Solution 3 opportunities and challenges

Does it meet the needs of all stakeholders?

Our central issue revolves around the presence of flammable gases in a space where this is/might me a source of fire as this is a huge safety hazard. All of our concepts achieve this goal. Additionally, our concepts are generally pretty customisable and hence each user could choose an alternative that fits their space best.

What are the risks? What do you (or others) have to "lose" if you use this solution?

The risks here are fairly minimal. The only risk comes from if the system malfunctions, other than that the system creates no new safety hazards.

By resolving this issue/problem, are you setting a precedent that may not be what you want?
An adverse social impact from this entire solution might come in the form of users becoming somewhat more careless, relying completely on this system. This is not an issue per se within the spaces the system is installed in but might become one if they move to another facility that lacks this device.

6 Concepts

Concept 1 - Motorized Windows

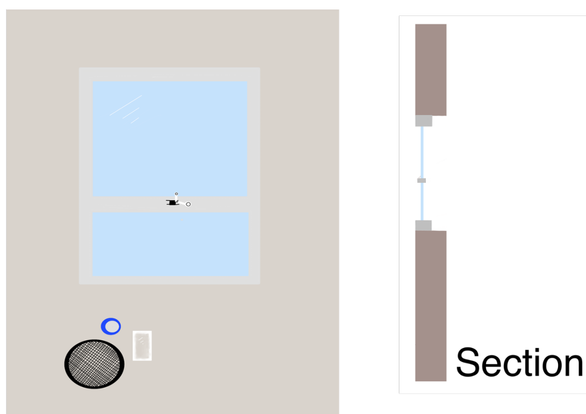


Figure 2: Motorized Windows Sketch

A motorized automated window with a gas sensor is a system designed to detect gas leakages and provide an automated solution for exhaust ventilation. The concept involves integrating a gas sensor into a window system, which continuously monitors the air for the presence of gases. When the sensor detects a gas leakage, it triggers the motorized window to open automatically, allowing for the release of the gases to the outside environment.

Concept 2 - Shutter Exhaust Mechanism

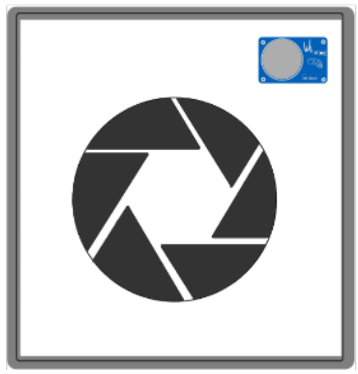


Figure 3: Mechanical Shutter Sketch

The concept of a mechanical shutter, inspired by camera shutters, to exhaust gases is a system designed to detect gas leakages and provide a mechanical mechanism for controlled gas ventilation. Drawing inspiration from camera shutters, this concept employs a similar mechanism to regulate the flow of gases and ensure proper exhaust ventilation when gas leakages are detected.

Concept 3 - Grate on Sliding Panel Exhaust Mechanism.

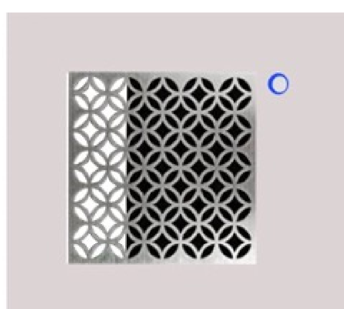


Figure 4: Sliding Panel Sketch

The concept of a grate on a sliding panel to exhaust gases involves using a sensor to detect gas leakages and incorporating a grate mechanism on a sliding panel for controlled gas ventilation. This concept utilizes a sliding panel with a grate, similar to a ventilation grate or grill, to regulate the flow of gases and facilitate their safe exhaust.

7 Concept Selection

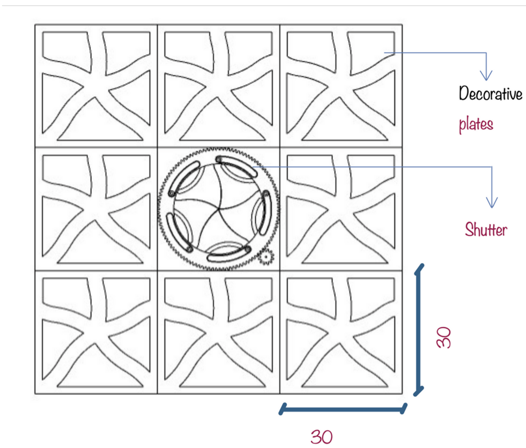
Categories	Factor	Weight	Concept 1	Concept 2	Concept 3
Feasibility	Balance in contribution	0.08	5.2	8.4	8.6
	Availability of materials	0.08	9	8.8	9.2
	Functionality of design	0.06	5.6	8.6	8.6
	Technical capabilities	0.14	6.8	7.2	7.2
	Ease of installation	0.04	5.2	7	6.4
Viability	Cost	0.14	6.6	7.2	6.4
	Time	0.21	6.6	6.6	7.2
Desirability	Reliability	0.0875	6.8	7.8	7.6
	Durability	0.07	5	7.4	8
	Comfort of use	0.0525	5.6	8.2	8.2
	Sustainability	0.035	7	6.8	6.6
	Aesthetics	0.0525	5.4	9	8.2
	Innovativeness	0.0525	4	8.8	7.2
TOTAL SCORES			6.9195	8.3775	8.307

Table 5: Decision Matrix

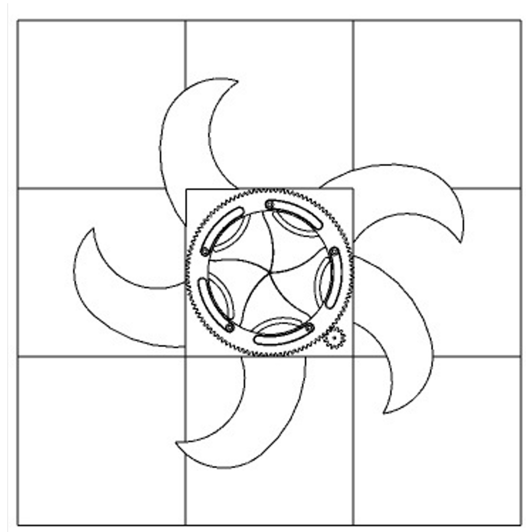
According to the decision matrix above, the best concept to implement is the mechanical shutter and the worst one is the motorized window.

8 Selected Concept

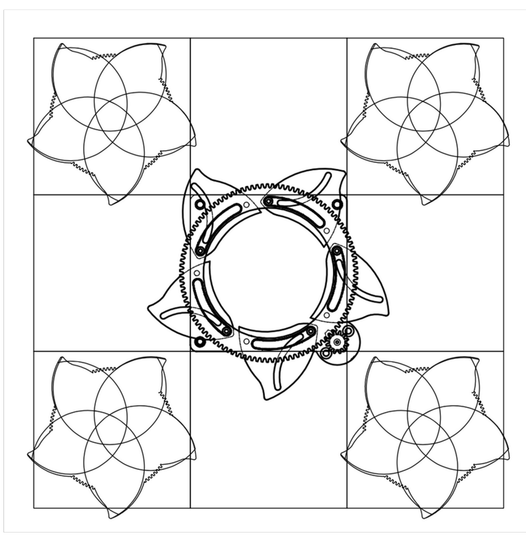
We decided to proceed with the mechanical shutter concept, and we started coming up with different designs for how it may look.



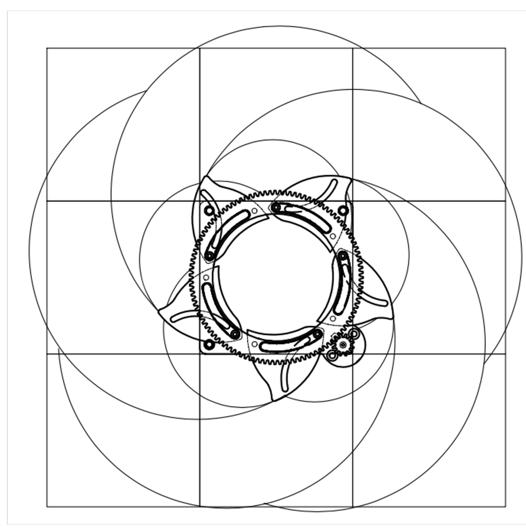
(a) Sample 1



(b) Sample 2



(c) Sample 3



(d) Sample 4

Figure 5: Four Design Samples

Given the time constraints imposed upon us for developing a prototype, our team opted for sample 4 as our preferred choice, primarily because it presented the most favorable characteristics as well as ease of modeling and implementation. Considering the limited time frame, the simplicity of sample 4's design and construction made it an ideal candidate for rapid prototyping, allowing us to expedite the development process and allocate our resources efficiently. By selecting this particular sample, we were able to streamline the modeling phase and focus our efforts on quickly bringing the prototype to fruition.

Engineering Drawings

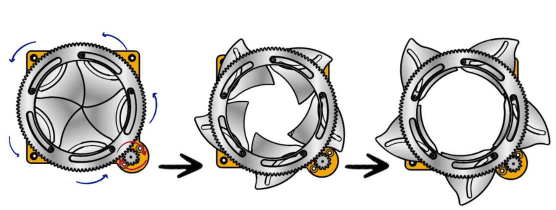


Figure 6: Shutter Mechanism

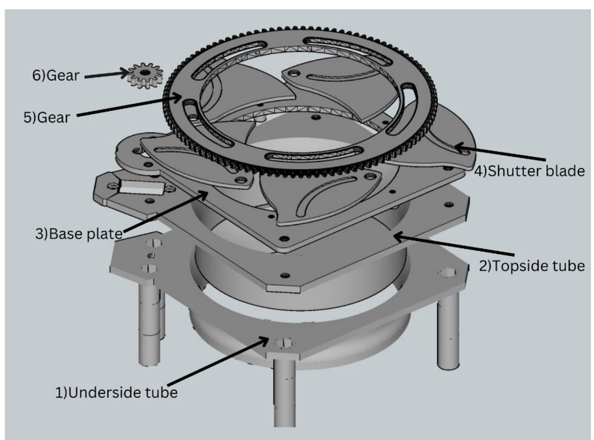
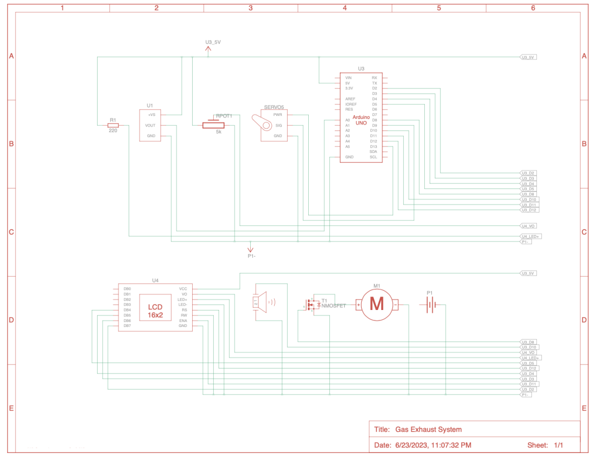
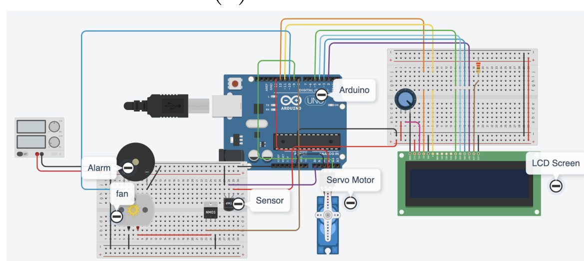


Figure 7: Exploded Diagram



(a) Schematic



(b) 3D Representation

Figure 8: Circuit

Name	**Quantity**	**Component**	**Specification**
SERVO5	1	Servo Motor	FT5835M Torque: 28.8 kg.cm @ 6.0V
U3	1	Arduino	Uno R3
U4	1	LCD	16 x 2
Rpot1	1	Potentiometer	5 kΩ
R1	1	Resistor	220 Ω
P1	1	DC Power Supply	RXN305D Single Output 0-30V 0-5A
PIEZO1	1	Buzzer	
U1	1	Gas Sensor	MQ-2
M1	1	Exhaust fan	2800 rpm
T1	1	NMOS Transistor	IRLZ44

Table 6: Bill of Materials with Specifications

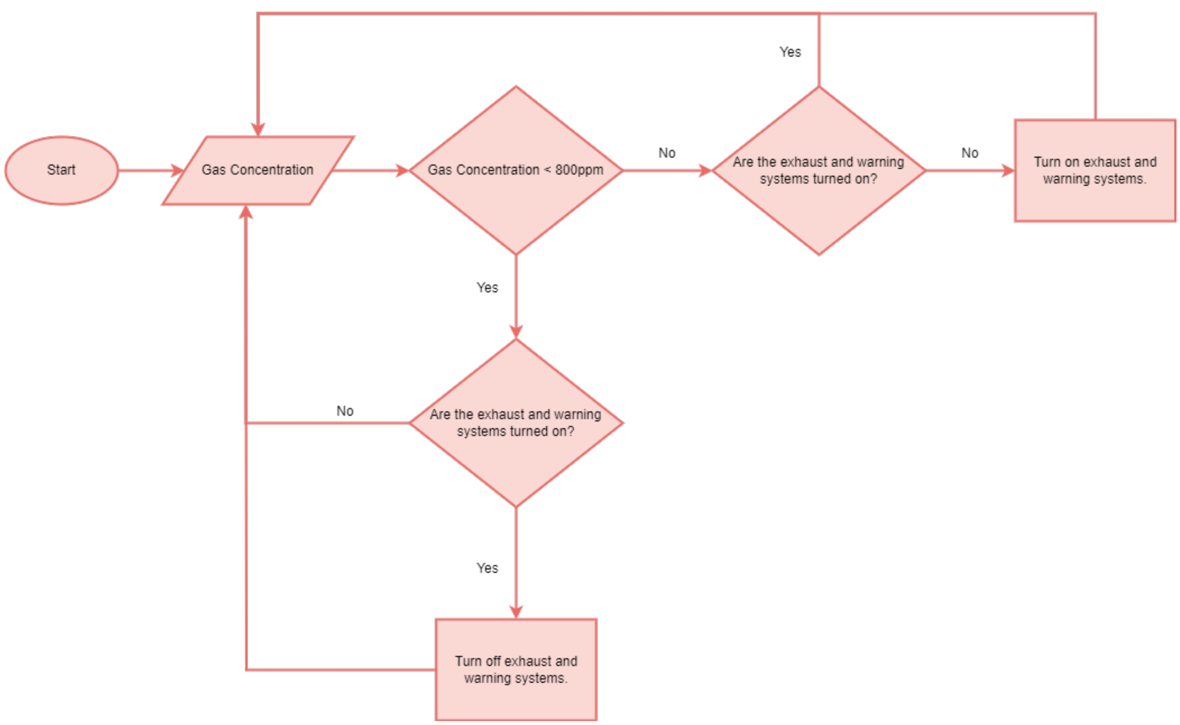


Figure 9: Flowchart

9 Risk and Reliability Analysis

Introduction

This section's objective is to give an in-depth examination of risk and reliability in the context of gas exhaustion. In order to evaluate the potential risks, weaknesses, and failures connected with complex systems or processes, risk and reliability analysis is essential. Organisations can improve safety, efficiency, and overall performance by methodically examining these aspects and coming to wise conclusions.

It is crucial for organisations to proactively identify and manage risks in the dynamic and interconnected world of today. Unexpected occurrences can significantly affect operations, financial stability, and reputation. Examples include equipment failures and natural calamities. On the other hand, reliability concentrates on comprehending the performance and dependability of systems or components under typical working circumstances. Organisations can create strategies to reduce possible threats and ensure system resilience by considering both risk and reliability.

In this section, important topics like hazard identification, risk assessment, reliability modelling, and mitigation measures will be covered. The analysis will be based on established methodology, standard procedures for the industry, and pertinent standards unique to the field.

Risk Register

ID	Risk Description	Category	Probability	Impact	Rating	Approach	Action	Responsible Person
R1	Gas sensor malfunction	Internal	Medium	High	High	Mitigate	1. Implement sensor redundancy for backup detection. 2. Regular calibration and maintenance of sensors.	Project Engineer
R2	Exhaust fan malfunction	Internal	Medium	High	High	Mitigate	1. Regular inspection and maintenance of exhaust fan. 2. Keep spare exhaust fan for immediate replacement.	Project Engineer
R3	False gas detection alarms	Internal	Low	Medium	Low	Monitor	1. Implement filtering algorithms to reduce false alarms. 2. Regular calibration and adjustment of alarm thresholds.	Project Engineer
R4	LCD screen malfunction	Internal	Low	Medium	Low	Mitigate	1. Regular inspection and maintenance of LCD screen. 2. Keep spare LCD screen for immediate replacement.	Project Engineer

ID	Risk Description	Category	Probability	Impact	Rating	Approach	Action	Responsible Person
R5	Communication failure with micro-controller	Internal	Medium	High	High	Mitigate	1. Implement communication error handling mechanisms. 2. Regular testing and monitoring of communication system.	Project Engineer
R6	Inadequate ventilation	External	Medium	High	High	Avoid	1. Design and install sufficient ventilation system. 2. Conduct periodic air quality tests.	HVAC Engineer
R7	Unauthorized access to the system	External	Low	Medium	Low	Mitigate	1. Implement secure authentication mechanisms. 2. Regular monitoring and auditing of access logs.	Security Engineer
R8	Fire hazard due to electrical malfunction or short circuits	External	Low	High	Medium	Mitigate	1. Implement fire safety measures and fire extinguishers. 2. Regular inspection and maintenance of electrical wiring.	Safety Officer

Table 7: Risk Register

Reliability Assessment

A micro-controller and a gas sensor are used in the gas detection and exhaust system discussed in this paper to search for odourless and colourless gases. It has a number of different parts, including an LCD screen for user interaction, an exhaust fan, a mechanical shutter driven by a servo motor, and an alarm system. This article will evaluate the system's reliability by focusing on its ability to rapidly and precisely detect gas leaks and notify the user of such occurrences.

1. Gas Sensor: The system's main purpose is to find gas leaks, especially those involving odourless and colourless gases. For the system to be effective overall, the gas detecting component's reliability is essential. The accuracy, sensitivity, and response time of the gas sensor are crucial components in defining the system's reliability. It is crucial to confirm that the gas sensor being utilised can accurately and reliably detect a variety of gases. The MQ-2 gas sensor that was utilised to create a prototype for our project can detect smoke as well as a number of gases, including butane and methane. Should our project enter the production stage, there are more versatile and precise gas sensors on the market that are better suited for high-quality products.

2. Mechanical Shutter and Servo Motor: A servo motor is used to operate the mechanical shutter, which is essential for getting rid of the gas leakage. The robustness and accuracy of the servo motor determine how reliable the mechanical shutter is. It is essential to pick a servo motor that can open and close the shutter consistently and properly in order to ensure adequate exhaustion of the gas. Furthermore, the material of the mechanical shutter should withstand wear and tear. The material we used in our prototype is wood; however, should our project enter the production stage, metal would be a better substitute for wood as it is better suited for the gears used in our shutter.

3. Exhaust Fan: The Exhaust Fan is in charge of eliminating the released gases from the environment and preventing their accumulation. To provide effective ventilation, the exhaust fan's reliability is essential. The fan should be able to produce enough airflow and run consistently for lengthy periods of time. To preserve the fan's reliability and avoid any potential failures, regular maintenance and periodic inspections are required.

4. Alarm System: The alarm system is a crucial safety component that warns people in the vicinity of a gas leak. The alarm system's ability to emit a loud, distinct sound that is easy to hear determines how reliable it is. To make sure the alarm system is reliable and effective, it must be tested frequently. The system's reliability during power outages can also be improved by including backup power sources, such as batteries.

5. LCD Screen and User Interaction: The LCD screen interacts with the user and displays messages about gas leaks and system status in real-time. The LCD screen's reliability is based on its sturdiness, visibility, and correct information display. It is essential to choose an LCD screen of superior quality that can withstand external factors and provide the user with clear and accurate information.

To increase the system's overall reliability, regular maintenance, testing, and the use of high-quality components are crucial. This gas detection and exhaust system can effectively reduce the risks associated with gas leakages by placing a priority on reliability, creating a safe environment for users.

Applicable Codes and Legal Requirements

When designing a gas detection and exhaust system, several legal frameworks and regulations need to be considered to ensure compliance with safety standards and requirements. Here are some relevant legal frameworks and regulations that may impact the design:

1. Occupational Safety and Health Administration (OSHA) Standards: OSHA has specific standards and regulations related to hazardous materials, including gases, ventilation systems, and alarm systems in workplaces. Compliance with OSHA standards ensures the safety and well-being of workers and helps prevent workplace accidents and injuries.

2. National Fire Protection Association (NFPA) Codes:
NFPA develops and publishes various codes and standards related to fire protection, including detection systems and ventilation requirements. Relevant codes may include NFPA 72: National Fire Alarm and Signaling Code and NFPA 54: National Fuel Gas Code.

3. International Mechanical Codes (IMC):
The IMC provides guidelines and requirements for the construction and occupancy of buildings. Specific sections related to ventilation, gas detection, and alarm systems should be considered to ensure compliance.

4. Environmental Protection Agency (EPA) Regulations:
EPA regulations focus on environmental protection, including emissions control and hazardous waste management. Depending on the type of gases detected, specific EPA regulations may apply, such as the Clean Air Act or regulations related to hazardous air pollutants.

5. Electrical Safety Standards:
Compliance with electrical safety standards, such as those outlined by the National Electrical Code (NEC), ensures the safe installation and operation of electrical components in the system.

6. Product Safety Certifications:
   Depending on the region or market where the system will be deployed, specific product safety certifications may be required, such as CE (Conformité Européene) marking in the European Union or UL (Underwriters Laboratories) listing in the United States.

7. Industry-specific Standards:
   Certain industries, such as pharmaceutical, chemical, or oil and gas, may have industry-specific regulations and standards that govern gas detection and ventilation systems.

The legal frameworks and regulations that apply in the particular region and sector where the gas detection and exhaust system will be used must be carefully studied. Working with professionals, consultants, and regulatory authorities can offer further direction and guarantee adherence to all pertinent regulations.

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