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AUTONOMOUS FLASHPOINT DETECTOR

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PROJECT REPORT

AUTONOMOUS FLASHPOINT DETECTOR

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ABSTRACT

The flash point is the lowest temperature at which a liquid can produce a flammable mixture with air through its vapors. This flash point temperature signifies how likely the test material is to create a flammable mixture with air when subjected to carefully controlled lab conditions. Consequently, the flash point of a substance hinges on the testing conditions and methods employed. The procedure for gauging the flash point is straightforward: A defined sample volume is placed into a test cup, which is held at the prescribed test temperature. After a specified duration, a test flame is introduced, and the presence or absence of a flash is noted. Flash point testing is utilized for a wide range of purposes, including quality control, hazard classification for transportation, compliance with waste disposal regulations, and contamination analysis. It stands as an essential testing method within the petrochemical industry. Petrochemical companies in Pakistan currently depend on foreign suppliers for acquiring flashpoint detection equipment. Consequently, the objective of this project is to design and manufacture an industrial-grade flashpoint detector locally. Our approach will involve employing electrical heating, a test flame, and temperature sensing mechanisms. The rate at which temperature changes will be tailored to the specific chemicals being tested and their respective flashpoint temperature ranges. To ensure precise temperature control, we will implement a PID (Proportional-Integral-Derivative) algorithm, which will effectively manage temperature fluctuations. Additionally, we will incorporate a user friendly Human-Machine Interface (HMI) for easy control, temperature adjustment, and other essential functionalities. Our ultimate aim is to create a flashpoint detector that can be manufactured within Pakistan, reducing the reliance on foreign suppliers in the petrochemical industry.

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LIST OF SYMBOLS

ASTM American Standard for Testing and Measurements

ISO International Organization for Standardization

OSHA The Occupational Safety and Health Administration

IP Ingress Protection

CC Closed Cup

OC Open Cup

PID Proportional Integral Derivative

PWM Pulse Width Modulation

Chapter 1 – INTRODUCTION

Flash point is defined as the lowest temperature of a liquid at which its vapours will form a combustible mixture with air. It is a convenient and reliable classification of the flammability of many substances. American Standard for Testing and Measurements defines Flashpoint as "the lowest temperature at which an ignition source causes the vapors of the test sample to ignite under specified conditions of the test." The flash point temperature then determines the tendency of the test specimen to form a flammable mixture with air when under these controlled laboratory conditions. This means that Flashpoint of a material depends on testing conditions and test methods used. The technique used to measure the Flashpoint is simple: A sample of specified volume is introduced to the test cup which is maintained at the test temperature. After a specified time, a test flame is applied and the presence or absence of a flash observed. Flashpoint testing is used for a variety of reasons:

1.1 Quality Control

Flash point testing is commonly employed by petroleum and chemical industries to detect contamination or adulteration of products, especially when multiple storage tanks with varying purity levels are connected through a shared pipeline system. The flash point serves as an indicator of potential contamination, with changes in flash point suggesting the presence of adulterants that can cause operational issues in costly equipment used in sectors such as shipping, power generation, construction, and mining.

1.2 Hazard classification for transportation

The flash point is employed in shipping and safety regulations to categorize the hazard potential of flammable and combustible materials, impacting transportation and storage costs. Industries utilizing solvents, such as paints and varnishes, can benefit financially by accurately determining the flash point of their finished products, especially when some solvents have lower flammability, allowing for potential cost savings.

1.3 Waste disposal regulations

It is important to measure the flashpoint of waste liquids on waste disposal plants so as to categorize the liquids for the combustion process. According to the new Punjab Hazardous Substances Rules, flashpoint of liquids determines their flammability category. Rapid testing of chemicals for this is required.

1.4 Contamination Analysis

Engine oil can behave as a thinner if it is contaminated with diesel or gasoline, which will cause the oil's viscosity to drastically decrease. Engine oil's viscosity is an important characteristic since it helps shield engine components from excessive wear and failure. If gasoline or diesel fuel is present in engine oil, a flash point test will reveal it. It can determine whether oil thinning is caused by contamination or degradation when used in conjunction with a viscosity test.

1.5 Motivation and Conclusion

Flashpoint Detection aims to classify chemicals for quality control, waste disposal regulation development, hazard classification and contamination analysis. It is essential in every type of petro-chemical production industry. There have been many standard methods developed for a flashpoint test. Classified broadly into Closed Cup and Open Cup, these include the conservative yet reliable Pensky-Martens test (a Closed Cup test) which has manual flash detection, gaseous heating and excitation of the vapor chamber. More modern alternatives of the Pensky Martens include the Setaflash Small Scale test and the Continuously Closed Cup test. These have modern electrical heating, electrical excitation and safety procedures built in. The Open Cup tests include Cleveland Open Cup, but that test is conservative, dangerous and has manual operation. There are also various regulations developed for safety. These include OSHA regulations, NFPA and CLP regulations. There are also various internal safety regulations developed by flashpoint detection OEMs. Ingress Protection standards also dictate the conduct and procedures related to each standard and their usage.

From our discussions above it is clear that we will need modern and automatic methods of flash detection. ASTM D3278, D3828, D7236, serve these purposes. These methods use a smaller sample size, allow the use of electric heating and electric arc generation for flash. Flash detection in these methods is also carried out by optic means. Thus, these are the methods we will be using in our project, as they allow for automation in operation.

Our aim from this project will be to bridge the gap between academia and industry. We will be making the first indigenously developed flashpoint detector in Pakistan. We aim to develop this using locally sourced parts and equipment. This will, thus, reduce development cost, clear out any import roadblocks that companies in Pakistan may have to face, and allow the emergence of new locally produced equipment for the future.

Chapter 2 – LITERATURE REVIEW

2.1 Flashpoint Detection Methods

There are two main methods of Flashpoint testing: Closed Cup (CC) and Open Cup (OC).

2.1.1 Closed Cup (CC)

The purpose of closed cup testing is to mimic a liquid spill in a confined space. When a potential ignition source comes into contact with a liquid that is at or above its flash point, there is a risk of fire or explosion. The sample is put within a sealed, closed test cup and the ignition source is inserted to determine the sample's flash point—the temperature at which it ignites or "flashes." Different closed cup procedures exist depending on the equipment, process, and type of liquid to be evaluated. Among the typical ones are:

2.1.1.1 Pensky-Martens closed cup test

One of the earliest flashpoint detection methods that is still in use today is the Pensky-Martens closed cup test. IP 34, EN ISO 2719, and ASTM D93 are the standards for it. These test procedures involve using a manual or automated PMCC device to determine the flash point of petroleum products in the 40–360 °C temperature range. They are also utilized by automated PMCC equipment to ascertain the biodiesel's flash point in the 60–190 °C temperature range. [1]

Fig. 1 Traditional PMCC apparatus

2.1.1.2 Abel closed cup test

For shipping and safety regulations, flammable and combustible goods are tested using the Abel Closed Cup Flash Point Test. IP 170, IP 491, IP 492, and ISO 1376 standardize this. The closed cup flash points of flammable liquids with inclusive flash points ranging from -30 to 70 °C are determined using these test procedures. Nevertheless, this method's precision is limited to flash temperatures between -5 and 66.5 °C.

Fig 2 . Traditional Abel Close Cup

2.1.1.3 Tag closed cup test

The ASTM D56, ASTM D3934, ASTM D3941, ASTM E502, IP 491, IP 492, ISO 1516, and ISO 1523 standards all apply to the Tag closed cup test. These test procedures address the determination of the flash point of liquids having a viscosity below 5.5 mm2/s (cSt) at 40 °C, or below 9.5 mm2/s (cSt) at 25 °C, and a flash point below 93 °C using tag manual and automatic closed testers.

[3]

Fig3. Traditional Tag Closed Cup Tester

2.1.1.4 Setaflash Small Scale

The Setaflash Small Scale test method is standardized by ASTM D1655, ASTM D3278, ASTM D3828, ASTM D7236, ASTM D8174, ASTM E502, CLP Regulations, DEF STAN 91-91, EPA 1020 A & B, IP 523, IP 524, IP 534, IP 602, ISO 3679, ISO 3680, ISO 9038 and UN Class 3 Non-Viscous Flammable Liquids. These techniques use a small size closed cup tester to cover petroleum products and biodiesel liquid fuels over a temperature range of -30 to 300 °C. The methods can be used to find the flash point of a sample (method B) or whether a product would flash or not at a certain temperature (flash/no flash method A). These techniques work well for biodiesel flash point tests, like FAME, when combined with an electronic thermal flash detector. In order to identify and categorize flammable and combustible items in accordance with safety standards like CLP, small-scale testers are also utilized in transportation.[4] [5] [6]

Fig 4. Setaflash Series 3 Apparatus

2.1.1.5 Continuously Closed Cup Test

This test method uses a constantly closed cup tester to determine the flash point of liquids such as solvents, lubricants, fuel oils, and other liquids. It is standardized by ASTM D6450, while ASTM D7094 standardizes the updated version covered in Section 5. This test method uses a constantly closed cup tester to determine the flash point of liquids such as solvents, lubricants, fuel oils, and other liquids. Samples with a flash point between 10 °C and 250 °C can be tested using this technique.[7] [8]

2.1.2 Open Cup (OC)

Open cup tests mimic the possibility of a liquid spill igniting in an unconfined space, such as a spilled liquid pool on the ground. Open cup instruments are used in fire point, combustibility, and prolonged burning testing. The lowest temperature of a liquid at which vapour combustion and burning begin when an ignition source is applied and continue to burn even after the ignition source is removed is known as the fire point. Tests for prolonged burning and combustibility are often conducted at a set temperature to ensure that the test specimen burns continuously. Since an open cup allows vapours to freely escape to the atmosphere above the instrument, an open cup instrument will always have a greater flash point than a closed cup. Closed cup test are usually specified due to improved precision.

2.1.2.1 Cleveland Open Cup Tester

ASTM D92 and AASHTO T48 provide standards for the Cleveland Open Cup Tester. These test procedures explain how to use an automated or manual Cleveland open cup apparatus to determine the fire and flash points of petroleum products. With the exception of fuel oils, it applies to all petroleum products having flash points between 79 and 400 degrees Celsius.

Fig 5. Cleveland Open Cup Tester

We will be focusing on Closed Cup Flashpoint Detection as it is most suitable for petroleum fuel and biofuel applications as well as a vast majority of other chemicals. Also in trying to make an Open Cup flashpoint detector we will also need to incorporate a method of Fire Point detection, which is both hazardous and outside the scope of our project. [9]

2.2 Review Table of Standards

The standards for the various methods described in the above sections dictate the working principle, design standard, temperature ranges and chemical test samples for the various test methods and test apparatus. As such it important to have a review table for quick referencing of the standards of each test method.

Table 1. Summary table for standards

Name of Method	ASTM	ISO	IP	OTHERS
Pensky Martens	D93	2719:2016	34	N/A
Abel	N/A	13763:2021	170, 491, 492	N/A
Tag	D56, D3934, D3941, E502	1516:2002, 1523:2002	491, 492	N/A
Setaflash	D1655, D3278, D3828, D7236, D8174, E502	3680:2004, 9038:2021	523, 524, 534, 602	CLP Regulations, DEF STAN 91-91, EPA 1020 A & B, UN Class 3 Non-Viscous Flammable Liquids
Continuously Closed	D6450, D7094*	N/A	N/A	N/A

*Modified Continuously Closed Cup Test

2.3 Advances in Flashpoint Detection Techniques

The fundamental ideas behind Flashpoint detection are still the same. However, several apparatus developments have been made possible by technological advancements. Sensors and computerized detection are among the modifications. Automated flashpoint checking for materials that are already known, and algorithm-based flashpoint prediction for novel materials. The production of digital flashpoint detectors for flashpoint analysis by the chemical, oil and gas, and other associated industries has typified this period in flashpoint detection. Comparable outcomes to manual testing have been obtained using this. For different standards, Seta, Koehler, Anton Parr, and Eralytics are just a few of the companies that have created detectors for Open and Closed Cup testing in single analysers.

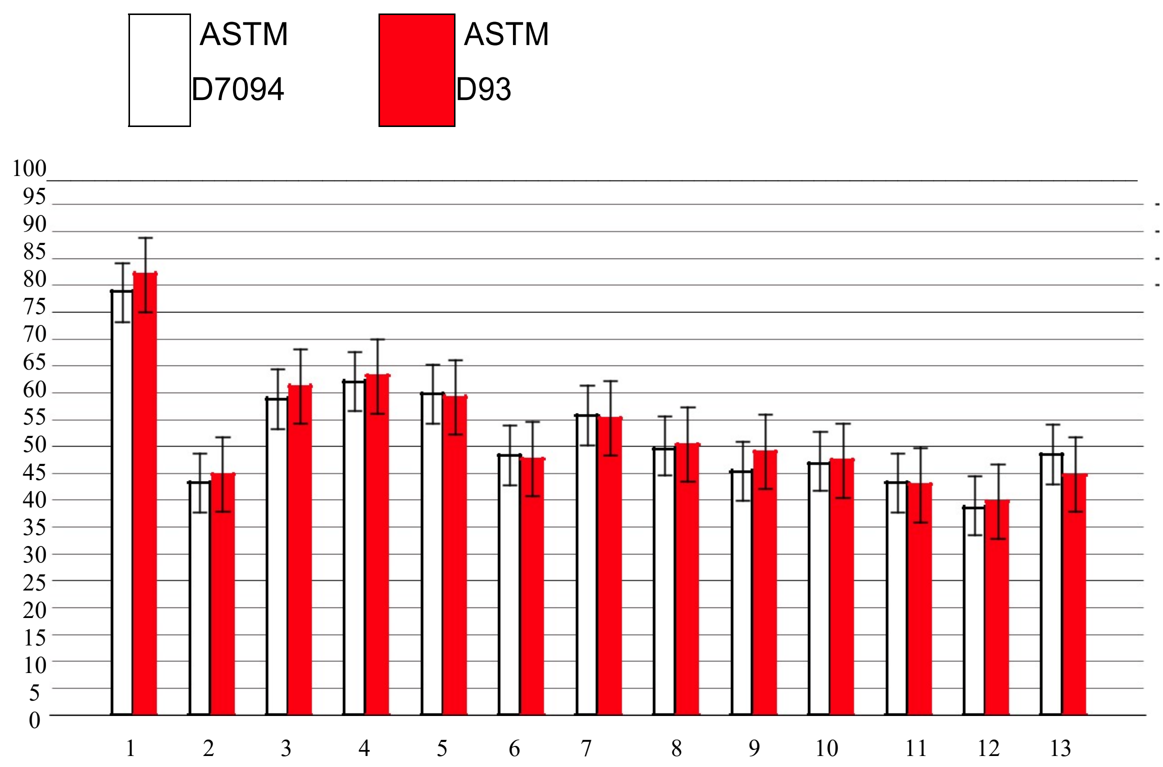
Fig 6. Anton Parr's PMA-5, a modern PMCC Apparatus

It is worth noting that Eralytics in this regard have developed the Eraflash. This detector/analyzer is based on the Modified Continuous Closed Cup Method. It is standardized by ASTM D7094. This was deemed as a modern alternative to the Pensky-Martens Closed Cup Method for being more efficient, practical and in line with modern digital technology. It was officiated by ASTM in 2013.

The Modified Continuous Closed Cup Method uses a continuously closed cup tester with a specimen size of 2 mL and a cup size of 7 mL with a heating rate of 2.5 °C per minute to determine the flash point of fuels, including diesel/biodiesel blends, lubricating oils, solvents, and other liquids. With this test procedure, air is injected into the test chamber through a closed, unsealed cup. This approach works at temperatures between 35°C and 225°C. This technique makes use of electric heating techniques. Optical sensing is necessary in all other methods to verify the liquid's flash point. This technique uses the change in pressure as flash occurs to determine the material's flash point.[10] [8]

An excerpt from Eralytics Eraflash Report states that:

“An ASTM round robin test proved that no statistically significant bias exists between ASTM D93 and ASTM D7094 for fuels and contaminated fuels. The test report states a repeatability (r) of 4.1 °C for both methods and a reproducibility (R) of 5.5 °C for ASTM D7094 and 6.9 °C for ASTM D93. Consequently, ASTM D7049 is now accepted in the specifications of Fuel Oils (ASTM D396), Diesel Fuel Oils (ASTM D975), Gas Turbine Fuel Oils (ASTM D2880), Kerosene (ASTM D3699) and Diesel Fuel, Biodiesel Blend (ASTM D7467).”[11]



[1] Dodecane

[2] Anisole

[3] Diesel (1)

[4] Diesel (2)

[5] Diesel (3)

[6] Diesel (1) w/ 0.5% gasoline

[7] Diesel (2) w/ 0.3% gasoline

[8] Jet A(1)

[9] Jet A(2)

[10] Jet A(1) w/ 0.25% gasoline

[11] Jet A(2) w/ 0.4% gasoline

[12] Jet A(2) w/ 0.7% gasoline

[13] Jet A(2) w/ 2.0% biodiesel

Fig 7. Eraflash's Comparison

Fig 8. Eralytics Eraflash Tester

Other modern methods also exist. For example the Setaflash Series 3, described above in Section 2.1.4, utilizes a modern approach called Small Scale Closed Cup testing method. The test method is applicable to paints, enamels, lacquers, varnishes, solvents, and related products having a flash point between 0 °C and 110 °C (32 °F and 230 °F) and viscosity lower than 15 000 mm2/s (cSt) at 25 °C (77 °F). [10]

2.4 Safety Standards and Regulations

The safety standards and regulations related to flashpoint detection in relevant industries are designed to protect workers and the environment from the hazards associated with flammable liquids. These standards and regulations typically specify the following:

- The type of flashpoint test that must be performed
- The equipment that must be used for flashpoint testing
- The safety procedures that must be followed when performing flashpoint testing [12]

The following are some of the most important safety standards and regulations related to flashpoint detection:

2.4.1 OSHA 29 CFR 1910.106:

This regulation requires employers to provide a safe workplace for workers who are exposed to flammable liquids.[13]

2.4.2 NFPA 30:

This standard provides guidelines for the safe storage and handling of flammable and combustible liquids.[14]

2.4.3 CLP Regulation:

The CLP (Regulation (EC) No 1272/2008) is a regulation in force in the European Union that provides a harmonized system for the classification, labelling and packaging of substances and mixtures. By guaranteeing that chemicals are packaged in a way that minimizes risks to human health and the environment, as well as by giving users clear and consistent information about their hazards, the CLP Regulation seeks to improve the safety of chemicals. The Globally Harmonized System of Classification and Labelling of Chemicals (GHS), created by the United Nations, serves as the foundation for the CLP Regulation. A global standard for the categorization, marking, and packing of chemicals is the GHS. It is utilized in more than 170 nations worldwide.

All compounds and combinations must be categorized and labelled in accordance with their dangers, as per the CLP Regulation. A substance's or mixtures chemical makeup, as well as its physical and chemical characteristics, define its dangers. All compounds and mixtures must be packaged in a way that minimizes hazards to the environment and public health, according to the CLP Regulation. The packaging needs to be appropriate for the kind of material or combination and properly labelled with all pertinent safety information.[15]

Here are some of the key features of the CLP Regulation:

- It is a harmonized system, which means that the same rules apply to all substances and mixtures placed on the market in the European Union.
- It is based on the Globally Harmonized System of Classification and Labelling of Chemicals (GHS), which is a global standard for the classification, labelling and packaging of chemicals.
- It applies to all substances and mixtures placed on the market in the European Union, including those used in industry, agriculture, households, and commerce.
- Requires that all substances and mixtures be classified and labelled according to their hazards.

  Requires that all substances and mixtures be packaged in a way that prevents risks to human health and the environment.

In addition to safety standards and regulations, there are also several best practices that can be followed to improve the safety of flashpoint detection. These best practices include:[15]

- Equipment: Using the proper equipment for flashpoint testing.
- Safety standard: Following all safety procedures when performing flashpoint testing.
- Ventilation: Flashpoint detection should always be performed in a well-ventilated area to prevent the buildup of flammable vapors.
- No smoking or open flames: Smoking and open flames should never be allowed in areas where flammable liquids are present.
- Proper disposal: Dispose of flammable liquids properly to prevent the contamination of the environment.
- Training: All personnel who work with flammable liquids should be trained in the safe handling and use of these materials.

- Knowledge: Ensure that every employee is aware of the risks associated with these substances and the consequences of handling them improperly. There should be a variety of indicators and Safety Data Sheets (SDS) available.
- Personal protective equipment (PPE): When handling combustible substances, wear the proper personal protective equipment (PPE), such as lab coats, closed-toe shoes, and safety glasses.
- Eye Protection: Vapors can cause eye irritation and dangerous situations. Eye protection needs to be qualified to withstand any corrosive materials since certain fumes can be corrosive. Eye protection equipment (PPE) includes face shields, glasses, and goggles.
- Gloves: The gloves should not only be non-flammable but also non-absorbent. Various elements can be absorbed by flammable and combustible liquids, potentially leading to dangerous situations. To prevent spills and mishaps, the gloves should also provide flexibility and grip.
- Protective Clothing: Adding more layers of protection can help keep workers safe from fires. Employees might put on HAZMAT suits or flame-retardant coveralls over their ordinary clothes, for instance.
- Footwear: If at all possible, boots should be neither absorbent nor flammable. Additionally, these boots need to have enough traction to prevent trips and falls when handling or transporting combustible and hazardous liquids.
- Headwear: It could be essential to wear helmets and other headgear to guard against falling objects. Additionally, by keeping hair off of the face, these devices help avoid eyesight impairment. Additionally, hair is very combustible, so covering it can help prevent an accidental fire.
- Breathing Apparatus: It is imperative for workers handling combustible and flammable chemicals to protect their respiratory systems from hazardous fumes. In many situations, a face mask should provide adequate protection; however, if the fumes are caustic or the vapor levels are excessive, workers may require an oxygen supply.
- Use Non-Static Clothing: Some liquids are so flammable that they can ignite from a single spark, so all workers should wear non-static clothing.

- Keep Liquids Out of Sunlight: A flammable or combustible liquid may evaporate when heated. Airtight containerized liquids have the risk of building pressure and exploding. Workers may be exposed to health risks due to vapor-rich air mixes created by sunshine, even in containers with ventilation.
- Bond and Ground Metal Containers: The process of joining two conductive items to give them the same electrical potential is known as bonding. Since energy flows into the earth when an object is grounded, it has no electrical potential. When storing or moving any metal container, make sure to ground and bind it to prevent sparks and electrical discharge.
- OSHA 29 CFR 1910.106: This standard sets forth requirements for the handling, storage, and use of flammable liquids. It includes requirements for such things as labeling, ventilation, and fire prevention.
- NFPA 30: This standard provides a comprehensive set of requirements for the safe storage and handling of flammable and combustible liquids. It includes requirements for such things as tank construction, spill control, and fire prevention.
- ANSI Z136.1: This standard specifies requirements for personal protective equipment (PPE) for use in flammable liquid environments. It includes requirements for such things as clothing, eye protection, and respiratory protection.
- Emergency procedures: These procedures are used to evacuate workers from the workplace in the event of a fire, explosion, or other emergency. Use of fir alarm, Safety exist.

2.4.4 Ingress Protection

It must follow Ingress Protection (IP) rating that indicates the degree of protection provided by an enclosure against the intrusion of foreign objects and liquids. IP ratings are defined by the international Electro technical Commission (IEC) and are used to help consumers and manufacturers make informed decisions about the suitability of electrical equipment for a particular environment. Usually flashpoint detector follow IP34.[16]

Here is a table that shows the different levels of protection provided by IP ratings:

Table 2. Complete table of Ingress Protection standards

IP Rating	Protection Against
IP00	No protection
IP01	Protected against drops of water falling vertically
IP02	Protected against drops of water falling vertically up to 15 degrees from vertical
IP03	Protected against spray of water from any direction
IP10	Protected against solid objects with a diameter greater than 50 millimeters (2.0 inches)
IP11	Protected against solid objects with a diameter greater than 12 millimeters (0.47 inches)
IP12	Protected against solid objects with a diameter greater than 2.5 millimeters (0.10 inches) and against water jets from any direction under a pressure of up to 30 kPa (4.3 psi)
IP13	Protected against solid objects with a diameter greater than 1 millimeter (0.04 inches) and against water jets from any direction under a pressure of up to 60 kPa (8.8 psi)
IP14	Protected against solid objects with a diameter greater than 0.5 millimeters (0.02 inches), against jets of water from any direction under a pressure of up to 100 kPa (14.5 psi), and against splashing water
IP20	Protected against falling dirt
IP21	Protected against dripping water when tilted up to 15 degrees from vertical
IP22	Protected against spraying water
IP23	Protected against spraying water from any direction
IP30	Protected against solid objects with a diameter greater than 2.5 millimeters (0.10 inches) and against water jets from any direction under a pressure of up to 100 kPa

	(14.5 psi)
IP31	Protected against dust and jets of water from any direction
IP32	Protected against dust and splashing water
IP33	Protected against dust, jets of water from any direction, and spray from a hose
IP34	Protected against dust, water jets from any direction, and powerful jets from a hose
IP35	Protected against dust and low-pressure jets from any direction
IP36	Protected against dust and high-pressure jets from any direction
IP50	Protected against dust
IP51	Protected against dust and dripping water
IP52	Protected against dust and splashing water
IP53	Protected against dust, splashing water, and low-pressure jets from any direction
IP54	Protected against dust, splashing water, and high-pressure jets from any direction
IP55	Protected against dust and jets of water from any direction
IP56	Protected against dust, jets of water from any direction, and powerful jets from a hose
IP60	Protected against total immersion for up to 30 minutes
IP61	Protected against total immersion for up to 1 minute
IP62	Protected against total immersion for up to 3 minutes
IP63	Protected against total immersion for up to 5 minutes
IP64	Protected against total immersion for up to 10 minutes
IP65	Protected against continuous high-pressure jets from any direction
IP66	Protected against continuous high-pressure jets from any direction and powerful jets

	from a hose
IP67	Protected against temporary immersion up to 1 meter for 30 minutes
IP68	Protected against permanent immersion
IP32	Protected against dust and splashing water
IP33	Protected against dust, jets of water from any direction, and spray from a hose
IP34	Protected against dust, water jets from any direction, and powerful jets from a hose
IP35	Protected against dust and low-pressure jets from any direction
IP36	Protected against dust and high-pressure jets from any direction
IP50	Protected against dust
IP51	Protected against dust and dripping water
IP52	Protected against dust and splashing water
IP53	Protected against dust, splashing water, and low-pressure jets from any direction
IP54	Protected against dust, splashing water, and high-pressure jets from any direction
IP55	Protected against dust and jets of water from any direction

Please note that IP ratings are only a guide and should not be used as a substitute for proper safety precautions.

2.4.5 OSHA

Federal regulations pertaining to the handling, storage, and transportation of flammable and combustible liquids are overseen by OSHA. Although there are much too many rules to mention here, a few fundamental ones are as follows:[17]

- OSHA-approved containers and portable tanks holding up to five gallons must be used to store all flammable and combustible liquids. Products and liquids that are difficult to pour and come in one-gallon or smaller containers should be stored in their original packaging.

- No flammable or combustible liquids are allowed to be kept in storage areas such as stairwells, entrances, or exits.
- Unless authorized storage materials or containers are used, a single room's maximum storage capacity is 25 gallons. In order to prevent combustion, wood used to store flammable or combustible liquids needs to be laminated and at least one inch thick. For storage, the majority of metal cabinets and shelves are suitable.
- Every cabinet and storage container needs to have a warning label that says, "Flammable - Keep Away from Open Flames."
- Combustible or flammable liquids should not be stored alongside any components that, when combined with water, could cause a fire.

Here are some additional safety tips for flashpoint testing:[13]

- Do not overfill the test cup.
- Use a test flame that is the correct size for the type of cup you are using.
- Do not leave the test running unattended.
- Be aware of the flash point of the liquid you are testing.

Here are some of the potential hazards associated with flashpoint detection:

- Fire: Flashpoint detection involves the use of flammable liquids, which can pose a fire hazard.
- Explosion: The vapors of flammable liquids can explode if they are ignited.
- Injuries: Exposure to flammable liquids can cause skin burns, eye injuries, and respiratory problems.

By following the safety standards and tips listed above, you can help to prevent accidents and injuries associated with flashpoint detection.

The National Fire Protection Association (NFPA) defines three classes for both liquid types. Here is a breakdown of each classification.[14]

Flammable Liquids:

Class I-A: Boiling point below 100 degrees F and flashpoint below 73 degrees F (23 degrees C). Diethyl ether and petroleum are examples of this class.

Class I-B: Boiling point at or above 100 degrees Fahrenheit and flashpoint below 73 degrees Fahrenheit. Ethanol and acetone are two examples.

Class I-C: No boiling point, flashpoint between 73 and 100 degrees Fahrenheit. P-xylene is one member of this class.

Combustible Liquids:

Class II: Flashpoint: 101–140 degrees Fahrenheit (39–60 degrees Celsius). Diesel fuel and other cleaning chemicals are two examples.

Class III-A: Flashpoint: 141–199 degrees Fahrenheit (61–93 degrees Celsius). Mineral oil and paintings with an oil basis are two examples.

Class III-B: Flashpoint 200 degrees Fahrenheit (93 degrees Celsius) or higher. Nectar from neat's-foot is one example.

The compounds' upper and lower explosive limits should also be taken into account. These limits relate to the concentration of vapors in the air and show when vapor is most combustible. It is too "lean" to ignite if the concentration is below the lower limit. The combination is too "rich" to ignite if the concentration is higher than the top limit. Rich vapor mixes are still harmful at high doses, though, as they can result in symptoms like headaches, vomiting, and dizziness.

2.5 Applications

We have already given some major applications of Flashpoint testing in industry and health safety. However here we give some applications of Flashpoint Testing for specific chemical industries. These industries range from pharmaceutical to makeup, oil and gas and many more. All require Flashpoints as a way to check chemicals and hence require different types of flashpoint detectors.[2]

Table 3. Uses of Flashpoint testing in various chemical industries.

Adhesives and sealants	For certification, esters and ketones must be tested. Transport rules' classification of flammability
Aviation and aircraft	Inspection of incoming oils and fuels for quality. Conformance to specifications
Chemicals	Testing the production-related solvents. Transport rules' safety classification
Chemical products (polishes, cleaners etc)	Most goods have stated flash point criteria. Transport rules' classification of flammability
Formulated pesticides	Research and flammability classification for transport regulations
Lubricants	Quality control and research. Used oil analysis
Oil and gas rigs	Quality of samples. Sump contamination of pump head machinery
Oil treatment/recovery	Monitoring the quality of base oils and determining whether recovered or used fuels and oils are contaminated. Transport rules' safety classification.
Other uses	These include research institutes, engine manufacturers and test laboratories
Paints and varnishes	Research, quality control, and safety. The flammability rating as per transport rules. Recommended for water-based paints
Perfumes, flavours and fragrances	Tests on combinations of water and solvent. Classification of flammability for transportation laws and operational safety
Petroleum and derivatives refining	Fully applicable on Aviation Turbine Fuel (D1655/DEF STAN 91-091), Diesel (D975), Fuel Oil (D396), Gas Turbine Fuel (D2880) and Kerosine (D3699)
Pharmaceuticals	Checks on manufacture stated flash points
Printing inks	Flammability classification for transport regulations
Road tanker terminals/shipping terminals	Quality control of storage tanks and deliveries. Safety classification for transport regulations

Synthetic resins	Tests on basic items based on solvent-resin. Transport rules' rating of quality and safety
Transport regulations	Flammability classification for road, rail, air and sea
Vegetable and edible oils	Some test to ensure low flammability classification
Waste disposal	Tests used to classify waste prior to disposal

In Pakistan there is a huge gap as these detection devices are not indigenously produced. They are ordered from overseas companies. Often, Pakistani companies have import problems and high import costs to overcome in order to acquire these devices. Also, these devices are made on an order to acquire basis, and, thus it is harder to estimate a price for them. Generally these devices cost anywhere from 1.2 million to 4 million PKR to order, acquire and install. Thus, there is a need for indigenous development in Pakistan for these devices, as development from off-the –shelf components and parts will enable a less costly development cycle for these products.

Chapter 3 – METHODOLOGY

3.1 3D Modeling

For the designing of our apparatus , we have designed different models and done analysis to determine the right model.

3.1.1 Chassis Design

For the designing of chassis, we used SolidWorks software. After designing different models and analyzing through ANSYS we came up with the following design and material.

- 12in width * 6in breadth *9in height.
- Hollow 0.5in * 0.5in steel pipe with thickness 1mm thickness.
- Left rectangle space for Cup and heating mechanism placement.
- Right rectangle space for Electronics placement.
- LLPD Lid for closing and sealing the cup.

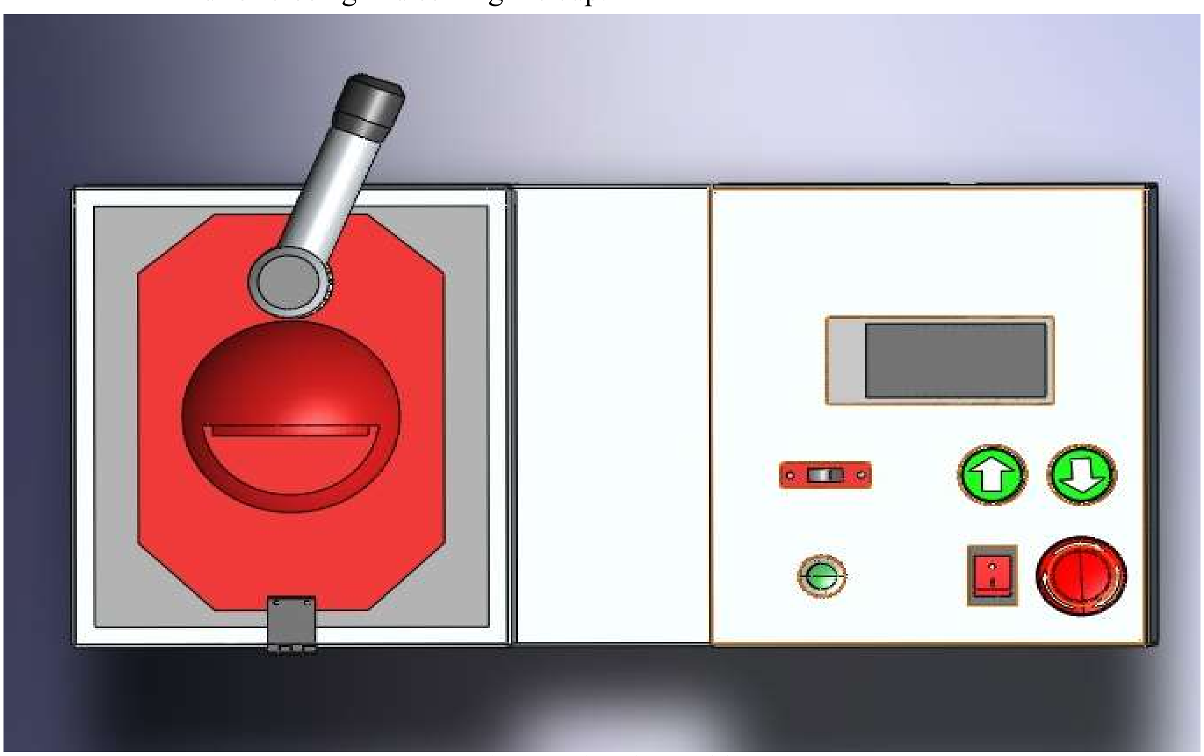


Fig 9. Top view of 3D Model

- Led for output display.
- Button for input.
- Center space for the separation of electronics and heating appliances.

3.1.2 Structural Analysis

We did static structural analysis because of which we decided to go with the following chassis design. Following are the boundary condition for the analysis.

- 200N Force applied on the top surface of the model.
- 10s time for simulation.
- Meshing size of 2mm.

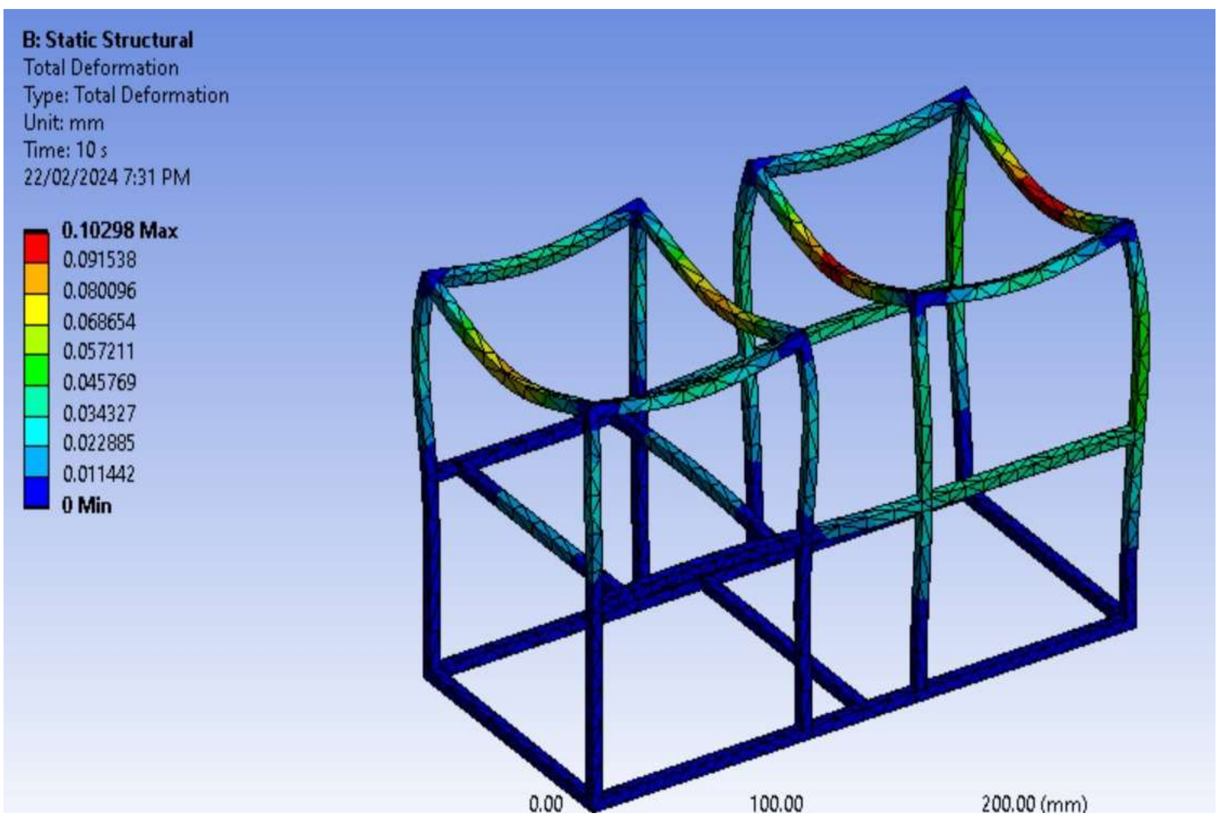


Fig 10. Structural Analysis of chassis

3.1.3 Thermal Analysis

We did thermal analysis to determine the behavior of different items and material used on the model. As we must determine the right material and design for the safe process of heating. For the insulation of steel chassis from the cup we test ceramic material for holding the cup. Then we tested on mortar material for holding the cup. Due to easy of making a mortar cup holder and insulation in are temperature range. We went for mortar for insulation purpose.

3.1.3.1 1st test

Following are the boundary conditions.

- 150 C applied from the bottom side of the cup where heating element is attached.
- 300 sec simulation time.
- Meshing size of 2mm.
- Aluminum cup used.
- Mortar insulation for holding the cup.
- Acrylic sheet for outside covering of the chassis.

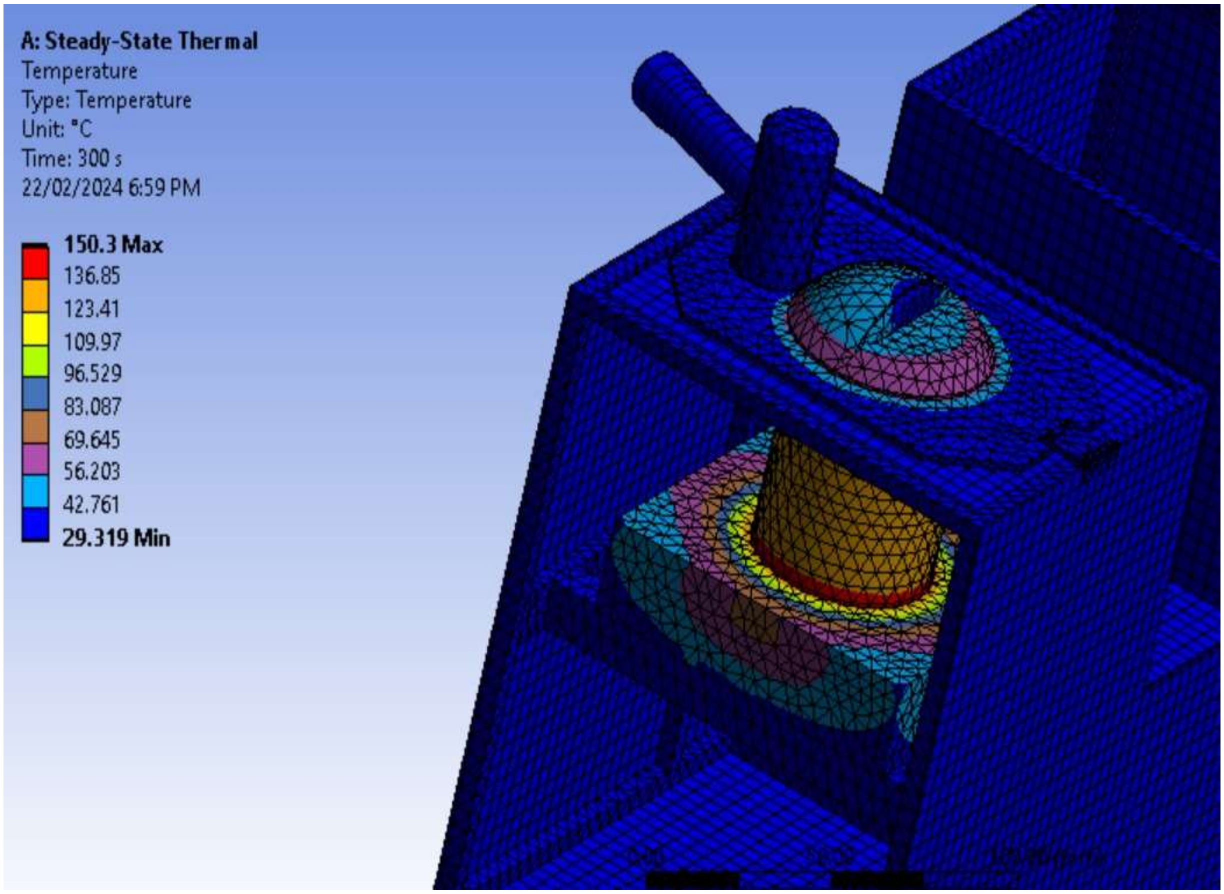


Fig 11. Thermal analysis of aluminum cup and insulation

Conclusion:

Perfect option for heating as it heats and cools down rapidly. Insulation heats up to a safe temperature . Due to unavailability of cheap manufacturing facility. We must find other options.

3.1.3.2 2nd test

- Steel cup .
- 150 C temperature.
- 300 sec simulation time.
- Meshing size 2mm.
- Mortar insulation for holding the cup.
- Acrylic sheet for outside covering of the chassis.

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Conclusion:

Due to easily availability of manufacturing steel cup, we selected steel cup for our prototype design.

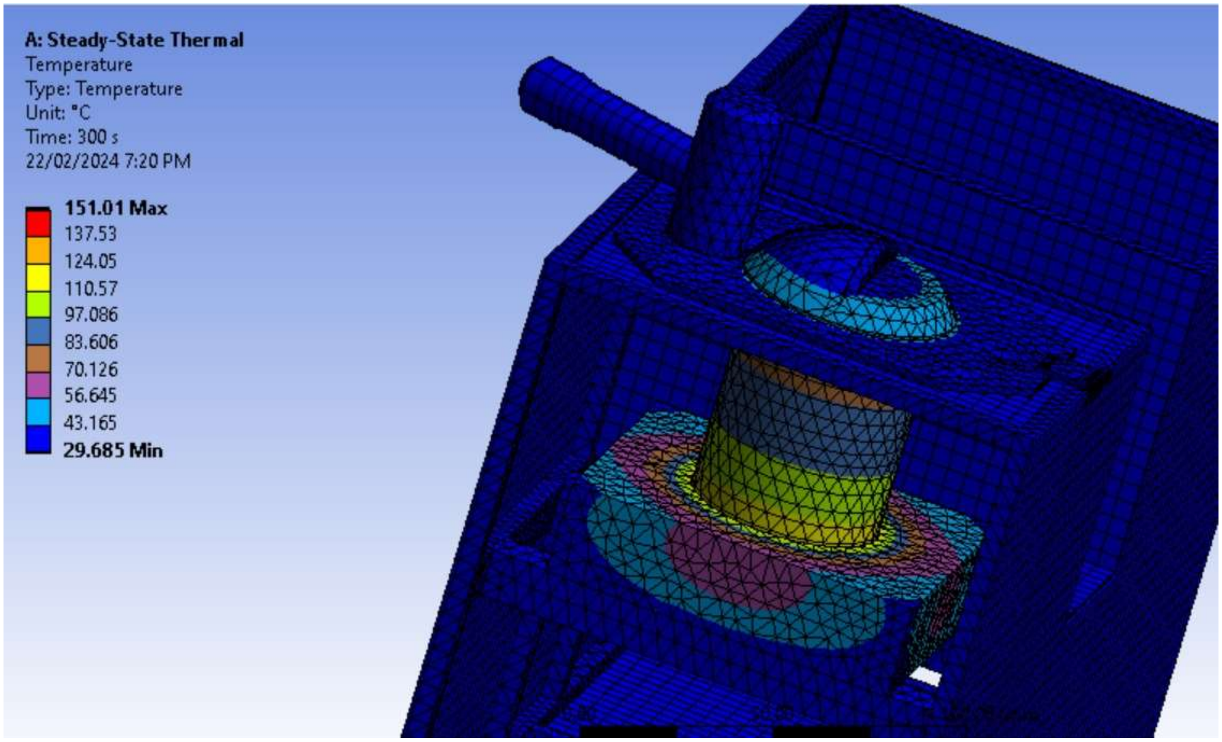

Fig 12. Thermal analysis of steel cup and insulation

3.2 Fabrication

The fabrication part consists of making steel chassis, steel cup, chassis covering, and mortar insulation.

3.2.1 Chassis

First, we buy steel pipe of the specified dimensions and cut it in the required length. We welded the part together. We used a 2mm thick acrylic sheet for the outside covering. We made a hole in the steel pipe for the attaching of acrylic sheets.

Fig 13. Chassis fabrication

3.2.2 Cup and insulation

We used steel sheets for the making of cup. For mortat insulation we mixed cement, sand , and water in the specified propoation and pour it in plastic mold of the required shape to make it.

Fig 14. Steel cup, mortar insulation and chassis

3.2.3 Lid

For the lid we used LLPD kettle lid for it. We laser cut acrylic sheet for the top covering. Weattached lid from one side for easy opening, closing of the cup and also to attach the sensor.

3.2.4 Electronics interaction board

For this we laser cut the acrylic sheet with the required space for LED and buttons. We have the following button.

- Red button is the start/stop button.

- Black circular push button for changing the set temperature.
- Small rectangular slide button for mode selection.

3.3 Hardware Components

3.3.1 ESP32 microcontroller

The ESP32 microcontroller, crafted by Espressif Systems, is a dynamic solution extensively employed in IoT endeavors. Boasting dual-core processors reaching speeds of up to 240 MHz, it offers robust processing capabilities. With integrated Wi-Fi and Bluetooth, it facilitates seamless connectivity, ideal for diverse IoT applications. Its array of peripherals, including GPIO, SPI, I2C, and UART interfaces, ensures adaptability to various sensors and devices. Moreover, its low power consumption and support for deep sleep modes make it a favored choice for battery-powered projects. This controller also enables us to use FreeRTOS. We are using this feature extensively to run and monitor various functions of our detection cycles.

Fig 15. Esp32-Wroom-32 Module

3.3.2 K-type thermocouple with max 6875 module

Known for its accuracy and adaptability, the K-type thermocouple in conjunction with the MAX6675 is a widely used temperature sensing solution. The K-type thermocouple is a versatile instrument that monitors temperatures accurately over a broad range by utilizing the thermoelectric properties of different metals. Through an integrated circuit, the K-type thermocouple's analog output is converted into digital temperature readings by the MAX6675.

This combination is preferred in sectors including manufacturing, HVAC, and food processing because it provides accurate temperature measurement with low error. For temperature monitoring in a variety of situations, the K-type thermocouple with MAX6675 is the recommended option due to its small size, simplicity of integration, and reliable performance.

Fig 16. K-Type Thermocouple

3.3.3 LDR flash detector

Passive electrical components known as Light Dependent Resistors (LDRs) display a variation in resistance in response to the intensity of light that strikes them. LDRs, which are frequently employed in light sensing applications, provide an easy-to-use and reasonably priced way to measure ambient light levels. They can be used in circuits to regulate lighting systems, detect daylight for automated switching, or even in light meters for photography because their resistance reduces with increasing light intensity. Because they are available in a variety of sizes and forms, LDRs provide for greater design freedom and seamless integration into a broad range of applications where light sensing is essential.

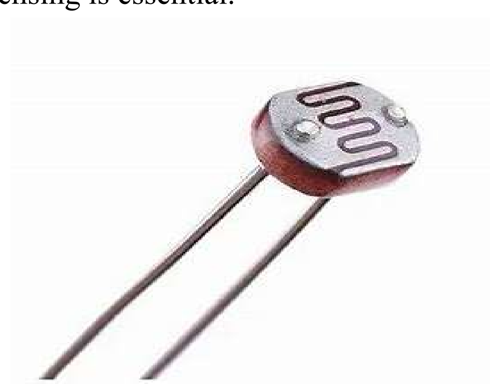

Fig 17. LDR for Light Detection

3.3.4 Flyback Transformer

Specialized transformers called flyback transformers are frequently employed in electronic circuits to regulate voltage and provide galvanic isolation. Their working concept involves storing and releasing energy, and this is commonly seen in applications like tiny fluorescent lights, CRT screens, and switch-mode power supply. Flyback transformers, in contrast to traditional transformers, allow for voltage conversion and control by storing energy in their magnetic cores during one part of the input cycle and releasing it during another. Their excellent efficiency, multiple output capability, and small size make them useful parts of several power supply systems. We are using this transformer to generate a spark to trigger the chemical for flashpoint.

Fig 18. Flyback Transformer

3.3.5 12v Heating Plate Element

Rectangular heating components are often used in a variety of applications, ranging from industrial procedures like plastic welding and heat sealing to home products like toaster ovens and grills. These elements, which are usually composed of materials like nichrome or Kanthal, produce heat when a current flows through them because of their electrical resistance. They are perfect for applications that need even heating over a large area because of their consistent, flat surface, which facilitates effective heat dispersion. This is being used as our main heating element.

Fig 19. Heating Plate

3.3.6 LCD Display

For text display in embedded systems, the 16x2 I2C LCD with the PCF8574 chip is a popular option since it provides an easy-to-use interface for microcontrollers. With its 16-character by 2-line display, this LCD module offers a small-sized yet legible interface. In order to save precious GPIO resources, the PCF8574 chip serves as an I/O expander, enabling the microcontroller to connect with the LCD over the I2C bus using just a few pins. Its I2C interface makes complicated wire configurations or projects with limited space possible by simplifying wiring and reducing the number of connections needed. This is being used to display the mode and current temperature as well as allow the user to see the set temperature.

Fig 20. LCD Display with i2c pack

3.3.7 Push Buttons

The push buttons are various from simple single edge input push buttons to slider and latch switch for various applications. In our applications they are being used for temperature setting, mode setting, start and stopping of tests and as power button. They along with LCD display make the user interface.

3.3.8 DHT11 module

DHT11 is a temperature and humidity sensor module. It uses a capacitive humidity sensor and thermistor for sensor humidity level and temperature and output digital values. It provides reliable readings within its specified range. It is usually used in environmental projects.

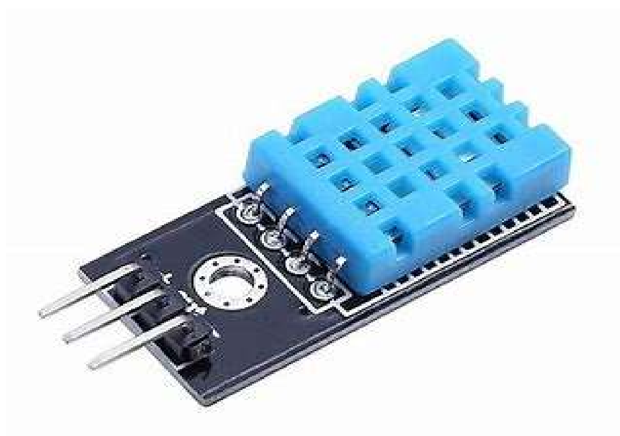

Fig 21. DHT 11 Temperature Sensor

3.4 ASTM Standards

Flashpoint testing employs many different methods for both modern and traditional type testing. There are various organizations that have standardized the flashpoint testing procedures. They have been mentioned extensively in Chapter 2. Here we will only give a brief overview of our chosen ASTM Standards. We have chosen these because of their ease of adoption and publically verifiable data available. We have also chosen for their adherence to many of the safety concerns regarding the handling of hazardous chemicals.

3.4.1 ASTM D7236-16a

The American Society for Testing and Materials (ASTM) developed ASTM D7236 as a standard test technique to evaluate the low-temperature fluidity and appearance of aviation fuels. This procedure is only meant for fuels that include impurities and water, as these could potentially clog fuel systems. A fuel sample is chilled to a certain temperature as part of the operation, and the fuel's behaviour is monitored, including the formation of any precipitates or gels. The test assesses the fuel's low-temperature fluidity, which is essential for guaranteeing optimal performance in airplanes operating in cold weather. To help preserve safety and efficiency in aviation operations, ASTM D7236 attempts to establish a standardized technique for evaluating the compatibility of aviation fuels for use in cold areas. Adherence to this standard guarantees that fuels fulfil the essential criteria for secure and dependable operation in aircraft motors.

3.4.2 ASTM D3278-21

The American Society for Testing and Materials (ASTM) created ASTM D3278 as a standard specification to specify the conditions for classifying ignitable liquid residues in extracts from samples of fire debris. This standard offers a methodical approach to group ignitable liquid residues according to their chromatographic properties, which can help identify accelerants that may have been utilized in arson incidents. This document describes how to prepare samples, perform instrumental analysis, and evaluate findings when using gas chromatography-mass spectrometry (GC-MS), a popular forensic investigation method. In order to aid forensic investigators in ascertaining the type and quantity of accelerants utilized in fire accidents, the standard also delineates the standards for detecting and categorizing the chromatographic patterns of ignitable liquid residues. Adherence to ASTM D3278 guarantees uniformity and dependability in forensic inquiries concerning the examination of fire debris specimens for the existence of combustible liquids, thus bolstering the legal proceedings through the provision of robust, scientific proof. In addition to aiding in the pursuit of justice and preventing erroneous convictions, this criterion is essential in improving the precision and objectivity of arson investigations.

3.5 Block Diagram

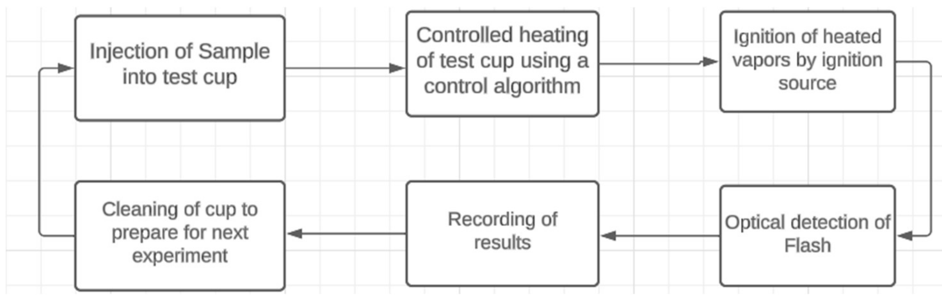

Fig 22. Block Diagram of Flash Detection

There are two modes of flashpoint detection in this project. Both of which are overall governed by the figure above. However they do have differences and are used for different applications. Their block diagrams are as follows:

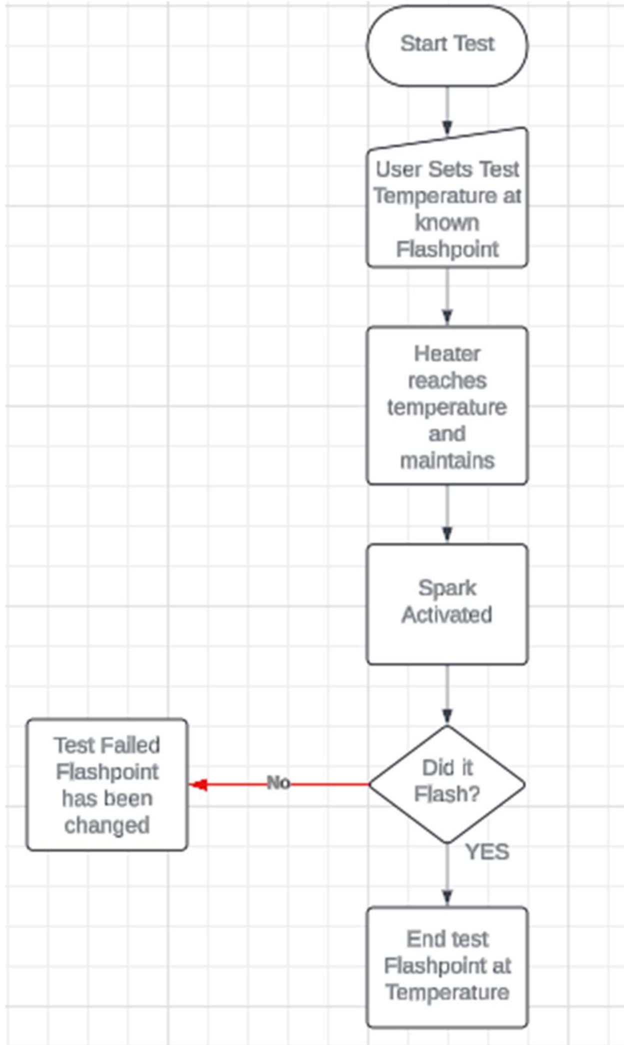

Fig 23. Flash/No Flash Test General Flowchart

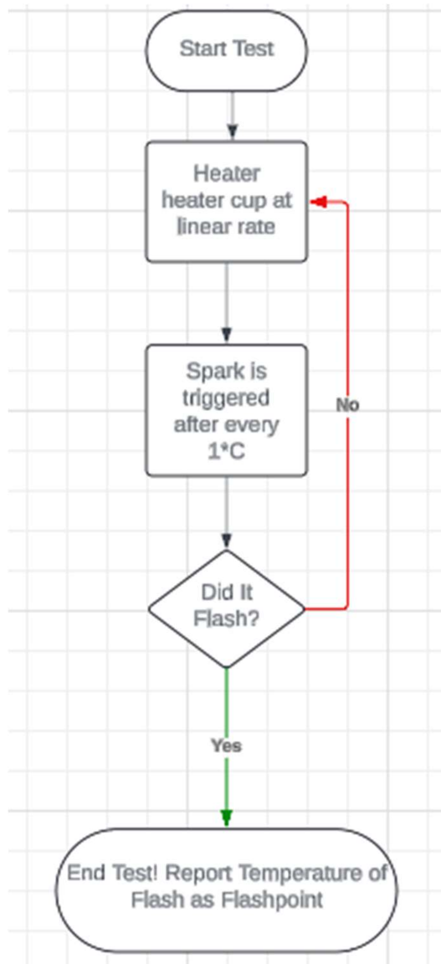

Fig 24. Ramp Test General Flowchart

3.6 PID Algorithm

A Proportional-Integral-Derivative (PID) controller is a widely used feedback control mechanism in engineering and automation. Its equation is represented as:

$$u(t) = K_p e(t) + K_i \int e(t)d + K_d \frac{de(t)}{dt}$$

where $u(t)$u(t) is the control output, $e(t)$e(t) is the error signal (the difference between the desired setpoint and the actual value), KpKp, KiKi, and KdKd are the proportional, integral, and derivative gains, respectively.

The proportional component $Kpe(t)$Kpe(t) responds to the current error, the integral component $Ki\int e(t)$ deals with past error accumulation, and the derivative component $Kd(de(t)/dt)$ anticipates future error trends. Adjusting these gains affects the controller's response: a higher proportional gain leads to a faster initial response but might cause overshooting; the integral gain helps eliminate steady-state errors, while the derivative gain improves system stability and reduces overshooting and oscillation. Balancing these gains optimally achieves desired control performance in various systems.

3.7 Control System

The development of the control system took place in three steps.
The first step is the data acquisition. For this we assume the heater, the cup with sample, and the k-type thermocouple as the system from which we need the data. This data is in the form of temperature points taken after every 1 second. These are then plotted on matlab and then used to develop the transfer function for the system. The data captured graphs are:

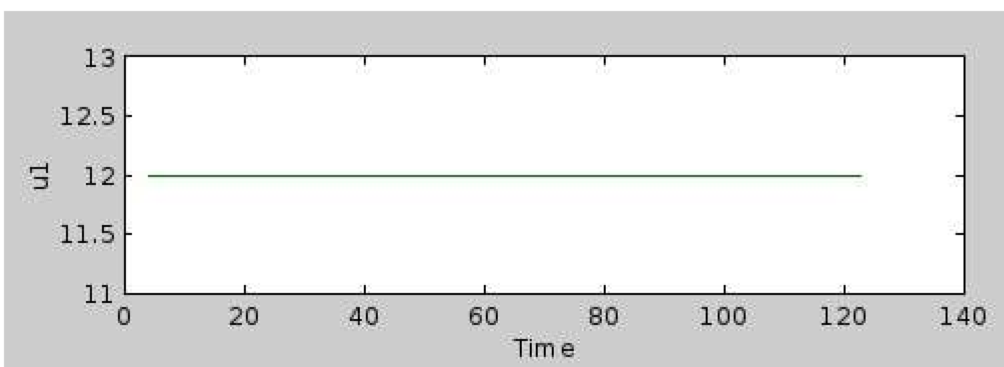

Fig 25. Input Data for System Identification

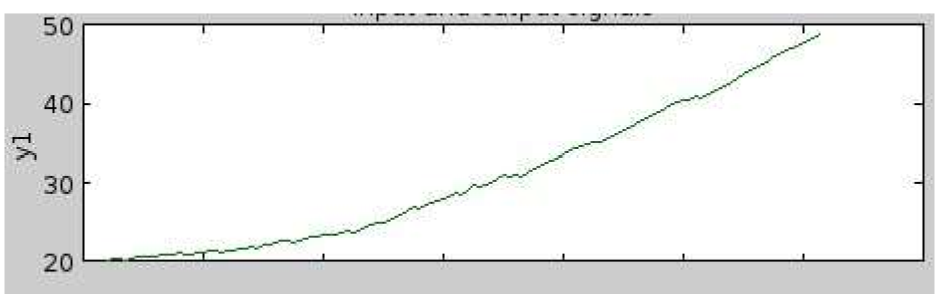

Fig 26. Output Data for System Identification

The next step is using Matlab System Identification Toolbox to generate a transfer function. For this we estimate by setting poles and zeroes arbitrarily and checking the how much data is fit for the transfer function estimated. We have set the poles = 3 and zeroes = 2 and have achieved 97.04% fit to estimation data. Using this we have a transfer function of:

$$\frac{H}{V} = \frac{20.02s^2 + 0.1477s + 0.00777}{s^3 + 11.51s^2 + 0.1049s + 0.0009124}$$

Where H is the heat in the system and V is the voltage provided by the Pulse Width Modulated Signal provided to the heater.

The third step is to set the PID constants. We use Matlab PID Tuner to generate constants initially then use a hit and trial method to set down the final PID constants. The final PID constants used are:

These constants are used to maintain temperatures at a set temperature for the Flash/No Flash test. The heating element is being controlled by our microcontroller i.e. Esp32 via Pulse Width Modulation (PWM) signals. These signals are provided to a transistor and MOSFET control circuit. The transistor and MOSFET circuit are used to protect the Esp32 pin from high voltage and high currents. The heating element is provided with this PWM signal and the supply of 12V is controlled. The PWM signals are changed in relation to the error calculated by the PID algorithm explained in section 3.3. The results are discussed in Chapter 4.

3.8 Circuit Board

For the circuit board we used a Vero board. On which ESP-32 is attached, power supply circuit is made, button, led, transformer, LDR, heating element, temperature sensor connection are attached. 12V supplied to transformer and heating element. 5V supplied to ESP-32, LDR, LED, temperature sensor, buttons. PWM signal is applied to the relay to operate the transformer only when required.

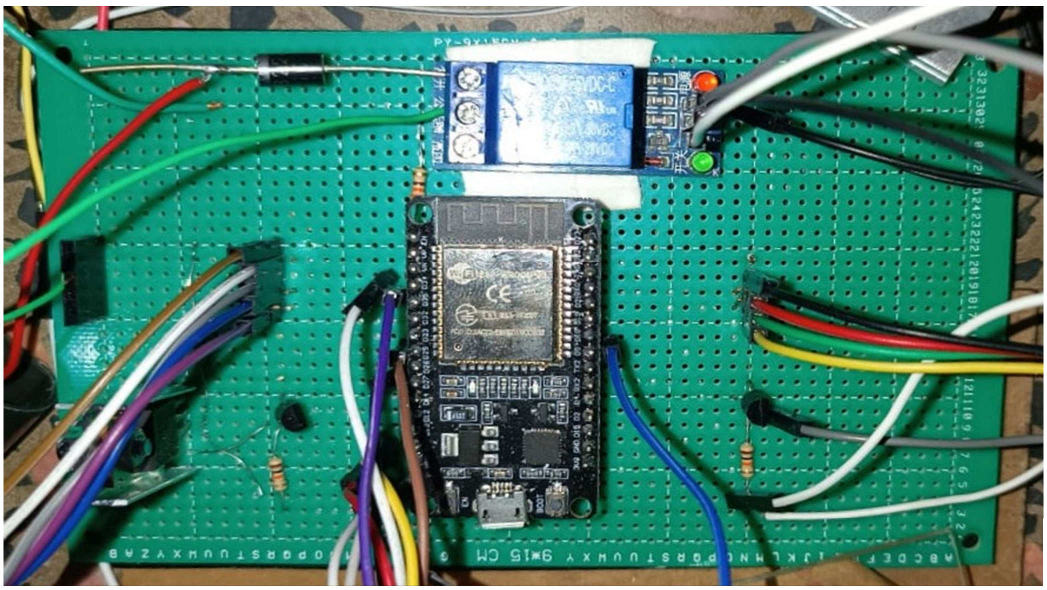

Fig 27. Control Board

First, we will measure 5ml to 7ml of our testing liquid sample. Pour into the cup. Set the flash point temperature on LED with the help of buttons. Press the start/stop button once to start the experiment. Heating element is controlled through ESP-32 to heat the liquid gradually. PID is implemented on heating element by taking input from the temperature sensor. The heating element heats the liquid to the set temperature. Once the required temperature is acquired the ESP-32 sends signal to relay to create spark through the transformer inside the cup. LDR detect flash/No flash and give output on the screen. The hating procedure stops automatically after the experiment. Once completed wait for the cup to cool down, then take out and clean it for the next experiment

3.10 Safety Procedure

For accuracy and safety. The cup is thoroughly cleaned before and after every experiment, even for the same material sample. For safety protocol there is DHT11 temperature and humidity sensor set inside the chassis. If the temperature of the chassis increases above the room temperature or there is any leakage of vapor it will detect and automatically stop the machine.

As we are following the standard of close cup flash point detector. The quantity of liquid we are using is 5ml to 7ml. The cup is closed. In case of fire inside the cup, it will automatically be extinguished as the quantity is very small and the oxygen is limited due to closed sealed cup.

<u>Chapter 4 - Results</u>

4.1 Kerosene Testing

For the first test we have used locally acquired Kerosene. Locally acquired kerosene has flash point between 38 C and 45 C. We performed 10 iterations. For every iteration:

- The cup was first cleaned.
- 5ml of kerosene was measured and poured in the cup using syringe.
- Lid was closed tightly and shut to make sure no air was added in the vapor mixture of above the chemical.
- Starting the system, the mode is set using the slider switch on the HMI
- For Ramp method the test is started using the start button. No temperature setting is required.
- For Flash/No Flash Test, the temperature at which the test is to be carried out is set using the Temperature add and Temperature subtract buttons. Then the test is started using the start button.

4.1.1 Ramp Method

For the Ramp Method no temperature is set. Instead a PWM Signal of 255 is given and an arc is given after every 1C. The results are compiled as follows:

Ambient Temperature: 33 C

Table 4. Experimental Results of Kerosene Ramp Test

Experiment No.	Flash Detected Temperature	Time Min : Sec
1	Not Detected	4:05
2	40.25 C	Out of range
3	39.75 C	4:02
4	Not Detected	Out of range
5	40 C	4:04
6	40.25 C	4:09
7	40 C	4:10
8	Not Detected	Out of range
9	39.75 C	4:01
10	40 C	4:06

After performing 10 iterations, we concluded the following result:

- Our system has 70% accuracy, which can be further improved.
- Average time taken for the experiment is 4 Minutes 07 seconds
- Average Flashpoint Temperature Detected is 40 C

4.1.2 Flash/No Flash

Mode set to Flash/No Flash.

The test temperature was set to 40 C.

The ambient Temperature was 33 C.

The result of every iteration is given in the table below.

Table 5. Experimental Results of Kerosene Flash/No Flash Test

Experiment No.	Set Temperature	Flash Detected	Time Min : Sec
1	40 C	Not detected	3:44
2	40 C	40.25 C	3:42
3	40 C	40 C	3:44
4	40 C	40.25 C	3:41
5	40 C	Not detected	3:52
6	40 C	39.25 C	3:40
7	40 C	40 C	3:45
8	40 C	40 C	3:41
9	40 C	40.25 C	3:47
10	40 C	Not detected	3:54

After performing 10 iterations, we concluded the following result:

- Our system has 70% accuracy, which can be further increased.
- Average time taken for the experiment is 3 Minutes 45 seconds

4.2 6.3 ml Kerosene 0.7 ml Petrol

For the second test we have mixed our locally acquired Kerosene 90% by volume and 10% petrol by volume. Locally acquired kerosene has flash point between 38 C and 45 C. Petrol has a flashpoint of -43 C.

We will be using a negation hypothesis test on this mixture. It is expected that the flashpoint of the mixture will be less than our range of temperature. If a flashpoint is found then our hypothesis will be proved false. However in the event that a flashpoint is not detected we will have validated our results. We performed 3 iterations. For every iteration:

- The cup was first cleaned.
- 6.3ml of kerosene was measured and poured in the cup.
- 0.7ml of petrol was measured and poured in the cup.

- Lid was closed tightly and shut to make sure no air was added in the vapor mixture of above the chemical.
- Starting the system, the mode is set using the slider switch on the HMI
- For Ramp method the test is started using the start button. No temperature setting is required.
- For Flash/No Flash Test, the temperature at which the test is to be carried out is set using the Temperature add and Temperature subtract buttons. Then the test is started using the start button.

4.2.1 Ramp Method

For the Ramp Method no temperature is set. A PWM Signal of 255 is given and an arc is given after every 1C. The results are compiled as follows:
Ambient Temperature: 33 C

Table 6. Experimental Results of Mixture Ramp Test

Experiment No.	Flash Detected Temperature	Time Min : Sec	Temperature Range of experiment
1	Not Detected	15:35	32.5 – 60 C
2	Not Detected	15:56	32.5 – 60 C
3	Not Detected	15.12	32.5 – 60 C

After performing 3 iterations, we concluded the following result:

- Our System detected no flashpoint within range of temperature as hypothesized.
- Average time taken for the experiment is above 15 minutes
- Since no Flashpoint is detected we can conclude that our system works well in our defined temperature range but if a flashpoint is not within range it will not be detected.

4.2.2 Flash/No Flash

Mode set to Flash/No Flash.

The test temperature was set to 35 C.

The ambient Temperature was 33 C.

The result of every iteration is given in the table below.

Table 7. Experimental Results of Mixture Flash/No Flash Test

Experiment No.	Set Temperature	Flash Detected	Time Min : Sec
1	35 C	Not detected	1:29
2	35 C	Not Detected	1:28
3	35 C	Not Detected	1:26

After performing 3 iterations, we concluded the following result:

- Our System detected no flashpoint within range of temperature as hypothesized.
- Average time taken for the experiment is above 15 minutes
- Since no Flashpoint is detected we can conclude that our system works well in our defined temperature range but if a flashpoint is not within range it will not be detected.

4.3 Results Summary

Results are combined in the following table:

Table 8. Results Summary of Experiments

Experiment No.	Ramp Method	Flash/No Flash	Average Time Ramp	Average Time Flash/No Flash
Kerosene	40 C	40 C	4:07	3:45
90% Kerosene 10% Petrol	Not Detected	Not Detected	>15	>15

Chapter 5 – Conclusions

5.1 Flashpoint Detector Final Specifications

Table 9. Final Specifications

Temperature Range	30°C to 60°C
Temperature Resolution	0.25 °C
Temperature Accuracy	±0.5°
Heating Rate	• Flash/No Flash: Variable Heating Rate • Ramp Method: 1°C/min
Cooling System	Passive Cooling
Ignition Source	Electric ignition (Electric Arcing)
Sample Cup	Stainless Steel
Test Volume	5-7mL
Detection System	LDR Detector
Display and Interface	16 x 2 LCD Display
Automation	Fully Automatic
Data Logging and Connectivity	None – It is currently directly controlled by serial communication with computer
Safety Features	Emergency Stop
Compliance	Conformance to ASTM 3278, ASTM 3828 & ASTM 7236

5.2 Reasons for Inaccuracies

Various reasons can be attributed to deviations as well as inaccuracies. Some of them are listed here:

- Calibration errors: Errors due to calibration of LDR or Arc lighter may be one of the reasons why results may be erroneous as flash may not be detected. Due to erroneous

LDR calibration, it may be so that instead of detecting the flash the arc lighting may be detected. This is solved through rigorous testing and experimentation.

- Sample sizing error: Change in sample size may lead to inaccuracies due to unknown vapor mixture being made. This may lead to various problems in testing and may be the reason for our first non-detection (Refer to Chapter 4).
- Problems with Control Circuitry: As there are various power rails in our flashpoint detector it is very important to isolate the components that are required. We experienced various problems regarding transformer and its isolating relay isolation.

5.3 Recommendations and Future Work

There is a lot of future work that can be done on this flashpoint detector.

- Use of another standard: Other standards of both ASTM and ISO can be used to develop this flashpoint detector into a multipurpose flashpoint detector.
- Portability: We are currently focusing on the autonomous working of our detector. An addition of battery for three different types of power rails can be added along with its conversion circuitry
- Use of Aluminum: We have used a steel cup as liquid container, but using an aluminum cup increases rate of change of temperature due to aluminum's high heat conductivity. For faster heating aluminum cup can be made
- Use of Peltier Cell: As our range is limited due to our heating element, using a Peltier cell for both heating and cooling increases the range of temperature and through that the range of testable chemicals.
- Addition of memory storage device: We are not using any data storage device. Instead we are simply monitoring the situation via serial communication with the esp32 and computer. A data storage device for data logging and result storage may be used or added.
- IOT: Addition of web based results logging via web server or IOT connectivity.

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