Innovation for Safe Travel

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Abstract- Every engineering creation should ultimately give comfort for human life and bring joy to humanity. Engineering marvels are created and given to users for assuring the desired functions of that specific marvel. Transportation modes by road, train, air enable the occupant a safe and speedy destinations giving them advantage of technology for better life. Even though utmost care is taken during the design to manufacturing a very low probable incident or accident might endanger the life of user. Transportation accidents pose a challenge to engineering community as it involves many parameters interacting dynamically. A survey of aircraft, train, bus accidents that took place in recent times is undertaken for understanding the end effects of accident and to identify root causes. While the root cause will enable a better engineering design where end effect is necessary to safe guard the human life. In a recent study, it was brought out that the majority of fatalities are due to fire accidents. The occupant's inability to respond quickly to fire will lead to fatality. Even though Trains, Buses, aircrafts etc., are equipped with fire sensors that could sense and give an alarm but quick response mechanism is needed. As the progress in technology is happening, sensing technology is being improved. There is a need to put together all the available sensing techniques of smoke and fire so that a sophisticated technique can be developed which is more useful for current and future. Current research aims at a consolidation of the available fire and smoke sensors as on date. In general fire consists of a visible part flame and other smoke which is gas form; hence sensors for both are discussed. A start of the art review of sensors which will guide the designers for choosing a fire or smoke detector is presented.

Keywords –Fire, Smoke, Sensors, Semi-conductor

I. INTRODUCTION & MOTIVATION

Every engineering creation should ultimately give comfort for human life and bring joy to Humanity. Engineering marvels are created and given to users for assuring the desired functions of that specific marvel. Transportation modes like road, train, air enable the occupant a safety speedy destinations giving them advantage of technology for better life. Even though utmost care is taken during the design and manufacturing a very low probable incident or accident might endanger the lives of users. Transportation accidents pose a challenge to engineering community as it involves many parameters interacting dynamically. A survey of aircraft, train, bus accidents that took place in recent times is undertaken for understand the end effects of accident rather than root causes. While the root cause will enable a better engineering design where end effect is necessary to safe guard the human life. In a recent study [1] it was brought out that majority of fatalities are due to crash accidents. In each of these crash accidents end effect of fire endangered the lives of people. The occupant's inability to respond quickly to fire will lead to fatality. Even though Trains, Buses, aircrafts etc., are equipped with fire sensors that could sense and give an alarm but quick response mechanism is needed. As the progress in technology happening, sensing technology is being improved. There is a need to put together all the available sensing techniques of smoke and fire so that a sophisticated technique can be developed which is more useful for current and future. Current research aims at a consolidation of the available fire and smoke sensors as on date. In general fire consists of a visible part flame and other smoke which is gas form. This will ultimately help in better system design for future. A start of the art review of sensors which will guide the designers for choosing a fire or smoke detector is presented.

II. A REVIEW ACCIDENT STATISTICS

People all over the world depend on transportation for day to day needs so they should be assured safety in the all modes of transport. In India in recent times there been numerous fire mishaps during last year. While some fire accidents have been blamed on short circuits, a majority of them are due to the negligence of the transport authorities. Now-a-days fire accidents are getting increased in all the means of transport. Some of the recent fire accidents are mentioned below. Hence, fire alarms or sensors should be used effectively in order to reduce the fire accidents. Majority of them have led to loss of lives and property. A root cause analysis of these events indicates that fire & Smoke was the initial indicator.

Table -1 List of Fire accidents

Year & Date	Mode of transport	Cause	Name of train/bus/Area	Lives lost	Injured(approx.)
May 21,2013	**Train**	**Fire**	**Banglore-Bound Hampi**	**25**	**30**
May 29,2013	**Train**	**Fire**	**AP Express**	**0**	**0**
Oct 15,2013	**Train**	**Fire**	**Dibrugarh-New Delhi Rajdhani Express**	**0**	**0**
Oct 30,2013	**Bus**	**Fire**	**Private volvo bus**	**51**	**7**
Nov 15,2013	**Bus**	**Fire**	**Private volvo bus**	**7**	**46**
Dec 25,2013	**Bus**	**Fire**	**AP Tourism Luxury bus**	**0**	**NA**
Dec 28,2013	**Train**	**Fire**	**Nanded Express**	**26**	**9**
Mar 24,2014	**Building**	**Fire**	**Begumpet,Hyderabad**	**0**	**NA**

III. FLAME DETECTOR

Based on working principle, there are several types of flame detectors. The optical flame detector is a detector that uses optical sensors to detect flames. There are also ionization flame detectors, which use current flow in the flame to detect flame presence. The literature on fire flame detectors has following types.

3.1 Optical Types of Flame Detectors

- Ultraviolet
- Near IR Array
- Infrared
- UV/IR
- IR/IR flame detection
- IR3 flame detection
- Visible sensors
- Video
- Ionization current flame detection
- Thermocouple flame detectors

Ultraviolet Flame Detector:

Ultraviolet (UV) detectors work with wavelengths shorter than 300 nm. These detectors detect fires and explosions within 3–4 milliseconds due to the UV radiation emitted at the instant of their ignition. False alarms can be triggered by UV sources such as lightning, arc welding, radiation, and sunlight. In order to reduce false alarm a time delay of 2-3 seconds is often included in the UV flame detector design.

Near IR Array Flame Detector:

Near infrared (IR) array flame detectors, also known as visual flame detectors, employ flame recognition technology to confirm fire by analyzing near IR radiation via the pixel array of a charge-coupled device (CCD).

Infrared Flame Detector:

Infrared (IR) flame detectors work within the infrared spectral band. Hot gases emit a specific spectral pattern in the infrared region, which can be sensed with a thermal imaging camera (TIC) a type of thermo graphic camera. False alarms can be caused by other hot surfaces and background thermal radiation in the area as well as blinding from water and solar energy. A typical frequency where single frequency IR flame detector is sensitive is in the 4.4 micrometer range. Typical response time is 3-5 seconds.

UV/IR Flame Detector:

UV and IR flame detectors compare the threshold signal in two ranges in configuration and their ratio to each other to confirm the fire signal and minimize false alarms.
IR/IR flame detection
Dual IR (IR/IR) flame detectors compare the threshold signal in two infrared ranges. In this case one sensor looks at the 4.4 micrometer range whereas the other sensor at a reference frequency.

IR3 flame Detection:

Triple IR flame detectors compare three specific wavelength bands within the IR spectral region and their ratio to each other. In this case one sensor looks at the 4.4 micrometer range and the other sensors at reference bands above and below. This allows the detector to distinguish between non flame IR sources, and flames that emit hot CO2 in the combustion process (which have a spectral characteristic peak at 4.4 micrometer). As a result, both detection range and immunity to false alarms can be significantly increased.

IR3 detectors can detect a 0.1m2 (1ft2) gasoline pan fire at up to 65m (215ft) in less than 5 seconds.
Most IR detectors are designed to ignore constant background IR radiation, which is present in all environments.

Visible sensors:

In some detectors a sensor for visible radiation is added to the design in order to be able to discriminate against false alarms better or improve the detection range. Example: UV/IR/vis, IR/IR/vis, IR/IR/IR/vis flame detectors.
Video
Closed-circuit television or a web camera can be used for video detection (wavelength between 0.4 and 0.7 µm). Like humans, the camera can be blinded by smoke or fog.

Ionization current flame detection
The intense ionization within the body of a flame can be measured by means of the current which will flow when a voltage is applied. This current can be used to verify flame presence and quality. They are normally used in large industrial process gas heaters and are connected to the flame control system and act as both the flame quality monitor and the "flame failure device".
Thermocouple flame detection
Thermocouples are used extensively for monitoring flame presence in combustion heating systems and gas cookers. They are commonly used as the "flame failure device" to cut off the supply of fuel if the flame fails. This prevents the danger of a large explosive mixture building up, or the hazard of asphyxiation in a confined space due to exclusion of oxygen.

3.2 Applications of Flame detectors:

UV/IR flame detectors are used on hydrogen stations
Gas fuelled cookers
Industrial heating and drying systems
Domestic heating systems
Industrial gas turbines
Smoke detector

IV. TYPES OF SMOKE DETECTORS

A smoke detector also called a smoke alarm is a device that detects smoke, typically as an indicator of fire. Commercial, industrial, and mass residential devices issue a signal to a fire alarm system; while household detectors, known as smoke alarms, generally issue a local audible or visual alarm from the detector itself. Smoke detectors are one of those amazing inventions that, because of mass production, cost practically nothing. We can get a smoke detector for as little as $7. And while they cost very little, smoke detectors save thousands of lives each year. In fact, it is recommended that every home have one smoke detector per floor. All smoke detectors consist of two basic parts: a sensor to sense the smoke and a very loud electronic horn to wake people up. Smoke detectors can run off of a 9-volt battery or 120-volt house current. Smoke detectors are typically housed in a disk-shaped plastic enclosure about 150 millimetres (6 in) in diameter and 25 millimetres (1 in) thick, but the shape can vary by manufacturer or product line. Most smoke detectors work either by optical detection (photoelectric) or by physical process (ionization), while others use both detection methods to increase sensitivity to smoke.
Sensitive alarms can be used to detect smoking in areas where it is banned such as toilets and schools. Smoke detectors in large commercial, industrial, and residential buildings are usually powered by a central fire alarm system, which is powered by the building power with a battery backup. However, in many single family detached and smaller multiple family housings, a smoke alarm is often powered only by a single disposable battery.
In the United States, the National Fire Protection Association estimates that nearly two-thirds of deaths from home fires occur in properties without working smoke alarms/detectors.

4.1 Optical

Smoke detectors are typically housed in a disk-shaped plastic enclosure about 150 millimeters (6 in) in diameter and 25 millimeters (1 in) thick, but the shape can vary by manufacturer or product line. An optical detector is a light sensor. When used as a smoke detector, it includes a light source (incandescent bulb or infrared LED-Light-Emitting Diode), a lens to collimate the light into a beam, and a photodiode or other photoelectric sensor at an angle to the beam as a light detector. In the absence of smoke, the light passes in front of the detector in a straight line. When smoke enters the optical chamber across the path of the light beam, some light is scattered by the smoke particles, directing it at the sensor and thus triggering the alarm.
Also seen in large rooms, such as a gymnasium or an auditorium, optical beam smoke detectors are devices that detect a projected beam. A wall-mounted unit sends out a beam, which is either received by a separate monitoring device or reflected back via a mirror. When the beam becomes less visible to the "eye" of the sensor, it sends an alarm signal to the fire alarm control panel. According to the National Fire Protection Association (NFPA), "photoelectric smoke detection is generally more responsive to fires that begin with a long period of smoldering (called smoldering fires)." Also, studies by Texas A&M and the NFPA cited by the City of Palo Alto California state, "Photoelectric alarms react slower to rapidly growing fires than ionization alarms, but laboratory and field tests have shown that photoelectric smoke alarms provide adequate warning for all types of fires and have been shown to be far less likely to be deactivated by occupants."
Although optical alarms are highly effective at detecting shouldering fires and do provide adequate protection from flaming fires, some fire safety experts and the National Fire Protection Association recommend installing what are called combination alarms, which are alarms that either detect both heat and smoke, or use both the ionization and photoelectric/optical processes. Also some combination alarms may include a carbon monoxide detection capability.
Combination ionization/photoelectric smoke alarms are controversial. The World Fire Safety Foundation (WFSF), the International Association of Fire Fighters (IAFF), the Australasian Fire and Emergency Service Authorities Council (AFAC), the Fire Protection Association of Australia and a growing number of fire departments, consumer and fire safety experts around the world do not recommend them. The official positions of the WFSF, the IAFF and AFAC state, "Ionization smoke alarms may not operate in time to alert occupants early enough to escape from smoldering fires." However, stand-alone photoelectric smoke alarms are proven to provide adequate egress time in both the smoldering and flaming stages of fire. Not all optical or photoelectric detection methods are the same. The type and sensitivity of the photodiode or optical sensor, and type of smoke chamber differ between manufacturers.

4.2 Ionization

An ionization smoke detector uses a radioisotope such as americium-241 to produce ionization in air; a difference due to smoke is detected and an alarm is generated. Ionization detectors are more sensitive to the flaming stage of fires than optical detectors, while optical detectors are more sensitive to fires in the early smouldering stage.
Smouldering (or smoldering) is the slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phase fuel.
The radioactive isotope americium-241 in the smoke detector emits ionizing radiation in the form of alpha particles into an ionization chamber (which is open to the air) and a sealed reference chamber. The

air molecules in the chamber become ionized and these ions allow the passage of a small electric current between charged electrodes placed in the chamber. If any smoke particles pass into the chamber the ions will attach to the particles and so will be less able to carry the current. An electronic circuit detects the current drop, and sounds the alarm. The reference chamber cancels effects due to air pressure, temperature, or the aging of the source. Other parts of the circuitry monitor the battery (where used) and sound an intermittent warning when the battery nears exhaustion. A self-test circuit simulates an imbalance in the ionization chamber and verifies the function of power supply, electronics, and alarm device. The standby power draw of an ionization smoke detector is so low that a small battery can provide power for months or years, making the unit independent of AC power supply or external wiring; however, batteries require regular test and replacement.

An ionization type smoke detector is generally cheaper to manufacture than an optical smoke detector; however, it is sometimes rejected because it is more prone to false (nuisance) alarms than photoelectric smoke detectors. It can detect particles of smoke that are too small to be visible.

Table 2: Few commercially available sensors

Sl no	Name	sensor type	fire/smoke	conclusion	dimensions
1	MQ2	Semi-conductor type	smoke/combustible gas	less weight&300:10000ppm	38*27
2	MQ4	semi-conductor type	combustible gas	less weight&300:10000ppm	
3	md61	thermal	CO2	wide detection range	10×14×18
4	MQ7	semi-conductor type	CO	20:2000ppm	16*16
5	MG811	semi-conductor type	CO2	0:10000ppm	16*21mm
6	AQ7	semi-conductor type	Co		
7	MQ9	semi-conductor type	Co/flammable gas	10:10000ppm	
8	MQ135	semi-conductor type	air quality(CO)		
9	MQ303a	semi-conductor type	smoke		
10	mq307a	semi-conductor type	CO	similar to mq7 but low voltage	
11	mq309a	semi-conductor type	Co/flammable gas	similar to mq9	
12	mg811	semi-conductor type	CO2		
13	AQ2	semi-conductor type	smoke/combustible gas		
14	MQ3	semi-conductor type	smoke/alcohol		
15	Md62	thermal	Co2/Freon/lpg		10*14*18
16	me2b-co	electro chemical	Co2	0:1000ppm	

Americium-241, an alpha emitter, has a half-life of 432 years. Alpha radiation, as opposed to beta and gamma, is used for two additional reasons: Alpha particles have high ionization, so sufficient air particles will be ionized for the current to exist, and they have low penetrative power, meaning they will be stopped by the plastic of the smoke detector or the air. About one percent of the emitted radioactive energy of 241Am is gamma radiation. The amount of elemental americium-241 is small enough to be exempt from the regulations applied to larger sources. It includes about 37 kBq or 1 µCi of radioactive element americium-241 (241Am), corresponding to about 0.3 µg of the isotope. This provides sufficient ion current to detect smoke, while producing a very low level of radiation outside the device.
The americium-241 in ionizing smoke detectors poses a potential environmental hazard. Disposal regulations and recommendations for smoke detectors vary from region to region. Some European countries have banned the use of domestic ionic smoke alarms.

Table3: Radiation and energy

Type	Energy	Percentage
Alpha	**5485 keV**	**84.5%**
Alpha	**5443 keV**	**13.0%**
Gamma	**59.5 keV**	**35.9%**
Gamma	**26.3 keV**	**2.4%**
Gamma	**13.9 keV**	**42%**

4.3 Air-sampling

An air-sampling smoke detector is capable of detecting microscopic particles of smoke. Most air-sampling detectors are aspirating smoke detectors, which work by actively drawing air through a network of small-bore pipes laid out above or below a ceiling in parallel runs covering a protected area. Small holes drilled into each pipe form a matrix of holes (sampling points), providing an even distribution across the pipe network. Air samples are drawn past a sensitive optical device, often a solid-state laser, tuned to detect the extremely small particles of combustion. Air-sampling detectors may be used to trigger an automatic fire response, such as a gaseous fire suppression system, in high-value or mission-critical areas, such as archives or computer server rooms.

Most air-sampling smoke detection systems are capable of a higher sensitivity than spot type smoke detectors and provide multiple levels of alarm threshold, such as Alert, Action, Fire 1 and Fire 2. Thresholds may be set at levels across a wide range of smoke levels. This provides earlier notification of a developing fire than spot type smoke detection, allowing manual intervention or activation of automatic suppression systems before a fire has developed beyond the smoldering stage, thereby increasing the time available for evacuation and minimizing fire damage.

Carbon monoxide and carbon dioxide detection

Some smoke alarms use a carbon dioxide sensor or Carbon monoxide sensor to detect characteristic products of combustion. However, some gas sensors react on levels that are dangerous for humans but not typical for a fire; these are therefore not generally sensitive or fast enough to be used as fire detectors. Other gas sensors are even able to warn about particulate-free fires (e. g. certain alcohol fires).

Performance differences

Photoelectric smoke detectors respond faster (typically 30 minutes or more) to fire in its early, smouldering stage (before it breaks into flame). The smoke from the smouldering stage of a fire is typically made up of large combustion particles — between 0.3 and 10.0 µm. Ionization smoke detectors respond faster (typically 30–60 seconds) in the flaming stage of a fire. The smoke from the flaming stage of a fire is typically made up of microscopic combustion particles — between 0.01 and 0.3 µm. Also, ionization detectors are weaker in high air-flow environments, and because of this, the photoelectric smoke detector is more reliable for detecting smoke in both the smoldering and flaming stages of a fire.

Table 4: Common types of smoke detectors are ionization and photo-electric.

Market	Detector Style	Technology
Commercial	**Stand-Alone Detector**	**Ionization Chamber**
Industrial	**Detection System / Component**	**Photoelectric**
Residential	**Smoke Detector IC**	**Other**

V.CONCLUSION

Sensors play a major role in ensuring the safety of travelers, there is need for innovation in fire and smoke sensing techniques. Over the period of time sensor technology has been improving with alternative methods of sensing. A tiny, light weight high resolutions sensing of fire and smoke will enable better systems design. Further response of the sensor has to be coupled with control system for better engineering the future air travel. Today due to advancement in engineering analytics an integrated systems with effective sensing can be used for fire and smoke sensing and mitigation.

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