Design and Development of High Sensitivity Gas Detection System for Monitoring Safety during Welding Activity in Habitat

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Abstract— **In oil and gas environment, safety is the main issue highlighted especially in welding activities. Therefore, this study is an attempt to investigate and design a new mechanism in monitoring the safety via detecting gas concentration level. The objective of this project is to design and develop a new safety precaution system during welding activity in habitat using low cost microcontroller. Furthermore, the study been carried out by divided in three stages; sensing, controlling and notification. Different gas concentration level has been tested and verified for determine the safety range in sensing stage. While, the controlling part control the response based on the detection of the gas in the environment. Indicator and Secure Digital (SD) memory have been used to notify and record the activity in notification stage. At the end of this paper, the system has been successfully designed, developed, tested and verified at prototype level. Besides, the system starts to trigger when sensing level produce 1.416V which represent 30% of gas concentration. Nevertheless, the gas sensor required 10 seconds initialized time to stabilize and produce the desired sensing level.**

Keywords- Gas sensor, safety of welding

I. INTRODUCTION

There are a lot of accident due explosion of flammable gasses at oil rig recorded from time to time especially for the works related to welding activity as reported in [1]. Therefore, a handheld gas monitoring has widely used in current practice but it cannot guarantee the safety during the welding activity. On the other hand, the type of handheld gas monitoring system used is a general gas monitoring system and not a specific device develop for the monitoring gas concentration during welding activity. Furthermore, it is not equipped with notification or alarm to alert the existence of the high concentration flammable gas in surrounding and it based on individual.

The individual gas monitoring factor contributes for scattered location of gas monitoring during welding activity in workspace and increased the potential of accident occurs. While, the fan that supplied air inside the habitat to keep the pressure is unsynchronized and not controlled by any mechanism. Due to this circumstance, the air flow to the habitat via air vent is not guaranteed and explosion will occur if the high concentration flammable gas is entering [7]. Therefore, the demand for a systematic, synchronize and precise location solution is needed.

This project is an attempt to develop a new mechanism and system to avoid explosion during welding activity in oil and gas field especially at oil rigs via close monitoring. The focus of this project is to study, construct and develop a sensitive system which capable to sense and detect flammable gasses during welding activities using low cost microcontroller.

Therefore, several topics have been added in this paper to complete the preliminary study until the complete prototype was constructed and tested. The input from the existing practice is outline in Section II. This is including the existing system and the block diagram of handheld gas detector system. The operational of gas sensor system and their response to the environmental gas concentration changing also discussed in specific sub topic.

The new proposed architecture and design are described in Section III. Three subtopics were added to complete the section outline: overall system design in applied environment, the flow of system operational and the final subsection is the block diagram components inside the system.

In section IV, the overall system design from schematic level design was outlined. Five subtopics have been added under this section: System schematic, Gas sensor circuit, microcontroller schematic, Logging system schematic and notification schematic. The construction and function of each component are detailed discussed in their sub-topic.

The system integration and testing were discussed in Result and Discussion Section. Four subtopics have been added to complete the analysis and discussion of the design. System response analyzed the performance of the system in real environment. Several reading has been recorded to test the system performance in different gas concentration environment. Finally, the Conclusion section will conclude the finding from this project from the starting until the implementation stage.

II. Review On Current Practice

The review on current practise has been included in this paper for complete the paper overview. Three sub-topics have been include in this section start with the existing system implementation. The operational system if gas sensor is covers in the following subtopics and block diagram of the system is the last topics discussed in this section.

A. Existing System Implementation

The overview of the current practice is shown in Fig 1.

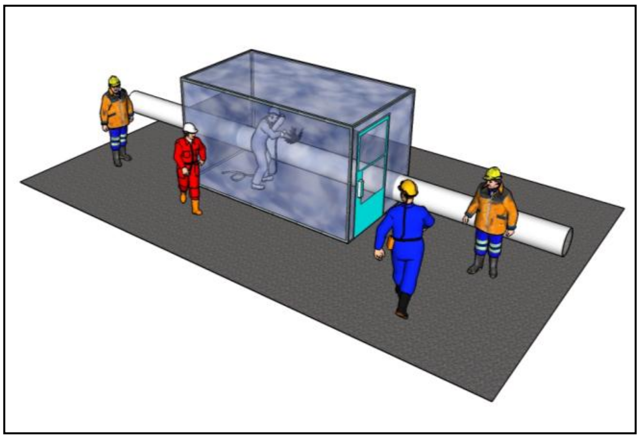

Fig 1: Overview of existing system implementation

In the current practice, the placement of the sensor is depending on the location of the worker. This is due to the type of the handheld gas sensor system [12].

B. Operational System of Gas Sensor

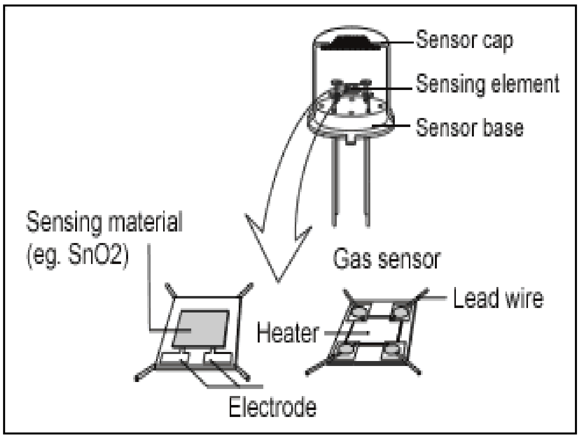

Fig 2: Sensor Structure

Fig 2 shows the basic structure of gas sensor that commonly used in industry and commercial. Gas sensor consists 3 parts; sensor cap, sensing element and sensor base. The purpose of the sensor cap is to cover up the sensing element. The sensing element contains sensing material and heater. Depending on the gas, the sensing element will utilize different materials. It is normal when the gas sensor is hot because of the heater that built inside the gas sensor. The purpose of heater is to heat up the sensing element usually to 400^{o}C [2].

For this prototype, gas sensor module is used to apply in the application as referred in Fig 3. Gas sensor module is built in a circuit that has been wired. Furthermore, the sensitivity can be adjusted by the potentiometer.

Fig 3: Gas sensor module

The specifications, the power supply for the gas sensor is 5V. Hence, the heating consumption is 0.5mW to 800mW. It can be interface at any analog port of the microcontroller.

C. Block Diagram of Handheld Gas Detector

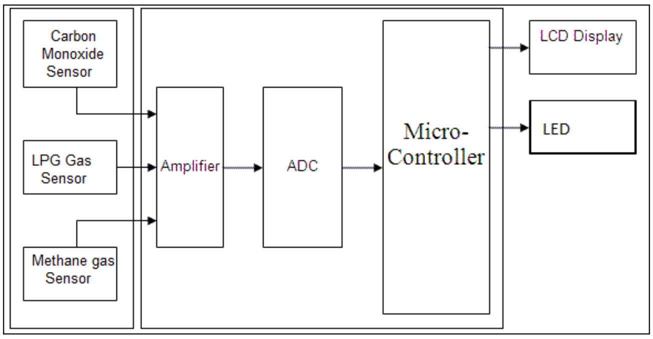

Fig 4: The basic block diagram of the gas detector

Fig 4 shows the basic block diagram of the gas detector. It’s divided by 3 parts; input, interface and output. For the input part, this consist gas sensor that will detect the existence of the gas surrounding. Furthermore, it is controlled by the microcontroller as the interface between input and output. The interface will convert the analog signal to digital signal through ADC. Thus, the microcontroller will read the signal and send it to the outputs which are LCD display and LED.

III. NEW PROPOSED ARCHITECTURE AND DESIGN

The review for the "new proposed architecture and design' is included in this paper for complete the paper overview. Three sub-topics have been included in this section start with the overall design in applied environment, the flow of system operational and the final subsection is the block diagram components inside the system.

A. Overall Design in Applied Environment

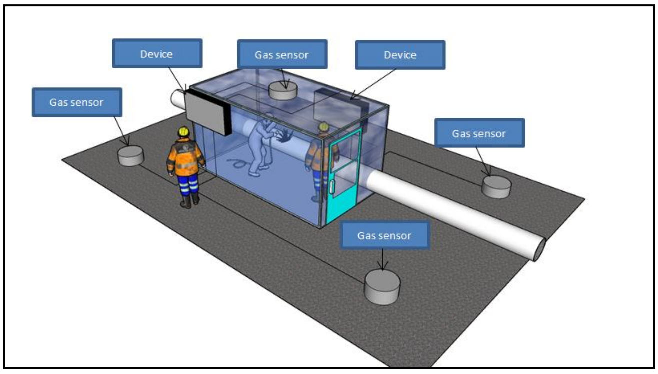

Fig 5: New proposed architecture and design

Fig 5 shows the proposed design of the architecture for the habitat. From the existing system, the architecture of the habitat is not consists the gas sensor or detector on it. The proposed of new innovation of the design, the high sensitive gas sensor is built surrounding the habitat referred to Fig 5. Furthermore, the main feature for this prototype is the gas sensor. The gas sensor is automatically controlled by the microcontroller. Hence, the notification, monitoring and logging also are been applied in the system.

B. The Flow of the System Operational

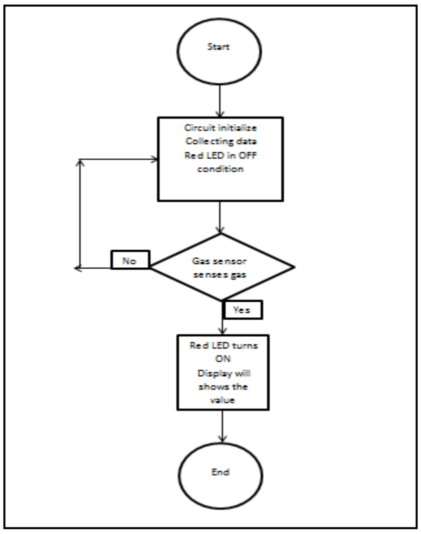

Fig 6: Flow operation

The work flow diagram in Fig 6 shows the basic operation of the prototype of this study. At start, the circuit must be put to ON mode and sensor will initiate about 10 seconds to do the stabilization. After initiating, the sensor is on standby mode that will ready to sense the existence gas around. When one of the sensor senses the gas surrounding, the red LED that represents the sensor will turn ON and the LCD display will shows the concentration of existing gas. Thus, there is different function at the sensor (Sensor 3) that attached at the motor. When sensor 3 detect the gas, the motor will turn OFF (Standby) and the LED indicators will turn to yellow that will indicate the motor is in standby mode. The purpose is to prevent the gas flow in the habitat. In the same time, the data will be collected to the SD logger that will save in "excel". So, the users can revise back the existence of the gas during the hot work. Graph can be generates through the "excel".

C. Block Diagram Components inside the System

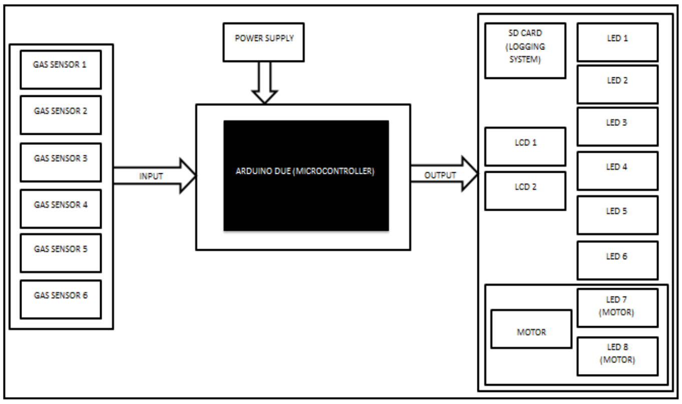

Fig 7: Block diagram

Fig 7 shows the block diagram of the system that contents the necessary components. There are 6 inputs which are the gas sensors that connected to the microcontroller and will trigger the 14 outputs. The outputs will responses based on the programming or coding that has been uploaded to the microcontroller.

IV. MATERIALS AND METHODOLOGY

In this section, the overall system design from schematic level design was outlined. Five subtopics have been added under this section: System schematic, Gas sensor circuit, microcontroller, Logging system schematic and notification schematic. The construction and function of each component are detailed discussed in their sub-topic.

A. System Schematic

Fig 8 shows the full schematic circuit of the prototype. All components are supplied with 5V power from the microcontroller. Digital pin 50 (MOSI), 51 (SCK) and 52

(MISO) are serial peripheral interface (SPI) connections which will connected to SD module. Then, 6 gas sensors are connected to analog pins (A0, A1, A2, A3, A4 and A5). Thus, the red LEDs are connected to digital pins (23, 25, 27, 29, 31, and 33). Each red LED represents 1 gas sensor as an indicator of gas sensing. Yellow and green LEDs are represent as motor indicator which connected to digital pin 39 and 37. Green LED turns ON when motor is in ON condition and yellow turns ON when motor in standby condition. LCD display 1 is connected to digital pin (2, 3, 4, 5, 6 and 7) and LCD display 2 connected to digital pin (22, 24, 26, 28, 30 and 32).

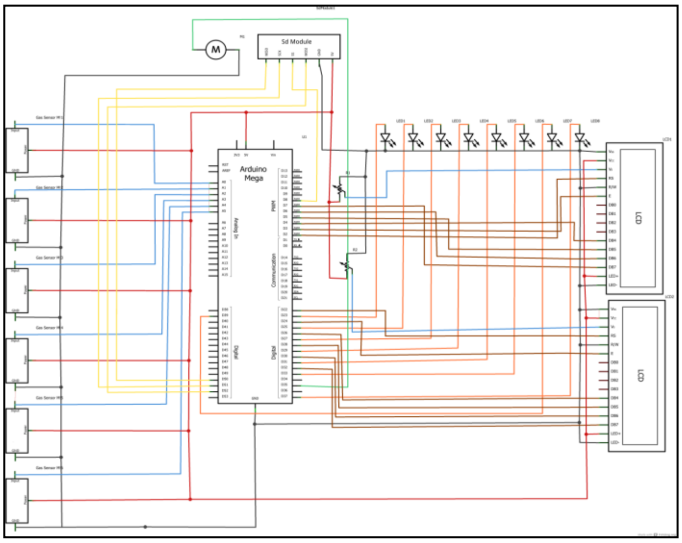

Fig 8: Full schematic circuit

B. Gas sensor Schematic

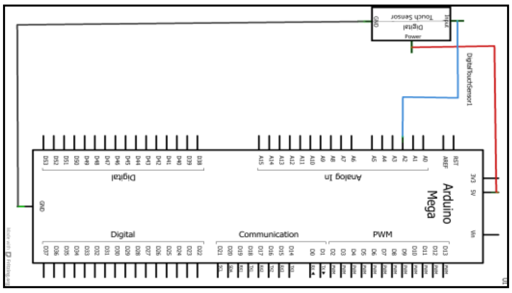

Fig 9: The connection of 1 gas sensor

Fig 9 shows the schematic circuit for the gas sensor. This is the connection for the pin for the gas sensor to connect. The gas sensor module consist 3 pin; analog input, power and ground. From Fig 9, the analog pin for the module is connected to the pin 2 analog. Hence, the microcontroller will convert the analog signal to digital signal. Furthermore, to power up the gas sensor, the gas sensor is connected to 5V pin.

In this project, MQ-5 gas sensor is used as an important component. MQ-5 gas sensor has high sensitivity to LPG and natural gas. It is also has fast response sensing and stable. Furthermore, it is long life[2].

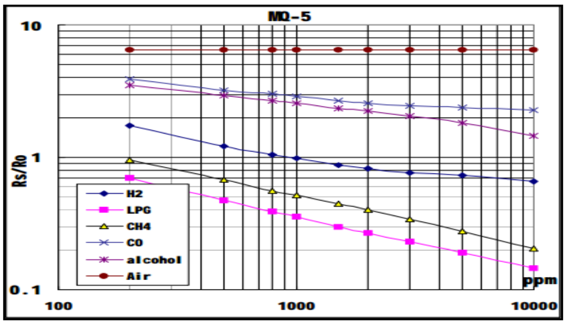

Fig 4: Showing the typical sensitivity characteristic of the MQ-5 for several gases

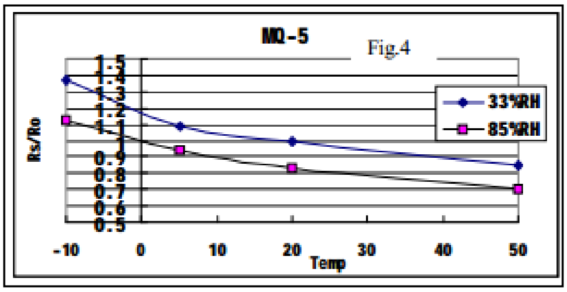

Fig 5: Shows the typical dependence of the MQ-5 on the temperature and humidity

C. Microcontroller

Fig 10: Arduino Due Microcontroller

Fig 10 shows the microcontroller that used for this project. Arduino microcontroller is used to control the circuit for this project. It is an open source single board microcontroller. Which is this interface needs to program it to control the circuit. The software consists of a standard programming language compiler and the boot loader that runs on the board. For programming, it uses C programming.

The brand for the microcontroller for this project is Arduino Due. It is based on the Atmel SAM3X8E ARM Cortex-M3 CPU that enables a higher level of performance. The Arduino Due has 54 digital input/output pins (of which

12 can be used as PWM outputs), 12 analog inputs, 4 UARTs (hardware serial ports), a 84 MHz clock, a USB OTG capable connection, 2 DAC (digital to analog converters), 2 TWI, a power jack, an SPI header, a JTAG header, and reset and erase buttons[4].

D. Logging System Schematic

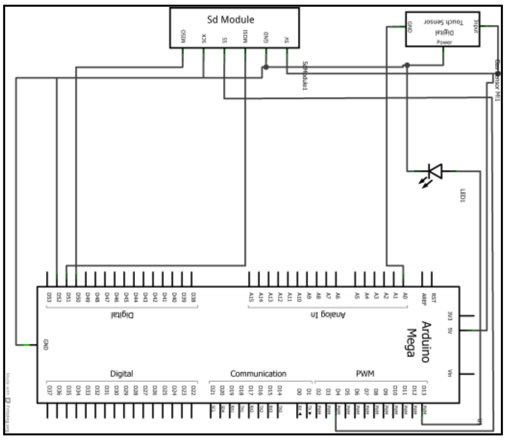

Fig 11: The connection for the SD module with 1 LED and gas sensor

Fig 11 shows the connection for the SD module. The purpose of the SD module is data log. Hence, its record and save the data from the gas sensor. Which mean the data of the concentration of the gas that sensed by the gas sensor is recorded to the Secure Data (SD) memory card. From the Fig 11, the SD module has 6 pins; MISO, MOSI, SCK, power, ground and selected chip. The pins are connected to the Serial Peripheral Interface (SPI) pin on the microcontroller. From data sheet for the microcontroller, the Serial Peripheral Interface (SPI) pin is located or connected to digital pin 50 (MOSI), 51 (SCK) and 52 (MISO) [9].

From the schematic circuit in Fig 11, MISO pin is connected to pin 52, MOSI pin is connected 50 and SCK pin is connected to pin 51 on the microcontroller.

E. Notification Schematic

For the notification schematic, Fig 8 shows all the notification, indicator and monitoring connection. LEDs are represented as the notifications and indicators for this project. Furthermore, 2 LCD displays 16 x 2 is used for the monitoring system.

LEDs are connected to pin 23, 25, 27, 29, 31, and 33 as referred from Fig 8. Thus, LCD display 1 is connected to digital pin (2, 3, 4, 5, 6 and 7) and LCD display 2 connected to digital pin (22, 24, 26, 28, 30 and 32).

V. Result and Discussion

Throughout the habitat technology evolution, there are concepts combining the advantages of the differences system. Which include the usage of the gas sensor, monitor and indicator. The design of habitat technology permits great flexibility, allowing the welders to optimize for a number of different benefits, such as efficiency in sensing, controlling, notification and monitoring.

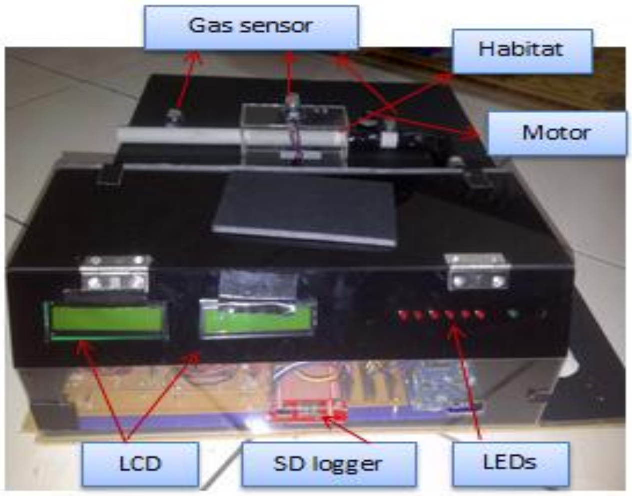

Fig 12: The prototype of habitat technology (Model)

Fig 13: The LCD displays the value of gas sensed by the gas sensors according to the concentration of the gas

Fig 14: The LEDs turn ON when the sensors sensed the gas surrounding

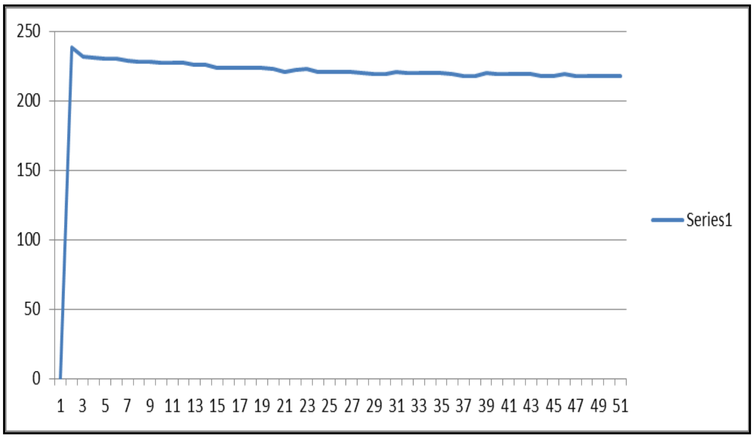

Fig 15: Averages of gas sensors during test. (51 readings) No gas is sensed.

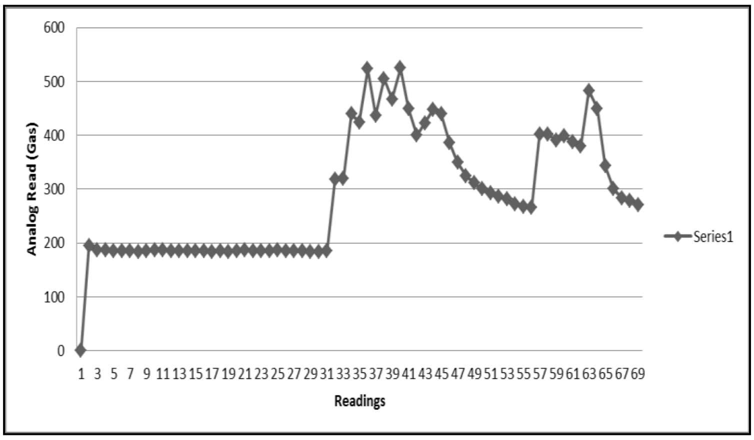

Fig 16: Averages of gas sensors during test (69 readings). Gas is sensed

Fig 12 shows the prototype of the project. All the components and circuit is put inside the prospect and it has been tested in prototype level. From the test that has been run, it produces result that desired. Referred to Fig 13 shows the LCD displays the concentration of gas that sensed by the gas sensors during the test. It is displaying the voltage of the gas sensors. The voltage will increase to 5V (max) when the concentration of the gas surrounding is high. Thus, the readings are according to the serial analog reader that has been implemented in the Arduino microcontroller. Then, there are several calculations to do to convert the value of analog reading to voltage values as displays in Fig 13. Fig 14 shows the notifications and indicators. The LED 3 and LED 4 are in ON condition which means the gas sensor 3 and gas sensor 4 is detecting the gas surrounding. As been mentioned, one of the gas sensors is attached with the motor which is gas sensor 3. The yellow LED is turn ON, notified that the motor is in standby condition (STOP). It avoids the motor to absorb the gas surrounding into the habitat. This will prevents the gas flow inside the habitat that will cause hazardous during hot work is performed. While in progress in sensing the gas surrounding, the data from the gas sensor is recorded and saved to the SD card. The log can be view through excel and the graph can be generate through it. It will shows the average of the gas that sensed by the 6 sensors.

Fig 15 shows the condition there is no gas surrounding the gas sensors. The reading from 0 – 230 are the moment or time taken for the circuit to initialize. The purpose of the circuit initialize is for stabilization of the components. Fig 16 shows the graph of the average (69 readings) of the gas sensors sense the gas surrounding during test of the prototype.

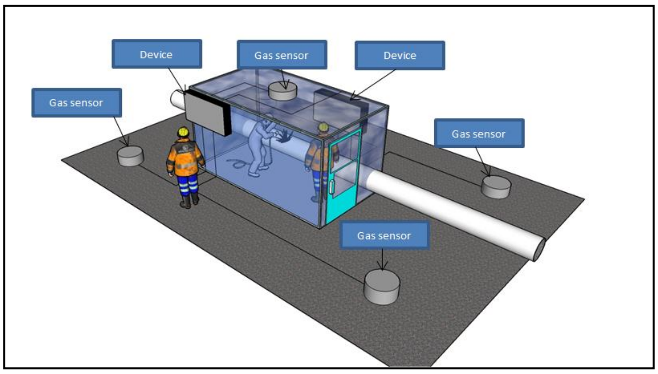

Fig 17: Illustration of result

Fig 17 shows the illustration or sketching of the result or product that can be implemented in reality. The gas detectors or sensors are located surrounding the habitat. Hence, the gas detectors or sensors are portable, can be located anywhere near the habitat.

VI. CONCLUSION

An innovation of habitat's technology is presented in this article. It is observed from the prototype/model that, not only does, it also consume more safety work environment during welding activity/hot work. The purpose of this innovation to create something new towards the technology. Thus, it also useful and able to solve the problems that related to hot work. It is able to be implemented into real world. In other hand, this idea can create a new modified product that will give more efficiently result.

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REFERENCES

[1] J. Santos-reyes and A. N. Beard, "A systemic approach to fire safety management," *Fire Safety Journal*, vol. 36, no. 4, pp. 359–390, 2001.

[2] K. Arshak, E. Moore, G. M. Lyons, J. Harris, and S. Clifford, "A review of gas sensors employed in electronic nose applications," *Sensor Review*, vol. 24, no. 2, pp. 181–198, 2004.

[3] L. S. Moiseeva, "Carbon dioxide corrosion of oil and gas field equipment," *Protection of Metals*, vol. 41, no. 1, pp. 76–83, 2005.http://hothed.com/products/habitat.html (12:58PM, 18 October 2012)

[4] [M. Banzi, *Getting Started with Arduino*, vol. 11, no. 4. Make:Books, 2008, p. 118.http://playground.arduino.cc/Main/MQGasSensors (1:03PM, 18 October 2012)

[5] B. W. Kernighan and D. M. Ritchie, *The C programming language*, vol. 78. Prentice Hall, 1988, pp. 1–217.

[6] C. G. Casso, Electrical safety in hazardous environments, (1994), Conference Publication No. 390, IEEE, 1994

[7] Y. Z. Wang, Y. H. Chen, Z. L. Nan, and Y. Hu, "*Study on welder training by means of haptic guidance and virtual reality for arc welding*" Proceedings of the 2006 IEEE

[8] Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance L101 HSE Books 1997 ISBN 0 7176 1405 0

[9] https://www.sparkfun.com/products/9802 (12.12AM, 01 December 2012)

[10] L. Muehlenbachs, M. A. Cohen, and T. Gerarden, "The impact of water depth on safety and environmental performance in offshore oil and gas production," *Energy Policy*, vol. 55, pp. 699–705, 2013.

[11] http://www.stshabitat.com/?gclid=COHIwoziibMCFYka6wod9igAIw (12:51PM, 18 October 2012)

[12] http://hothed.com/products/habitat.html (12:58PM, 18 October 2012)