MISR JOURNAL OF AGRICULTURAL ENGINEERING
https://mjae.journals.ekb.eg/
ISSN-Print: 1687-384X
ISSN-Online: 2636-3062

Misr J. Ag. Eng., 39 (2): 263 – 280
DOI: 10.21608/mjae.2022.94488.1046

A FIRE ALARM SYSTEM FOR AGRICULTURAL STRUCTURES

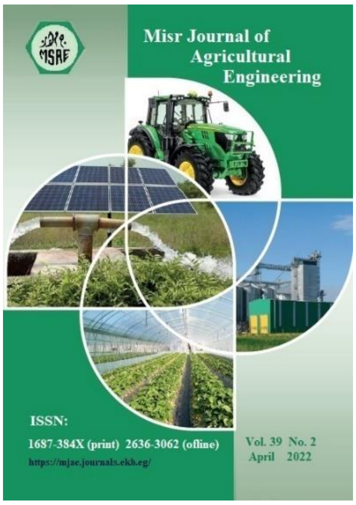
Khiery M. Ismail[1&*], Abdalla M. Zein Eldin[1], Shymaa M. Hamada[2] and Mohamed A. Rashwan[3]

[1] Prof., Dept. of Ag. & Biosystems Eng., Fac. of Ag., Alex. U., Alex., Egypt.

[2] MSc. Stud., Dept. of Ag. & Biosystems Eng., Fac. of Ag., Alex. U., Alex., Egypt.

[3] Assoc. Prof., Dept. of Ag. & Biosystems Eng., Fac. of Ag., Alex. U., Alex., Egypt. & Currently at Ag. Eng. Dept., College of Food & Ag. Sciences, SA.

* E-mail: Khieryismail@yahoo.com



Keywords:
Fire; Alarm; System; Smoke sensor; Heat sensor; Light sensor; Facilities; Firefighting; Structures.

ABSTRACT

The aims of this research were to; 1- construct a simple alarm fire system to early warn for a fire in the agricultural facilities, 2- test the performance of the sensors used, mainly heat, light, and smoke sensors. Basically, these three sensors were connected to control panel and power supply. The control panel is to control the input data from sensors and the output data to the other units in the system. The response time of any fire sensor is the time from fire starting up to the moment that sensor senses the fire. It was considered to be the best factor to express the sensor performance. The performance of smoke sensor was mainly affected by the sensor height and smoke density where the response time increased when the sensor height increased while it decreased when smoke density (no. of mats) increased. The data analysis of this relationship showed a determination coefficient of 99.66%. For heat sensor, increasing the combustion temperature of material used for making fire reduced the response time of heat sensor, while increasing the heat sensor height increased the response time. The determination coefficient was found to be 99.2%. For the light sensor, the response sensitivity increased with increasing the light intensity at a specific distance. Thus, the light sensor must be placed at an appropriate distance to obtain a fast response. The determination coefficient this relationship was found to be 99.5%.

1. INTRODUCTION

The data of the Central Agency for Public Mobilization and Statistics (CAPMS, 2019) showed that about 438 thousand fires occurred in Egypt during the past 10 years; where the recorded number of fires was about 51 thousand fires in 2010 comparing to about 47 thousand fires in 2009 (an increase of 7.8% was occurred). During the year of 2016, the recorded number of fires was about 46 thousand fires with an increase of 21.6% over the year of 2015. During 2017, the number of fires was slightly decreased to 45.7 thousand fires, which is about 0.1% comparing with 2016. A number of 46.3 thousand fires was recorded during 2018. In 2019, the number of fires (nationwide) reached 50,662 fires which form an increase by 9.4% comparing with 2018. In 2021, according to the data published by CAPMS, the total number of fires in Egypt was 51900 fire accidents versus 50600 in 2019. The industrial fire was the highest, 56.8% of that total while it was 20.3% for shortcut circuit fire and 12.2% for self ignition fire.

According to the criminal case in 2021, the negligence is considered to be the main cause of fire accidents which was 26100 which forms a rate of 50.4%. The main causes of the industrial fires are cigarette butts, matches, combustible material, and smoke). The CAPMS reported (2021) that the number of fire accidents in Cairo city was the highest comparing with the other cities of Egypt. This number was 13.3% of the total which was 51900 fire accidents. The Giza city came next where the number of fire accidents formed 7.4% of the total.

Saving lives is considered to be the first consideration when an indoor fire occurs. Thus, this requires a warning to those who are alive inside the building as soon as the fire occurs so that they can get out before the fire extends and the flames spread out. Therefore, there must be an effective and early warning system in the place to initiate an alarm signal before the fire becomes more dangerous. Thus, people inside the buildings can leave safely. The primary task for any alarm system is to sense the fire early and convert it into an electrical signal to be handled by electronic circuits. When the system sensor sends pulses to the control unit that emits an optical and audio signal in the areas surrounding the fire to inform the security management or firefighters. Therefore, it is imperative that the buildings and agricultural facilities must be equipped with an early warning system. In this case, there will be enough time to evacuate the buildings and fight the fires (El-Barbary, 2005). The first consideration in the event of a fire for any building is the safety of its occupants. The occupants must have time to safely evacuate the building. (User guide to fire detection & alarm system, 2014).

In the agricultural sector and in most agricultural structures, there is not enough information about the level of safety. Because the automatic and electronic extinguishing systems are very expensive, beside the difficulty to deal with these systems due to the lack of sufficient experience, the workers cannot easily own such systems. The only tool for firefighting in this case is a cylindrical fire extinguisher that contains carbon dioxide or some other chemical substances.

There are several different types of intelligent fire alarm systems available in the market. These systems have a control unit which used to decide whether there is a fire, fault, pre-alarm or whatever. The intelligent system with each detector effectively incorporates its signal to the computer which evaluates the environment around it and communicates with the control panel whether there is a fire, fault or the detector head needs cleaning. Essentially, however, intelligent systems are far more complex and incorporate far more facilities than conventional or addressable systems. Their primary purpose is to prevent the occurrence of a false alarm (Photain controls, 1998).

The performance of any alarm system basically depends on the response time of the sensor used to sense fire. It is the time from fire starting up to the moment that system gives a buzz. This response time depends on many variables such as location, height, smoke density, type used, and etc... Therefore, before constructing such alarm system, we should study the effect of these variables on the response time of the sensors used. Because they are many to investigate, only the most important variables were considered. For one type sensor at a fixed location (middle of the ceiling), the sensor height and smoke density were considered for the smoke sensor while both sensor height and surround temperature were considered for heat sensor. For light sensor, the main variable affects its response time is the illumination intensity (Qianga, 2011, and Yamauchi, 1988).

Thus, the main objectives of this paper are to 1-construct the proposed fire alarm system that relies on smoke, heat and light sensors together, and 2- to study the effect of sensor height and smoke density for smoke sensor on the response time to the fire, 3-the effect of height and temperature on the sensor response time to fire for heat sensor, and 4-the effect of illumination intensity on response time of light sensor.

2. MATERIALS AND METHODS

1- Description of location of the experimental work:

The laboratory experiments were conducted at the Agricultural Research Station of Alexandria University, Abees, Alexandria, Egypt. One of the station's storage rooms was allocated to conduct calibration tests for the proposed fire alarm system. The room area was 4×4 m^2 with a height of 2.9 m. It has one window (1×1.5 m) and one door (2.8 m height × 1.2 m wide). The room was completely cleared to carry out the experiments.

2-Description of sensors and methods of testing:

2-1-Smoke sensor:

Smoke sensor circuit consists of gallium arsenide infrared emitting diode (transmitter) coupled with a silicon phototransistor (receiver) for signal passes between them in a plastic housing. The gap between the transmitter and receiver provides a means of interrupting the signal with a smoke switching the output from an “ON” to an “OFF” state. When smoke passes through the gap between the transmitter and the receiver, a signal is developed and amplified by an amplifier (LM358) built into the sensor circuit. This case allows a connection of the output signal of the smoke circuit with the main control panel.

2-2-Heat sensor:

The heat sensor is a digital thermometer (DS18B20) that provides temperature measurements from 9 bits to 12 bits Celsius, and has an alarm function with user programmable upper and lower operating points. These types of sensors are fairly accurate and do not require external components to operate. The digital thermometer was connected via a single wire bus which only requires one data line (and ground) to connect it to a central microprocessor. The operating temperature range of the sensor is from -10 ° C to + 85 ° C and the accuracy is up to ± 0.5° C. In addition, it can directly consume power from the data line, where we eliminate the need for an external power source. Each DS18B20 contains a unique 64-bit serial code, which allows multiple DS18B20s to operate on the same single wire bus. Thus, it is easy to use a single microprocessor to control multiple DS18B20s distributed over a large area. Each device (master or slave) interfaces to the data line via an open-drain or 3-state port. This allows each device to “release” the data line when the device is not transmitting data so the bus is available for use by another device. The one-Wire bus requires an external pull-up resistor of approximately 5 kΩ, thus, the idle state of the one-Wire bus is high. If for any reason a transaction needs to be suspended, the bus must be left in the idle state if the transaction is to resume. Infinite recovery time can occur between bits so long as the 1-Wire bus is in the inactive (high) state during the recovery period. If the bus is held low for more than 480µs, all components on the bus will be reset. The 1-Wire port of the DS18B20 (the DQ pin) is open drain with an internal circuit equivalent to that shown in Figure (1).

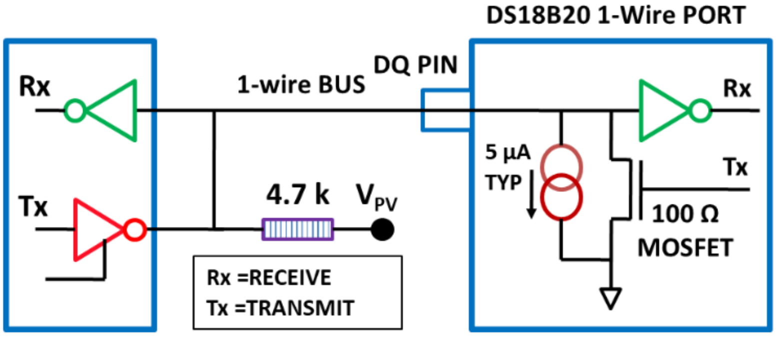


Figure 1: Heat sensor electronic circuit using DS18B20 one wire sensor.

2-3-Light sensor:

The light dependent resistor (LDR) is known as a photo resistor, photoconductor or photocell. It is a resistor whose resistance increases or decreases depending on the amount of light intensity. The LDR is a very useful tool in a light/dark circuits. It has many functions. For example, it can be used to turn on the light when the LDR is in darkness. It can also work in reverse when the LDR is in the light. It is also used for powering many electrical circuits. This component is enclosed in a plastic housing that allows the light circuit output signal to be connected to the main control board. The light sensor circuit component of LDR is connected with amplifier to receive and magnify the signal.

3-Method of fire igniting in the laboratory:

According to Siemens (2014), the standard test of the fire produced by burning mats using a chemical reaction involving fuel, heat, and oxygen. They are a fabric flat material made of white foam with a smooth surface. The dimensions of the mats are: 25 cm × 25 cm with a thickness of 2 cm, and a density of 5.2 kg/m^3. For testing purpose, an amount of Alcohol (2.5 ml) was added to the mat to start an artificial fire.

4- Description of hot air pump used with the heat sensor:

To test the heat sensor, a hot air pump (Model: Super 3000 – 220 V – 50-60 Hz – 2000 Watt) was used to heat the air around the heat sensor while a fan (220 V – 50 Hz – 55 Watt) was used to expel smoke from the room after completion of the experiment and before starting a new experiment.

5-Method of creating illumination intensity in the laboratory:

Five different light lamps (15, 25, 40, 100, 200 Watt) that give 135, 225, 756, 900, 1800 Lumen, respectively) were used to create illumination intensity to test the light sensor.

6-The programmer PIC kit 3:

The PIC kit 3 is a circuit debugger / programmer. It is a simple, low-cost in-circuit debugger, controlled by a computer running MPLAB X IDE software on the Windows platform. It is also used to develop hardware and software using Microchip PIC microcontrollers (MCUs). The PIC kit 3 features include; full-speed USB support using standard Windows drivers, real-time execution, built-in over-voltage/short circuit monitor, low voltage to 5V (1.8-5V range), read/write program and data memory of the microcontroller, erasing of all memory types (EEPROM, ID, configuration and program) with verification, and peripheral freeze at the breakpoint. The programming connector comes with a 6-pin header that connects to the target device as shown in Figure (2).

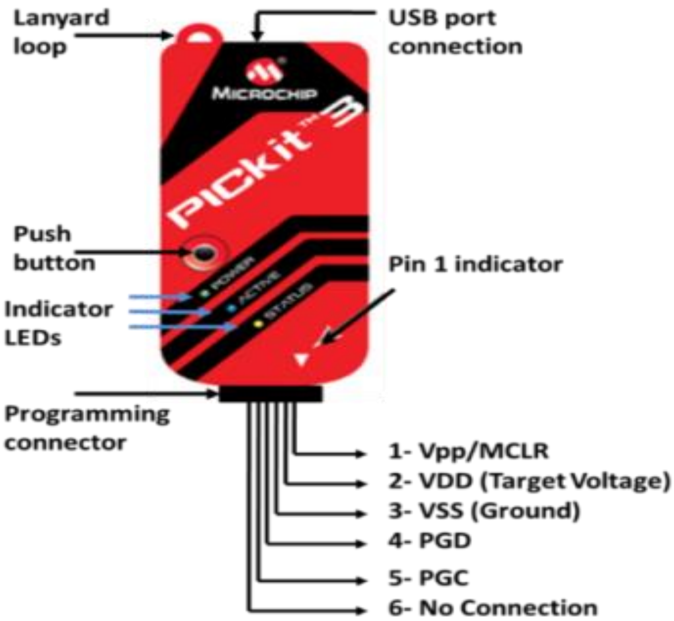


Figure 2: PIC kit 3, circuit debugger/programmer and standard connection target circuitry

7-Alarm system control panel:

The control panel contains an integrated chip (PIC16F877A) that has been shipped with software which evaluates the signals sent by peripheral devices such as smoke detectors, heat detectors, light detectors, horns and sirens. It controls the fire alarm and control installations and is also the point of interaction between the operator and system. It is installed in a protected area away from fire hazards. It is preferable to be next to the entrance that the fire fighters use and see it from outside the building. It must be also located in a common area for all building users so that the automatic detection could be done. It contains LCD screen for showing the temperature degree inside the room and displays the type of sensor that sends the signal.

8-Air Heater:

An air heater was used as a source of heat for sensor calibration where various air temperatures could be obtained. Its model was HT 2055, 220-240V, 50-60Hz, with 2000W.

9-Air fan:

Air fan was also used to get rid of smoke resulted from the artificial fires of previous test calibration in the experimental test room. It has a power of 55W energized with 220V and 50Hz.

10-Light lamps:

Light lamps of different power were used to obtain different illumination intensities that could be used for calibration of light sensor. Basically, five different lamps were used to give 15, 25, 40, 100, 200 Watt. The illumination intensities obtained were 225, 375, 600, 1500, and 3000 lumen respectively for the above lamps.

PROCEDURES

1-Tests of smoke sensor:

1.1-Experimental design:

Any laboratory experiment should experimentally design to determine the dependent and independent variables. Based on consulting of the fire experts, the most important independent variables required for determining the response time of smoke sensor were sensor height above the smoke source and the smoke intensity which could be represented as a number of mats where different smoke densities were obtained (Siemens, 2014). In addition to Siemens, 2014, Husted, B. P., 2004 repoted that the amount of smoke, which is generated in a fire, can be linked directly to the optical measure and the flow of smoke or it can be linked to the burning objects. Thus, in these calibration tests, the burning objects will be number of polymer mats. Thus, the independent variables were set up as follows:

1-Sensor height, h, with 3 levels (1.5, 2, and 2.9 m), and

2-Number of mats, *n* with 4 levels (1, 2, 3, and 4 mats)

Therefore, the proposed model that generally expresses the relationship between the response time of the smoke sensor (as a dependent variable) and the other independent variables named above (sensor height and no. of mats) can be written as follows:

$$t = f(h, n) \;\; for\ smoke\ sensor \text{ ----------(1)}$$

To determine this model statistically, a complete randomized was carried out using 3 replicates for each treatment combination. Thus, the number of experimental units is 36 (Cochran and Cox, 1980). The experimental data were analyzed using the statistical computer program (SAS) available on microcomputer (1982). The determination coefficient, R^2, of the resulted model would be computed by the SAS program. As a matter of fact, the determination coefficient (R^2) is defined as the ratio between the total sum squares of the tested treatments and the total sum squares of the whole experiment. The total sum squares of whole experiment are composed of the total sum squares of the tested treatments plus the error term. In another meaning, the value of R^2 expresses the powerful of the relationship between the dependent and independent variables. Thus, the R^2 is considered to be a good measure for the model strength.

1.2- Description of Experiments:

In these experiments, sensor was fastened in a wooden board which hung into the room ceiling at the selected height as shown as in Figure (3). This height was controlled with a rope that was connected to a bolt existed already in the room ceiling. As a matter of fact, the height of 2.9 m was the maximum height could be obtained as in the figure. The number required of mats according the treatment combination was placed in a plate as shown in Figure (4).

About 3mls of alcohol were uniformly added into the pot to expedite the fire as well as to obtain a uniform fire. Once the fire started, time was recorded by stopwatch until the control panel of the proposed system activated the buzzer to produce a buzz. The time recorded would be considered as a response time of the sensor under calibration. Before starting each experiment, an air fan was used to expel the air containing carbon dioxide so that the room became completely smoke-free before starting the second experiment. Test was repeated to complete the treatment combinations according the experiment design. Thus the data obtained were utilized to form the statistical model using SAS as previously explained.

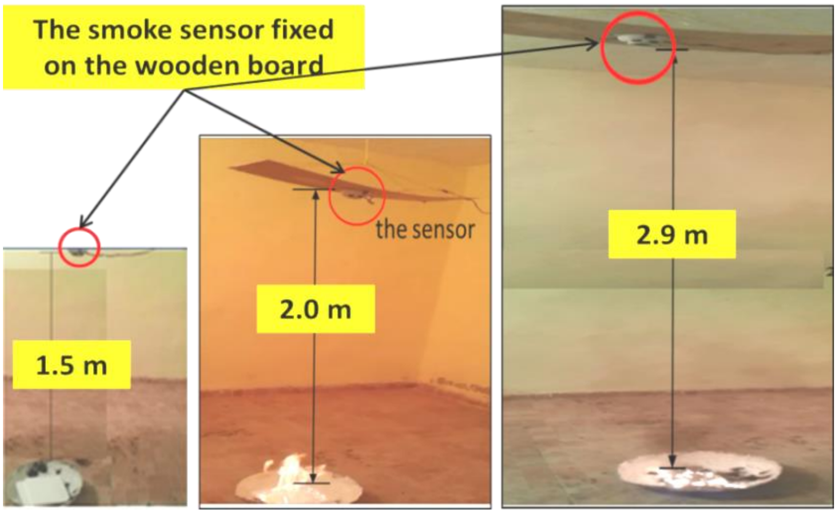


Figure 3: Smoke sensor heights of 1.5, 2, and 2.9 m

Figure 4: The mats used in the experiments

2-Tests of heat sensor:

2.1-Experimental design:

The calibration experiments of the heat sensor were also carried out using a complete randomized design (Cochran and Cox, 1980). The response time of the heat sensor (as a dependent variable) was considered to be a function of milieu temperature and sensor height above the fire source and temperature of the heat source. This response time, in fact, depended on the critical height of heat sensor above fire source and the temperature of heat source. For example, assuming the control panel is adjusted to give a buzz at a temperature of 35°C. This temperature is considered as critical temperature. If the sensor of the heat is placed in the medium of a lower temperature, say 25°C, the sensing system would not be activated. However; if the heat sensor is placed at specific height in a medium of higher temperature than 35°C, the system will feel the heat produced from the heat source after a certain time as long as there is a difference in temperatures. This time depends on the sensitivity of the sensor. The response time of heat sensor is the time taken from stating until a buzz is heard. Thus, the variables of height, h, and heat source temperature, T_{HS}, were considered to be the independent variables that affect the time response. At least three levels for each variable were tested as follows:

1-The heat temperature levels; T_{HS}, with levels; 40, 60, and 100^o C, and

2-Sensor height, h, with levels; 1.5, 2, 2.9 m above the fire source.

Now we have 9 treatment combinations. Each experimental unit was repeated three times. Thus, the number of experiments was 27. Thus, the proposed model that generally expresses the relationship between the response time of heat sensor (as a dependent variable) and the other independent variables named above could be written as follows:

$$t = f(h, T_{HS})\ \ for\ heat\ sensor \text{ ----------------(2)}$$

where;

h=height of sensor above the fire location, m, and

T_{HS}=temperature of heat source, ^{o}C.

Data obtained from the experimental tests were analyzed be SAS available on micro-computer (V9.1).

2.2- Description of Experiments:

The air heater that previously described was utilized to heat air to the required temperature (40, 60, and 100^{o}C). Heat sensor was placed at the required height according to the plan of the experimental setup. A fan was used to blow air in the room after each experiment to get rid of the heat of previous test until the room temperature becomes below 25^{o}C. This was because the room temperature was originally 25^{o}C before stating the experiment. The room temperature was measured by the thermometer which built in the proposed device. Figure (5) shows the setup calibration of the heat sensor. As soon as the air heater was operated, time was recorded until a buzz from the alarm system was heard. This was considered to be the response time of the heat sensor**.**

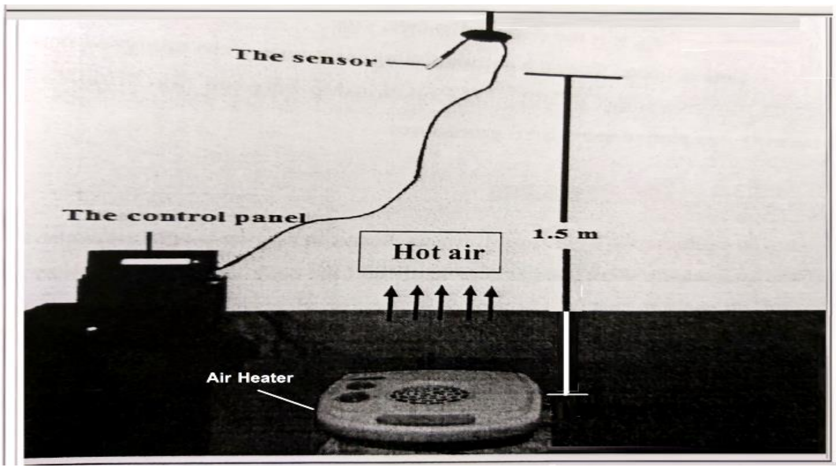


Figure 5: The setup of measuring the response time of heat sensor

3-Tests of light sensor:

3.1-Experimental design:

The calibration experiments of the light sensor were also carried out using a complete randomized design (Cochran and Cox, 1980). The distance from light sensor to a light source and the light intensity were considered to be the two main variables that affect the response time of the light sensor. The response time of light sensor in the calibration tests could not be measured due to the high light velocity. Instead, the distance from light sensor to the light source was measured at the moment of obtaining a signal (buzz) from the alarm system.

Thus, the sensor is placed at a fixed point while the source of light moves toward the light sensor until we heard buzz by the alarm system. This measured distance between the light sensor and light source is called as "critical distance" (d_{cr}) for specific light intensity. Figure(6) shows the setup of the light sensor calibration to measure the critical distance that causes a buzz by the alarm system.

Thus, five different levels of light intensity (I) were considered as 225, 375, 600, 1500, and 3000 Lumen. Consequently, the proposed statistical model could be expressed as follows:

$$d_{cr} = f(I) \quad for\ the\ light\ sensor \text{ ---------------(3)}$$

where;

d_{cr} = the critical distance, cm., I = the light intensity, Lumen (Lm).

In this model, the illumination intensity is the main factor that affect the response time of the sensor to the fire. Data obtained from the calibration experiments were analyzed using SAS (1982) available on the micro-computer (v9.1). The relationship between the critical distance and light intensity could be plotted.

3-2-Description of calibration experiments of light sensor:

Light sensor was placed in a known position on the wall. Five lamps of known intensity were used as source of light for each test. The lamp was moved manually toward the light sensor up to the position that causes a buzz by the fire alarm system. Distance from the lamp to the location of the light sensor was measured by a meter as shown as in figure (6). Same procedure was repeated for test with the other lamps. The results of these distances were plotted versus the light intensity used. Each test was repeated 3 times to decrease the experimental error. Regression procedures using SAS were used to analyze data obtained and to obtain the best model that relate the intensity, I, to the critical distance, d_{cr}, that causes a buzz by alarm system.

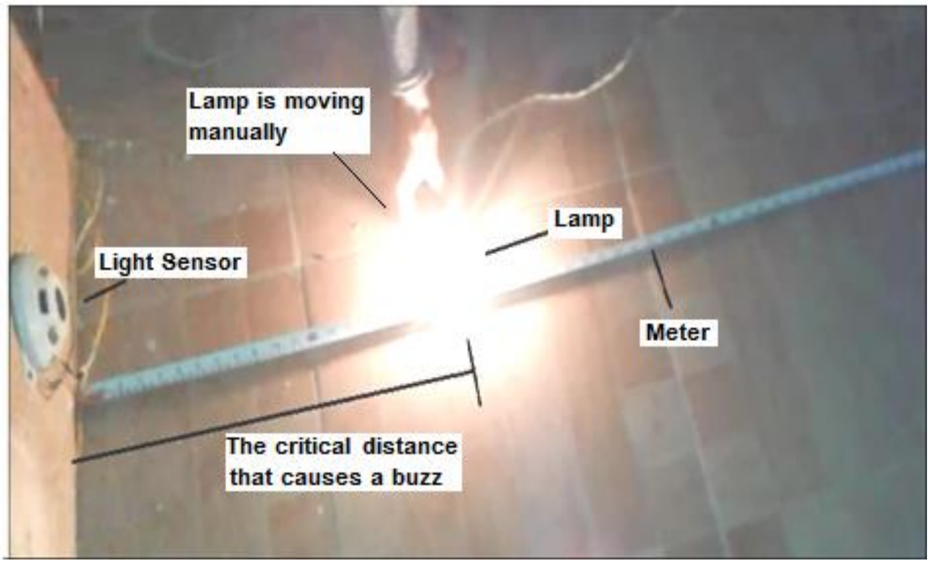


Figure 6: The setup used for measuring the critical distance, d_{cr} that causes a buzz.

4-Measuring the sensor response time:

The response time of a fire sensor is the time from fire starting up to the moment that sensor gives a buzz. It was measured by stopwatch (in seconds). It was considered the most important variable that expresses the sensor performance (David et al., 1985; Qianga,b . L, 2011; and Yamauchi, 1988).

3. RESULTS AND DISCUSSION

1-Smoke sensor calibration:

As it was considered, the most important factor when testing a smoke sensor is the response time. It has been found that sensor response time was influenced by the following parameters; sensor height, smoke levels represented by the number of cork pieces (mats) (Siemens Switzerland Ltd, 2014). Thus, the above relationship could be expressed using the following relationship:

$$t = f\ (h\ \&\ n) - - - (4)$$

where;

t= response time, h= the sensor height, and n= number of mats.

According to Figure (7), the height and smoke density of smoke sensor have an effect on the response time of smoke sensor. It is noticeable that, the relation between the height and response time is positive. That means when the sensor height increases, the response time increases, however, when smoke density (number of mats) increases, the response time decreases.

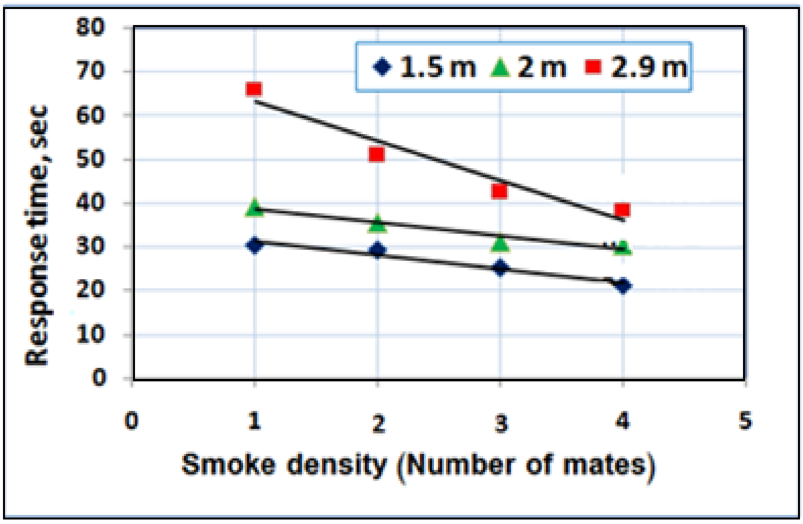


Figure 7: Effect of mats number and smoke sensor height on observed response time.

From figure 7, it seems that there is an interaction between the number of mats and the sensor height. So, the regression analysis of that relationship was implemented by SAS program is shown in Table (1), where the effects of sensor height and the number of mats as well as the interaction of height*mats were found to be very significant. Hence, the statistical model could be written as follows:

$$t = 26.072\,h - 2.636\,n + 1.176\,n^2 - 3.956\,h * n \text{ ---------(5)}$$

where; *t*: the response time of the smoke sensor (S), *h*: the sensor height (m), and *n*: the number of mats (represents the smoke density).

As shown in Table (1), the determination coefficient (R^2) was 99.6%. It strongly expresses the strength of the relationship between both sensor height and number of mats, and response time in Eq. 5. All effects in the model were found to be significant. The above model was utilized to draw the response surface of the response time (three-dimension graph) in order to give a better picture for the effect behavior of both independent variables (sensor height and number of mats) on the response time as shown in Figure (8). From this figure, it is noticed that there is an interfering between height and smoke density on the response time of the smoke sensor. As a result, the smoke sensor should put on low height if we have storage material with high risk and we need a fast response. Obviously, increasing sensor height makes, the smoke sensor takes a longer time to respond, while increasing the number of mats decreases the response time of the smoke sensor. By inspection the data obtained, it was found that the response time of the smoke sensor ranged from 20 to 68 sec. The exact values of the response time can be calculated from the above model (Eq. 5).

Figure (8) shows three-dimensional graph for the effects of mats number and sensor height on the response time. It is clear that response time of smoke sensor is affected by number of mats and sensor height above fire source.

Table 1. Data analysis for the effect of the sensor height and the number of mats on the response time of the smoke sensor

The General Linear Model (GLM) Procedure					
Dependent Variable: t		Response time, Sec			
Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	4	55208.33	13802.08	2625.98	< .0001
Error	33	173.45	5.25598		
Uncorrected Total	37	55381.78			
	R-Square	Coefficient Var.	Root MSE	time Mean	
	0.996868	6.210261	2.292593	36.91622	
NOTE: No intercept term is used: R-square is not corrected for the mean					
Source	DF	Type III SS	Mean square	F Value	Pr > F
Height	1	5034.390812	5034.390812	957.84	< .0001
Mats	1	23.706024	23.706024	4.51	0.0413
Mats * Mats	1	65.268566	65.268566	12.42	0.0013
Height * Mats	1	632.391181	632.391181	120.32	< .0001

Parameter	Estimate	Standard Error	t Value	Pr > | t |
Height	26.07171200	0.84240920	30.96	< .0001
Mats	-2.63623901	1.24131624	- 2.12	0.0413
Mats * Mats	1.17572806	0.33364288	3.52	0.0013
Height * Mats	-3.95574128	0.36063012	- 10.97	< .0001

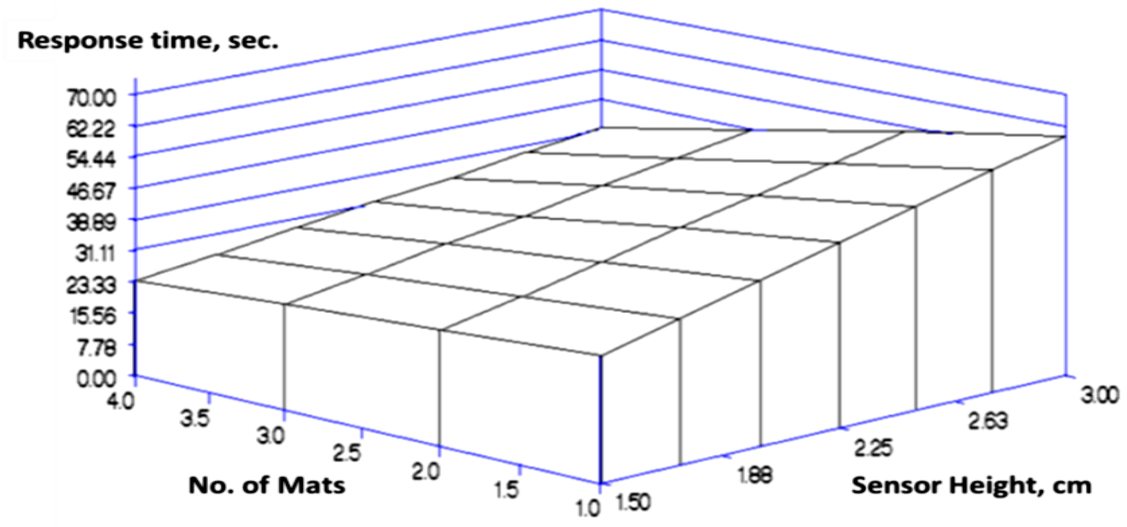


Figure 8: Effect of mats number and sensor height on the response time.

2-Heat sensor calibration:

As we mentioned previously, the calibration experiments of heat sensor were also carried out using a complete randomized design (Cochran and Cox, 1980). The response time of the heat sensor (as a dependent variable) was considered to be a function of temperature of the heat source and the sensor height above the center of fire location. The results of the heat sensor tests showed that there is a positive relationship between the combustion temperatures of the material and the response time as shown in Figure (9). This means that, if the combustion temperature of the material is high, the response time will be reduced. However, being the relationship between the response time and the height of the sensor is positive. It means, if the heat sensor gets higher, the response time will be logically increased. Therefore, when storing materials at high temperature (in summer), we should install the heat sensor at a low height.

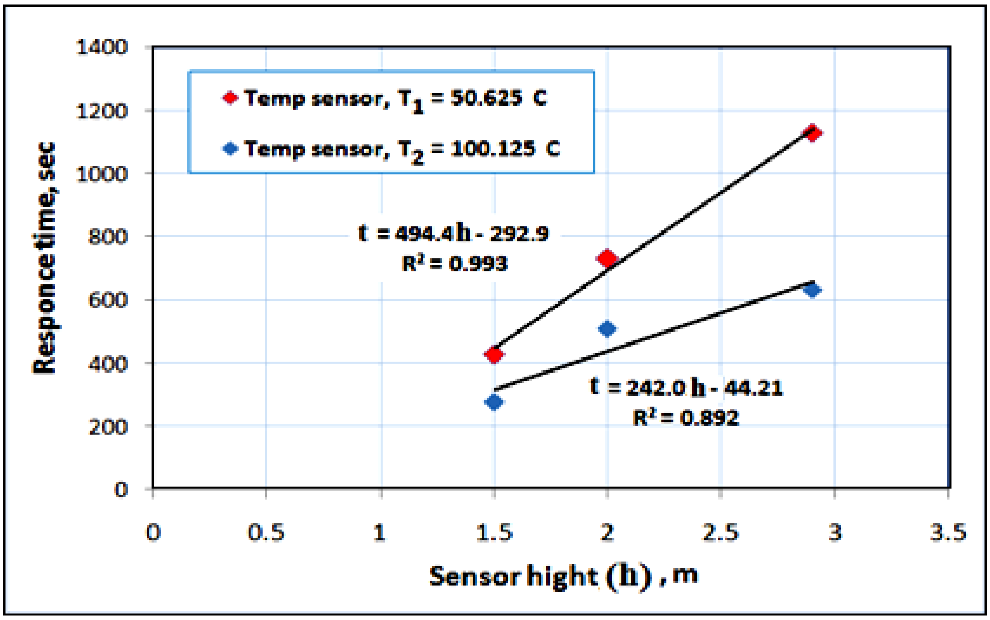


Figure 9: Effect of heat sensor height on the response time at two combustion temperatures

The statistical analysis showed that, the effects of the material combustion temperature and the sensor height on the response time are shown in Table (2). According to Table (2) an equation could be concluded to determine the response time of heat sensor as follows:

$$t = -26.062\,T_{HS} + 1279.199\,h - 186.677\,h^2 + 0.173\,{T_{HS}}^2 - 2.153\,T_{HS}\,h$$

where; t = the response time of the heat sensor.,

h = the height of heat sensor from the heat source, and

T_{HS} = the temperature of the heat source, ºC.

The above model was utilized to plot the response surface of the response time (three-dimensional graph) in order to give a better picture for the behavior of response time of heat sensor under the effect of both independent variables; sensor height and surrounding temperature as shown in Figure (10). It is obvious that the effects of surrounding temperature and sensor height on the response time are not linear according to the model in Eq. (6).

Table 2**.** Data analysis for the effect of heat source temperatures and sensor height from heat source on response time of heat sensor.

The General Linear Model (GLM) Procedure					
Dependent Variable: t		Response time, Sec			
Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	5	12969335.07	2593867.01	571.28	< .0001
Error	22	99889.13	4540.42		
Uncorrected Total	27	13069224.21			
	R-Square	Coefficient Var.	Root MSE	t Mean	
	0.992357	10.39856	67.38260	647.9993	
NOTE: No intercept term is used: R-square is not corrected for the mean					
Source	DF	Type III SS	Mean square	F Value	Pr > F
Temp	1	151487.8298	151487.8298	33.36	< .0001
Height	1	384633.0565	384633.0565	84.71	< .0001
Height * Height	1	117688.6517	117688.6517	25.92	< .0001
Temp * Temp	1	136969.7766	136969.7766	30.17	< .0001
Temp * Height	1	30001.4582	30001.4582	6.61	0.0174

Parameter	Estimate	Standard Error	t Value	Pr > ǀ t ǀ
Temp	-26.061649	4.5119139	-5.78	< .0001
Height	1279.198558	138.9832419	9.20	< .0001
Height * Height	-186.676837	36.6666234	-5.09	< .0001
Temp * Temp	0.172819	0.0314650	5.49	< .0001
Temp * Height	-2.153248	0.8376656	-2.57	0.0174

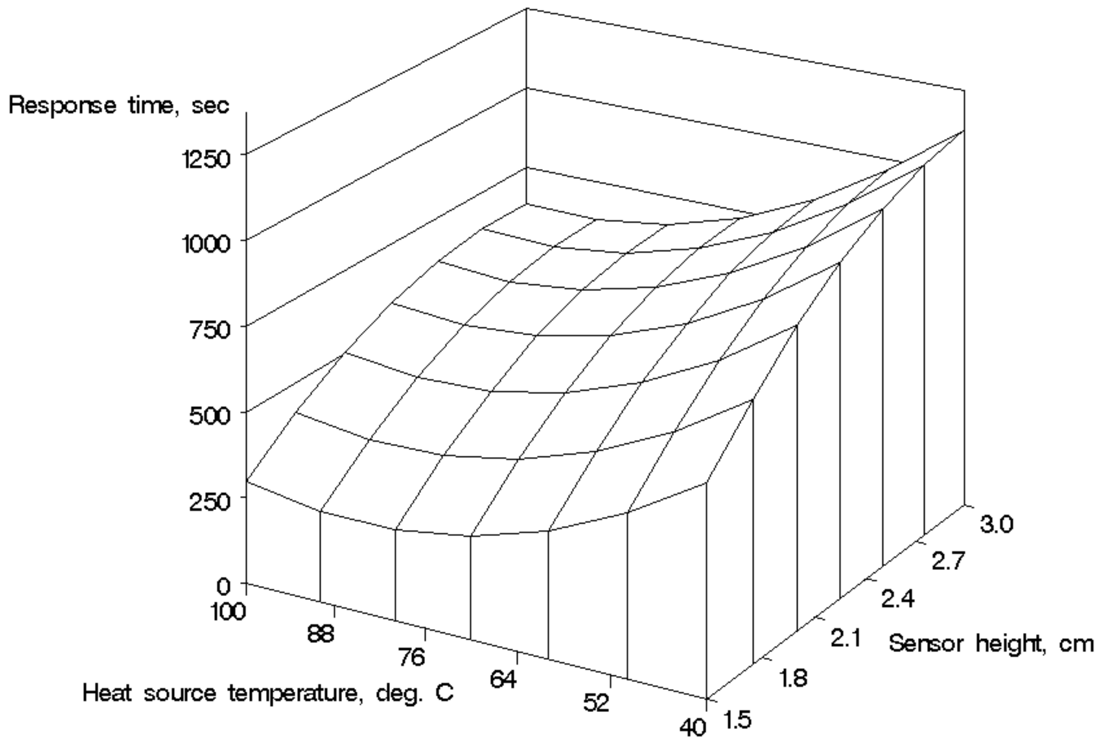


Figure 10: The effect of combustion temperatures of the material and the sensor height on the predicted response time.

3-Light sensor calibration:

Figure (11) the effect of the illumination intensity on the critical distance of light sensor. From this figure, it is clear that, the critical distance is proportionally increased with increasing the illumination intensity. In another meaning, the light sensor could be placed at larger distance when we increase the light intensity. It is also noticed that, the response sensitivity increased exponentially at the high levels illumination intensity. Obviously, the relationship between the critical distance, d_{cr}, and light intensity is not linear. Therefore, the regression procedures were used to produce the best fit model for these data. Table (3), shows the regression analysis of this relationship where, the determination coefficient (R^2) was found to be 99.25%. According to Table (3), the statistical model that expresses of this relationship was found to be as follows:

$$d_{cr} = 0.112273\, I + 0.0000175\, I^2 \quad R^2=99.2\% \qquad ----(7)$$

where; d_{cr} = the critical distance, cm., and I = the light intensity, lumen (Lm).

When analyzing the model data, it was assumed that the crossed portion of the vertical axis in this equation is equal to zero to match the reality of the application where the critical distance becomes zero (no buzz) when no light is present.

For the simplicity, the data obtained were used to plot the relationship between the critical distance and illumination intensity in an exponentially form. The model shown in the graph is nonlinear, however; it simpler to understand than the linear model in Eq. (7), but it is less in R^2 than in the linear model came from SAS.

Table 3. Data analysis for the effect of the light intensity and the critical distance.

The General Linear Model (GLM) Procedure					
Dependent Variable: d		Critical distance, m			
Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	2	887369.5368	443684.7684	864.60	< .0001
Error	13	6671.1932	513.1687		
Uncorrected Total	15	894040.7300			
	R-Square	Coefficient Var.	Root MSE	d Mean	
	0.992538	12.72892	22.65323	177.9667	
NOTE: No intercept term is used: R-square is not corrected for the mean					
Source	DF	Type I SS	Mean square	F Value	Pr > F
I	1	881308.8002	881308.8002	1717.39	< .0001
I*I	1	6060.7366	6060.7366	11.81	< .0044
Source	DF	Type III SS	Mean square	F Value	Pr > F
I	1	34082.20221	34082.20221	66.42	< .0001
I*I	1	6060.73658	6060.73658	11.81	0.0044

Parameter	Estimate	Standard Error	t Value	Pr > ǀ t ǀ
I	0.1122738548	0.01377669	8.15	< .0001
I*I	0.0000175167	0.00000510	3.44	0.0044

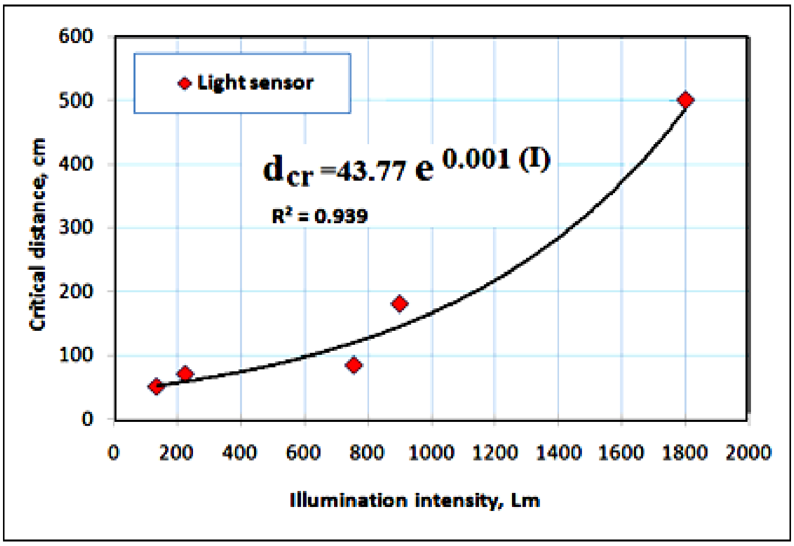


Figure 11: The effect of the illumination intensity on the critical distance of the light sensor.

4-Installation of the proposed alarm system:

The calibration results of the sensors used in the proposed construction of the alarm system (Figure 12) are considered to be very important because they contain information about the system characteristics that may be used in future for alarm system installation in farm buildings. The exact values of these characteristics can be computed from the statistical models previously obtained.

In the new system that used in the calibration experiments, the three sensors; smoke, heat and light were used. It is a great advantage to obtain when the three sensors are installed together in one system this will increase the performance of the systems existed already in the market.

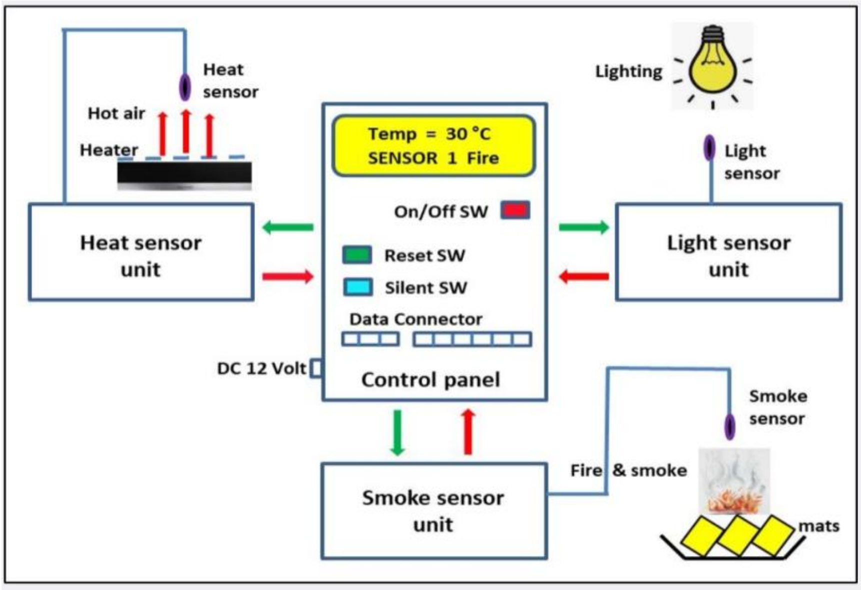


Figure 12: The setup of the fire alarm system with three sensors.

4. CONCLUSION

This study aimed to construct a new warning system, locally manufacturing and easy to use in agricultural facilities at reasonable prices. It depends on three sensors. Therefore, it is expected to be more efficient than the systems in the market. The results of this study can be summarized as:

Factors influencing on the alarm system response time:

1. **For smoke sensor:**
   The study proved that the height of the detector and the density of smoke had an effect on the response time of the sensor. When the height increased, the response time increased while the increase in smoke density levels decreased the response time.
2. **For heat sensor:**
   Logically, increasing the combustion temperature of material lead to a decrease in the response time of the sensor while increasing the height of the sensor lead to an increase in the response time.
3. **For light sensor:**
   The response sensitivity of the light sensor increased when light intensity increased at specific distance (named as a critical distance), so the light sensor must be placed at a critical distance to give a fast response according to the light intensity caused by the burning materials.

RECOMMENDATIONS

The authors recommend that:

1. It is good to use the proposed alarm system for early warning of fire in the agricultural structures.
2. More experiments should be done for the actual conditions in the open and closed storage areas using the three sensors at the time.
3. Comparing the proposed system with another in the market in terms of performance and cost.
4. Actual use of proposed alarm system in the agricultural structures is required to test its effectiveness and efficiency to increase the level of security and safety.

5. REFERENCES

CAPMS (Central Agency for Public Mobilization and Statistics), (2019-2021) Cairo.

https://www.capmas.gov.eg/

https://almalnews.com/%D8%A7%D9%84%D8%A5%D8%AD%D8%B5%D8%A7%D8%A1-3-6-%D9%85%D9%84%D9%8A%D8%A7%D8%B1- %D8%AC%D9%86%D9%8A%D9%87-%D9%81%D9%8A-%D8%AE%D8%B3%D8%A7%D8%A6%D8%B1-%D9%85%D8%B5%D8%B1-%D9%85%D9%86-%D8%A7/

https://www.almasryalyoum.com/news/details/2020633

Central Station Alarm Association (ASAA), (2011) A Practical Guide to Fire Alarm Systems, Third Edition -8150 Leesburg Pike-Suite 700-Vienna, VA 22182-Stanley Oppenheim Committee Chairman-DGA Security Systems, Inc., New York, NY. July 2011

Cochran, W. G., and G. M. Cox (1980) Experimental Design. John Wiley & Sons. NY., USA.

David D. Evans and David W. Stroup, (1985) 'Methods to Calculate the Response Time of Heat and Smoke Detectors Installed Below Large Unobstructed Ceilings' Fire Technology, Vol. 22, No. 1, February 1985, p. 54.

El-Barbary, A, (2005) Occupational Safety & Health Guide, adamelbarbary @hotmail.com, adamelbarbary@yahoo.com.

National Bureau of Standards, Gaithersburg, MD, (1975) Ref: & Market 018 Issue 2 Date: 17/3/98 Guide to Fire Alarm Systems.

Husted, B. P, (2004) Optical smoke units and smoke potential of different products. . Danish Institute of Fire and Security Technilogy. DIFT REPORT 2004:01

Qianga,b . L, (2011) Estimation of Fire Detection Time. The 5th Conference on Performance-based Fire and Fire Protection Engineering. Published by Elsevier Ltd in Science direct. Procedia Engineering 11 (2011) 233–241

Rowland, J.H. , C.D. Litton, and R.A. Thomas, (2016) Evaluation of detection and response times of fire sensors using an atmospheric monitoring system. Trans Soc Min Metall Explor Inc. Trans Soc Min Metall Explor Inc. 2016; 340(1): 104–112.

Photain Controls PLc, (1998) Guide to fire alarm systems. http://www.safety guide.biz /Company-Photain controls-PLc-in-Arundel-1802 3

Siemens Switzerland Ltd, (2014) Fire safety guide, Siemens Aktingesells chaft, http://www.downloads.siemens.com/download-center/Download.aspx? pos= download&fct =getasset&id1= A6V1 0308640

https://sid.siemens.com/v/u/A6V10430678

Statistical Analysis System (SAS), Institute. (1982) User's Guide: Statics.. Eds. Inc. Cary, N.C.

System sensor Europe (SSE), (2004) Guide to intelligent fire systems, UK November 2004, sales@sseuk.com, www.systemsensoreurope.com.

User guide to fire detection & alarm system, (2014) West yorkshire, fire & rescue Service, ver 5 pp.1-4., Ref: FS-PAN029.

https://studylib.net/doc/7040540/users-guide-to-fire-detection-and-alarm-systems

Yamauchi, Y., (1988) Prediction of Response Time of Smoke Detectors in Enclosure Fires. National Bureau of Standards, National Engineering Laboratory. Gaithersburg, MD 20899.

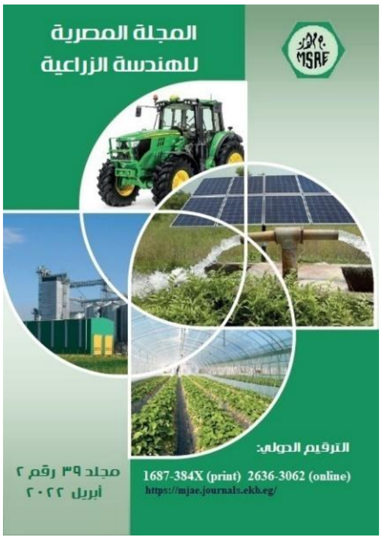
نظام للتنبيه بالحريق في المنشآت الزراعية

أ.د/ خيري مصباح إسماعيل[١]، أ.د/ عبد الله زين الدين[١]، م/ شيماء حمادة[٢] و د./ محمد رشوان[١]،

[١] أستاذ - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة بالشاطبي - جامعة الأسكندرية - مصر.

[٢] طالبة ماجستير - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة بالشاطبي - جامعة الأسكندرية - مصر.

[٣] أستاذ مساعد - قسم الهندسة الزراعية والنظم الحيوية - كلية الزراعة بالشاطبي - جامعة الأسكندرية - مصر. & حالياً معار بجامعة الملك سعود - قسم الهندسة الزراعية – كلية الزراعة والعلوم الغذائية - الرياض - السعودية.



الكلمات المفتاحية:

حريق، إنذار، حساس دخان، حساس حرارة، حساس ضوء، منشآت زراعية.

الملخص العربي

تعتبر المباني والمنشآت الزراعية من الأماكن الأكثر تعرضاً لمخاطر الحريق، لذلك يجب تزويدها بنظام إنذار جيد وفعال. عادة ما تكون أنظمة الإنذار الموجودة بالسوق باهظة الثمن ويصعب التعامل معها من قبل العمال الزراعيين بسبب عدم وجود الخبرة الكافية في التعامل مع الحريق كما أنها تعتمد على حساس واحد وغالبا" حساس الدخان. بالتالي كانت أهداف هذا البحث هو: ١- إنشاء نظام إلكتروني للإنذار المبكر باستخدام متحكم دقيق مع ثلاث حساسات هي حساس الدخان والحرارة والضوء بالإضافة إلى مكونات إلكترونية أخرى، ٢-تقييم وقت الاستجابة لكل حساس في هذا النظام المقترح على حدى. تم التوصل الى العلاقات المختلفة التي تربط زمن استجابة لكل حساس بالعوامل المحتملة الأخرى التي تؤثر على أداء الحساس. ولكون النظام الجديد معتمد على ثلاث حساسات فإنه من المتوقع أن تزيد قدرة النظام المقترح على اكتشاف أي حريق والإنذار به.

أثبتت النتائج بالنسبة لحساس الدخان: أنه كلما زاد ارتفاع حساس الدخان طال زمن الاستجابة، بينما الزيادة في مستويات كثافة الدخان يقلل من زمن الاستجابة. أما بالنسبة لحساس الحرارة فإن زيادة درجة حرارة الاحتراق للمادة المستخدمة في الاختبار أدت إلى تقليل وقت استجابة حساس الحرارة، بينما تؤدي زيادة ارتفاع حساس الحرارة إلى زيادة زمن الاستجابة. أما بالنسبة لحساس الضوء فإن حساسية استجابته تزيد مع زيادة شدة الضوء عند وضعه على مسافة معينة تسمى المسافة الحرجة والتي تسبب حدوث إنذار مسموع من النظام وفقًا لشدة الضوء التي تسببها المواد المحترقة.