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# Design of Refrigerant Leak Detector on Arduino Uno – Based Refrigeration System

**Sobri[1*], M. Subroto Aliredjo[1], Yusuf Aditya Nugraha[1], Istianto Budhi Rahardja[2]**
[1]Department of Fisheries Machinery, Politeknik Ahli Usaha Perikanan Jakarta, Indonesia
[2]Plantation Products Processing Technology Department, Politeknik Kelapa Sawit Citra Widya Edukasi, Bekasi, Indonesia

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**ABSTRACT**

Refrigeration loos has big impact on inefficient system operation, increase power consumption, higher maintenance cost and moreover contribute to global warming. The purpose of this study is designing refrigerant leak detection device, making a refrigerant leak detector, and testing the refrigerant leak detector in a refrigeration system. Research was conducted for six months, starting in November 2018 until Mei 2019 at the ice block factory owned by KUD. Usaha Mina, Semarang City. The stages of method used in this study include studying of literature, designing device, making device, and testing refrigerant leak detection device. As for the research result are as follows 1) The design of the refrigerant leak detector is made using CorelDraw Grapichs Suite X7 very easily according to the input and output to get desired function 2) In assembling components using jumper cable, it must be in accordance with the input that is in the program so that it does not cause a short circuit to component. Sensitivity level of this refrigerant leak detection device is very high, depending on how in programing the desire level of sensitivity and other factors such as $NH_3$, NOx, Alcohol, Benzene, Smoke, $CO_2$, and other gases. Because the gases will affect the level of sensitivity of device. 4) The testing of a refrigereant leak detector must be close to the source of leakage which serves to accelerate the device to detect leakage 5) The voltage needed by this tool is between 5 – 20V (DC).



## INTRODUCTION

Refrigeration systems have been widely used in various fields, including industry, households (domestic), and air conditioning systems and are an important requirement in modern society. The type of refrigeration that is most widely used today is a refrigeration system with a steam compression cycle [1,2]. For the cooling process, it is needed a refrigerant that is easily changed its form from gas to liquid and vice versa to take heat in the evaporator and dispose of it in the evaporator. Most types of refrigerant used are types of chloro fluorocarbons (CFCs), hydro chloro fluoro carbons (HCFCs) and Hydro fluoro carbons (HFCs) that are not friendly to the environment and have high global warming potential [3,4].

All refrigeration systems have a natural tendency to experience leakage because the working pressure is higher than the atmospheric pressure [5]. Refrigerant leakage in the refrigeration system will lead to inefficient system work, increased energy consumption, higher maintenance costs and encourage environmental damage thereby accelerating the process of global warming [6]. Refrigerant leak detection devices are simple, effective, and not too expensive to monitor refrigerant leaks from the refrigeration system to the work environment [7].

Anurag Jha, et al., 2016 in their research concluded that leaks in the refrigeration system may occur in piping joints, compressors, evaporator condensers, valves, and so on. And to reduce leakage, preventive maintenance is needed, such as periodic inspections and safe handling of the system [8]. Moreno 2017 concludes that it is not enough just to ensure the tightness of the channel, but to ensure that leakage does not occur, a procedure must be tested 100% of the leak in the unit used [5].

Arduino is an electronic kit or open source electronic circuit board in which there are main components, namely a microcontroller chip with type AVR (Alf and Veg's Risc Processor) from the company Atmel [9,10]. Research by using Arduino as a microcontroller and sensor type to detect various kinds of gases and air has been carried out. Fina S., et al 2013 and Mifza F., et al, 2017 made a

* Corresponding author.
E-mail address: sobrisobri37@yahoo.com
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safety device for the alarm model of the LPG gas detector system that works automatically so that it can dispose of gas in the event of an arduino-based leak [11,12]. In other studies, cigarette smoke is used as an input control system with MQ type sensors to reduce the number of smokers in certain areas [13,14]. Arduino is also used as a base for CO and CO2 air pollutant detectors where it is concluded that the decrease in emission levels will be accompanied by a decrease in air temperature and humidity will increase [15,16]. Fire, smoke and rising temperatures are inputs that can be used on fire detectors. Dani Sasmoko, et al 2017 observed that a fire sensor is able to detect the presence of a fire but its ability is limited by the area, while the smoke sensor is influenced by the direction of the wind to the sensor [17]. In another study by Sofyan, et al, 2019 observed that the range of smoke sensors increased with more smoke being detected. Lilik, et al, 2017 in their research used a gas sensor with ≥ 3500 PPM and a light sensor ≥ 12 lux [17].

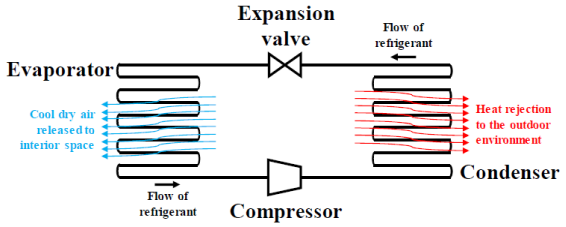


**Fig. 1.** Simplified Schematic Diagram of refrigeration system

## Material and Methods

Components of the design of refrigerant leak detection devices include:

### 1. Arduino IDE Software

Some Arduino software is written using the Java programming language including the IDE, so that it doesn't need to be installed like software in general but can be run immediately as long as your computer has installed the Java runtime and installed the driver first [19].

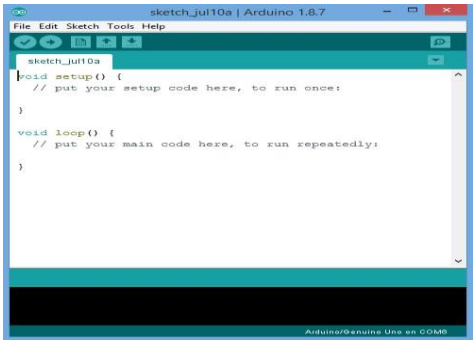


**Fig. 2.** Display Arduino IDE software with a sketch

### 2. Arduino UNO microcontroller

The main component in the Arduino board is an 8-bit microcontroller with the AT mega brand made by the company Atmel Corporation. Various Arduino boards use different ATmega types depending on the specifications.

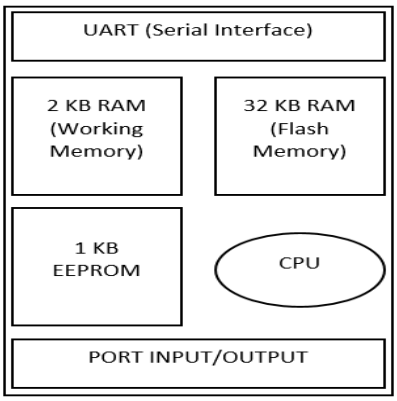


**Fig. 3.** Simple block diagram of a microcontroller

The blocks above are explained as follows:

a) Universal Asynchronous Receiver or Transmitter (UART) is the interface used for serial communication such as RS-232, RS-422 and RS-485.

b) 2KB of RAM in working memory is volatile (lost when the power is turned off), used by variables in the program.

c) 32KB of RAM flash memory is non-volatile, used to store programs loaded from a computer. Besides the program, flashmemory also saves the bootloader. Bootloaders are small initiation programs, run by the CPU when the power is turned on. After the bootloader has finished running, the next program in RAM will be executed.

d) 1KB EEPROM is non-volatile, used to store data that cannot be lost when the power is turned off. Not used on Arduino boards.

e) Central Processing Unit (CPU), part of the microcontroller to run every instruction from the program.

f) Input / output ports, pins for receiving digital or analog data (input), and outputting digital or analog data (output).

### 3. MQ 135 Sensor

A sensor that monitors air quality to detect ammonia gas (NH3), sodium dioxide (NOx), alcohol / ethanol (C2H5OH), carbon dioxide (CO2), sulfur gas (SO2) and smoke / other gases in the air. This sensor reports the results of air quality detection in the form of changes in the analog resistance value at the output pin. This output pin can be connected to the ADC (Analog to Digital Converter) pin on the arduino analog microcontroller / pin [11] [16].


**Fig. 4.** MQ135 Sensor

**4. LED lights**

LED (Light Emitting Diode) is a type of diode that emits light. This component is commonly used in flashlights or emergencies. Just like a diode that only conducts direct current, LEDs too. That is why the LED installation in the electrical circuit must not be reversed. This LED can be used as output when a user creates a program and he needs a marker from the program's running. This is a practical way when users do trials. Generally the microcontroller on the Arduino board has loaded a small program that will turn on the LED flickering in a one second delay. So it is very easy to test whether a new Arduino board is in good condition, just connect the board to a computer and see if the power indicator LED is constantly on and the LED with pin-13 is blinking [4].

**Fig. 5.** LED Lights

**5. Buzzer**

Buzzer is an electronic component that functions to convert electrical vibrations into sound vibrations. Basically the working principle of the buzzer is almost the same as the loud speaker, so the buzzer also consists of a coil mounted on the diaphragm and then the coil is flowed so that it becomes an electromagnet, the coil will be attracted inward or outward, depending on the direction of the current and the magnetic polarity. used as an indicator that the process has been completed or an error occurs in a tool (alarm) [4] [10].

**Fig. 6.** Buzzer

**6. Batteries**

The most important component before assembling a leak detection device is a battery that is useful as a Power Supply (voltage input) and as a determinant of the flame resistance of the refrigerant leak detection device. In this series of tools the author uses a 4V battery with a capacity of 1200 mAh two pieces are assembled with a series circuit so that it produces 8V with a capacity of 1200 mAh [14].

**Working Principle and Function of the Refrigerant Leak Detection Tool**

The working principle of this tool is based on the input rather than the sensor (MQ 135) in the form of changes in the analog resistance value (when exposed to gas) on the output pin. The output pin is then connected to the arduino microcontroller / pinanalog input which was previously programmed and connected to the buzzer which will be used as an indicator that the process has finished or an error has occurred in an instrument (alarm) and the LED light is used as an indicator that the device is working or not. Both components are used as output rather than the tool. The function of this tool is to detect or give a sound warning rather than a buzzer that there is a refrigerant leak in the refrigeration system which after knowing the leak will be repaired immediately.

## EXPERIMENTAL METHOD

This research includes three main activities, namely designing tools using Corel Draw Graphics Suite X7 software that will be used as a guide or basis for assembling (making) refrigerant leak detection tool, making refrigerant leak detection devices must be in accordance with the design that was late made and testing refrigerant leak detection devices to find out whether the device made can function to detect refrigerant leakage well or not. Coupled with Literature Study as a support for library materials in this study.

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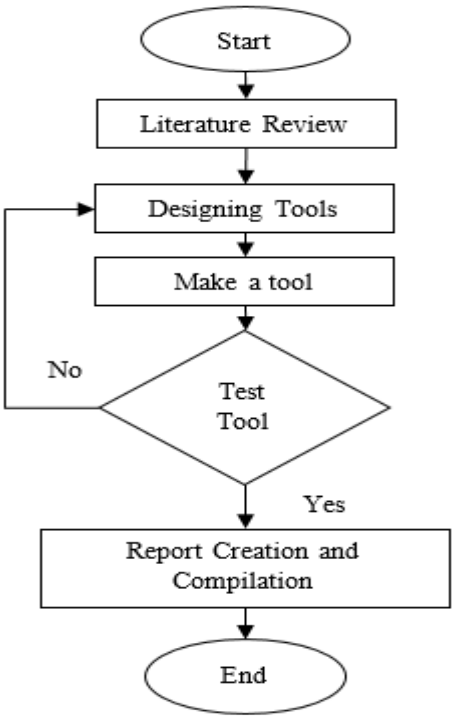


**Fig. 7.** Flow chart design and manufacture of refrigerant leak detection devices

## RESULTS AND DISCUSSION

### Design of Refrigerant Leak Detection

At this stage the design of the refrigerant leak detection device is designed using the CorelDRAW Graphics Suite X7 application that will be used as a basis for assembling or manufacturing refrigerant leak detection devices.

Where the final result of the design of this tool is to produce tools to detect refrigerant leaks in refrigeration systems that are more economical than commercially available devices by assembling components that have been prepared in advance. The following is the design of refrigerant leak detection devices.

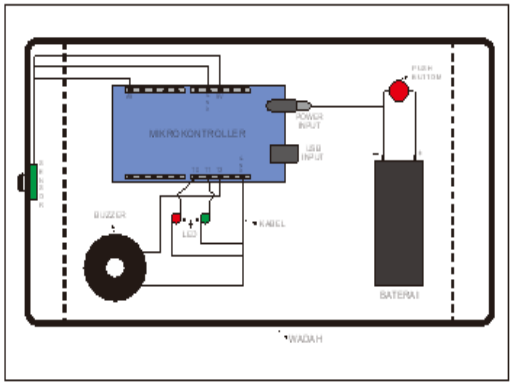


**Fig. 8.** Design of leak detection devices

### Making Refrigerant Leak Detection Equipment

In this process or stage is a continuation of the design phase of the tool, where the components that have been prepared are assembled into a tool and the tools to be made must be in accordance with those previously designed. In making tools, several things need to be prepared, namely: 1. Preparing tool components (Sensor MQ-135, Arduino UNO 328 Microcontroller, Buzzer, LED Lights, Jumper Cables, Push Buttom, and Batteries). 2. Casing or place to place the tools that have been strung together. 3. Other tools and materials to support the production of these tools (Solder, Solder Tin, Scissors, etc.). After everything is ready, the instrument assembly is then done.

### Installing Arduino IDE

The IDE (Integrated Development Environment) used in the development of this application is the Arduino IDE version 1.8.7 which is installed into a computer or laptop. After installing the Arduino software the next stage is to make a program (Coding) that will be inputted into the microcontroller, the programming is the most important part to make a refrigerant leak detection device because in the programming there is a setting of the level of sensitivity of the refrigerant leak. So the programming must be in accordance with the needs or desired so that the tool can run perfectly. Programming in Arduino IDE software that is written using the Java language. After making the program the next stage is uploading or entering the program data into the microcontroller [1] [12].

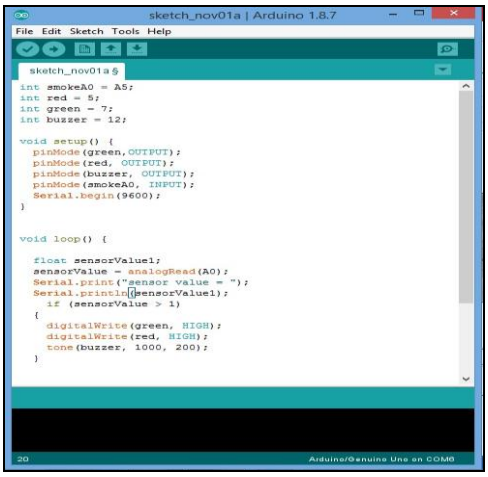


**Fig. 9.** Arduino IDE sketch software

### Design of Refrigerant Leak Detection

The Arduino Uno system has 14 pin digital I / O and 6 pin analog I / O. These pins can be used as inputs from sensors and outputs to activate other components. [14] The selection of materials used for

the refrigerant leak detection device casing which is seen from the use of components in the tool, can then reduce research costs and costs in making tools so that the resulting tool becomes more economical compared to refrigerant leak detection devices such as electric leak detectors, halide leak detector, and UV light leak detector flash, material that is easy to obtain, and lightweight but the level of hardness of the material is in accordance with what is needed (not easily broken and strong) so that the selection of materials used in making this refrigerant leak detection tool is to use a paralon casing with a size of 2 inches with a length of 20 cm. After testing the refrigerant leak detection device, this tool is able to detect the presence of several refrigerant leaks such as ammonia, R-134a, R-22, R-404a and R-12 but on the sensor specifications used in this refrigerant leak detection device, the sensor able to detect other gases such as alcohol, benzene, sodium dioxide, carbon dioxide, sulfur gas and smoke or other gases in the air.

The size or dimensions of the tool can be seen in the image below:

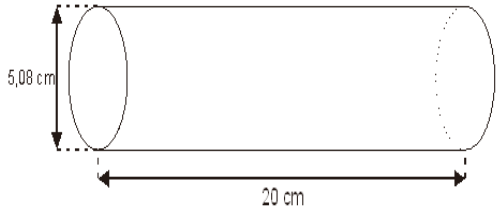


**Fig. 10.** Size or dimensions of the container (paralon)

After designing each component, the next step is to insert the components into cashing as shown below.

**Fig. 11**. Leak detection devices that have been made

**Testing tool**

Testing of this tool aims to determine whether this tool works well or not, according to the desired design or not.

Tests carried out in this section include:

1. Testing the MQ-135 Sensor and Buzzer with the Arduiono System.
2. Testing the Refrigerant Leak Detection Tool Series.

In the actual media in the field (Cooling Machine) rarely found leakage, simulation of a way to test (Testing) the tool is to use media (Refrigerant Material) that is safe and does not result in losses. The media is R-134a with a weight of 390 grams.

**Fig. 12.** Cooling material R-134a

**Testing the MQ-135 Sensor and Buzzer with the Arduiono System**

Smoke sensor MQ-135 is a major component in making refrigerant leak detection tools. Sensors have a function to measure the gas data (refrigerant) around the sensor or in the area of refrigerant leakage and when the sensor detects refrigerant leakage then a buzzer is needed as an alarm or reminder when a refrigerant leak is detected and must sound as a sign that refrigerant is leaking in the refrigeration system. The results of trials on the sensor MQ-135 that is there is a heater or heater so that before using the appliance, heating is done first in order to get maximum results or detection. Then at the time of mounting the value of the sensor is higher than what has been determined so that it turns on the buzzer then after a while when the value of the sensor drops the buzzer turns off. To detect refrigerant leakage, it must be close to the leakage point (the refrigerant enters the sensor) because the distance of the sensor to the refrigerant leakage location greatly affects the sensitivity of the device, if the refrigerant is too far out of the leakage point, then the detection process is not optimal because the refrigerant is evaporated or blown by the wind first. Can be seen in the table below, the sensor in the refrigerant leak detection device is able to detect small leaks as far as 20 cm, the next sensor in the refrigerant leak detection device is able to detect a medium leak with a maximum distance of 80 cm, and at a large leakage level the sensor is able to detect refrigerant leakage by maximum distance of 160 cm.

**Table 1**. Variation in the distance between the sensor and the refrigerant leakage point

| No | Leakage rate | Distance Variations (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 20 | 40 | 80 | 100 | 120 | 160 | 200 | 240 |
| 1 | Small | ✓ | ✓ | - | - | - | - | - | - | - |
| 2 | Medium | ✓ | ✓ | ✓ | ✓ | - | - | - | - | - |
| 3 | Large | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - |

Information:
1. Small = Small openings up to half the faucet rotation
2. Medium = One tap faucet
3. Large = Maximum tap rotation (Two tap taps)
4. ✓ = Refrigerant leak was detected
5. - = Refrigerant leak was not detected

**Testing the Refrigerant Leak Detection Tool Series**

The series of refrigerant leak detection devices in this study serves to determine how long the appliance is able to ignite when standing by or when it detects a refrigerant leak and to find out whether the device is functioning properly or not.

Trials on a series of refrigerant leak detection devices on battery life were carried out four times in two different stages. The first stage is carried out twice with the standby device condition with the result that the tool is able to light for 2-3 hours. The second stage is carried out twice with the condition of the tool lights up when it detects a refrigerant leak (LED, Buzzer, Sensor MQ-135 lights up) and get the results the tool is able to light for 1-2 hours. This battery life depends on the use of these devices more or more often the detection of refrigerant leakage, the faster the battery runs out.

Test the refrigerant leak detection device thoroughly in a series of refrigerant leaks by bringing the sensor tip or device closer to the hose end and opening or turning the tap on the refrigerant tube (R-134a with a weight of 390 grams) starting from the maximum opening and closing slowly until the tap closes again and uses a different variation of distance so that it can be seen how sensitive (sensitive) the tool is to leakage.

**Fig. 13.** How to do a tool sensitivity experiment

After testing the instrument, a number of results are obtained as shown in table 3.

**Table 2.** Tool Test Results

| No | Test Activities | Trial Results | Explanation (Ok/Not yet) |
|---|---|---|---|
| 1 | Detect aleak in the refrigation system | High Level of Sensitivity | Ok |
| 2 | Microcontroller activates a reminder alarm | buzzer goes off | Ok |
| 3 | Suitability to needs | Can detect refrigerant leakage | Ok |
| | | High battery life (long) | Ok |
| 4 | Microcontroller activates the LED Light | Turns on green when the device is standby | Ok |
| | | Lights up in red when it detects a leak | Ok |

## CONCLUSION

Based on the design results and testing of refrigerant leak detection devices, it can be concluded as follows:

1. The design of refrigerant leak detection devices using Corel DRAW Grapichs Siute X7 is very easy, but in designing refrigerant leak detection devices must be in accordance with the input and output programming to be entered into the microcontroller, because if it is not appropriate then the tool will not be able to function . This design is very important to be used in assembling refrigerant leak detection devices.
2. In assembling components (MQ-135 Sensor, LED, Buzzer, Push Button, Micricontroller, Battery) using jumper cables, it must be in accordance with the input that is in the program so that it does not cause a short circuit to the component. The dimensions of the refrigerant leak detection device are using a paralon casing with a diameter of 5.08 cm (2 inches) with a length of 20 cm and using two paralon caps with a diameter of 5.08 cm (2 inches). The voltage needed for this tool is between 5 - 20V (DC). If the voltage source is less than this number, the device will not function normally. When the voltage source is over, it will cause damage to the components of the tool. The tool can light for 1-2 hours when the device detects refrigeration leaks (LED, Buzzer, Sensor MQ-135 lights up) and can light for 2-3 hours on standby device conditions.
3. The sensitivity or sensitivity level of this refrigerant leak detection tool is very high, depending on how to program the desired sensitivity level and other factors such as $NH_3$, NOx, Alcohol, Benzene, Smoke, $CO_2$, gases from combustion remains, and other gases because they affect the sensitivity of the device. However, the sensors used are more sensitive to the gas Alcohol, Benzene and $NH_3$. This refrigerant leak detection tool can detect refrigerant leaks with a small leakage rate with a distance of 20 cm, at moderate leak rates the refrigerant leak detection tool is able to detect leaks as far as 80 cm, and at large leak rates this refrigerant leak detection tool is able to detect leaks refrigerant with a maximum distance of 160 cm in a closed room or in a room that is not too much wind, but if the distance is longer the leak the longer the tool detects refrigerant leakage. Because if there is wind, the process of detecting refrigerant leakage will be hampered because the refrigerant is unable to hit the sensor.

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