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Monitoring Oxygen Concentration and Humidity Parameters of Bubble CPAP Based on IoT

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ABSTRACT Existing Bubble Continuous Positive Airway Pressure (CPAP) devices used in neonatal care. Specifically, the lack of digital result display and monitoring capabilities for oxygen concentration and humidity parameters is identified as a major issue. This study aims to address the shortcomings of existing Bubble Continuous Positive Airway Pressure (CPAP) devices used in neonatal care by designing a monitoring system for oxygen concentration and humidity parameters. The lack of digital result display and monitoring capabilities for oxygen rate, concentration, temperature, and humidity necessitates an improved solution. The proposed system utilizes Internet of Things (IoT) technology, allowing remote monitoring by healthcare professionals. Oxygen concentration is detected using the OCS-3f sensor, and humidity is measured with the DHT22 sensor. Data from these sensors are processed by the ESP32 microcontroller and transmitted to the https://thinger.io site via built-in Wi-Fi. The monitoring tool ensures accurate measurements between 21% to 95% oxygen concentration, with a maximum error of 4.6% and a minimum error of 0.04%. This high accuracy enhances the reliability of the CPAP bubble device for oxygen therapy. The study's significance lies in its contribution to neonatal care, offering a real-time monitoring system that facilitates prompt diagnosis and treatment. By integrating IoT and telegram notifications, healthcare professionals can remotely monitor and respond to the baby's condition, improving overall care quality. This innovative tool holds promise in enhancing neonatal care, ensuring optimal oxygen therapy, and supporting the well-being of infants receiving CPAP bubble therapy. Implications of this study are promising in terms of improving neonatal care, enhancing the reliability of CPAP devices, and leveraging technology to facilitate better healthcare practices for the most vulnerable population: premature and critically ill infants.

INDEX TERMS Bubble CPAP, Oxygen Concentration, Humidity, OCS-3f, DHT 22

I. INTRODUCTION

Continuous positive airway pressure (CPAP) is a form of noninvasive respiratory support that has been used to assist the spontaneous breathing of premature newborns at constant pressure and avoid intubation and positive-pressure inflation[1]. Correct use of CPAP has been shown to reduce difficulty breathing, reduce dependence on oxygen, help repair and maintain residual lung capacity, prevent upper airway obstruction, prevent lung collapse, reduce apnea, bradycardia, and cyanotic episodes, and reduce the need for hospitalization. Intensive room[2]. Bubble CPAP works by using an oxygen supply and compressor mixed by a blender machine to produce oxygen concentration[3], [4], there is a humidity chamber as a producer of warm air and optimal humidity, Bubble chamber adjusts the depth of PEEP[5]–[7] as a giver of expiration. Many parameters are set for this CPAP bubble tool, namely oxygen pressure, compressor pressure, percentage of oxygen concentration (FiO2), flow meter, and into PEEP but this tool has minimal monitoring, causing it to be unable to monitor the correctness of the desired setting. One of them, such as the absence of media monitoring the level of oxygen concentration given[3], [4], [5]. For example, if we adjust the oxygen concentration (FiO2) in the blending machine, the user makes the baby's condition an indicator of achieving the desired concentration setting in the success of therapy. This causes nurses' instincts to be the only source of certainty for the value of oxygen levels using Bubble CPAP [10]–[13].

The design of the CPAP module has been developed by several previous researchers with advantages and disadvantages. There are several developments in the design of Bubble CPAP, including the use of different sensors, data storage methods until the latest is sending sensor reading data. To measure the oxygen concentration, previous researchers used an ultrasonic gas board 7500e oxygen sensor and also KE-25[14], [15]. Both have good accuracy. However, the continuous use of the KE-50 oxygen gas sensor will reduce the Life Time of the sensor, the sensor will be less sensitive in detecting oxygen gas, so that the oxygen level reading is unstable. For the measurement of the oxygen flow rate, the OCS 03f sensor is used. This sensor has an accuracy of ±0.2L/min.

This paper collects several references from proceedings and journals related to the CPAP tool module. The results of the study indicate that the development of CPAP monitoring has been carried out by previous studies as described. However, the development of CPAP monitoring that can send information to users (doctors, nurses) via a web-based network has not been done much. Therefore, the purpose of this study is to develop Internet of Things (IoT)-based CPAP[16], [17] monitoring through the Thinker IO provider so that it can monitor gas pressure continuously, as well as a warning system if gas pressure is outside the standard range via the internet network.

The research summary indicates that while some developments have been made in CPAP monitoring, there is a significant research gap in the development of an Internet of Things (IoT)-based CPAP monitoring system. The proposed study aims to address this gap by designing an IoT-based monitoring system using the OCS 03f sensor for oxygen concentration and the DHT22 sensor for humidity. The data collected from these sensors will be processed by the ESP32 microcontroller and displayed on an LCD screen. Moreover, the IoT-based system will allow continuous gas pressure monitoring and provide a warning system if the gas pressure falls outside the standard range.

The aim of the research is to develop an IoT-based monitoring system to address the shortcomings of current CPAP devices and improve neonatal care. The justification lies in the importance of CPAP therapy, the limitations of existing devices, and the potential positive impact of the proposed IoT-based monitoring system on the well-being and treatment outcomes of premature newborns shown in FIGURE 1.

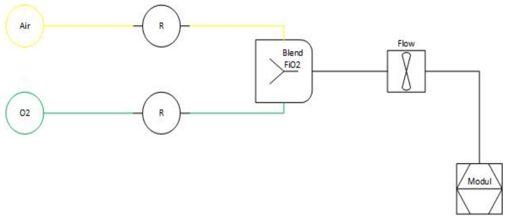

FIGURE 1 . Mechanical diagram of the tool

II. METHODOLOGY

This study uses a dataset from measurements taken during the experiment of Bubble CPAP brand Sechrist by using settings for oxygen levels: 21%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 95%. As for the oxygen flow: 0-10L/min. Data collection was repeated 5 times using Bubble CPAP brand Sechrist and oxygen cylinders.

This research uses Bubble CPAP brand Sechrist for data collection. Oxygen cylinders are used for experiments. The ocs 03f sensor functions as a detector of the concentration of oxygen levels in Bubble CPAP, and the dht22[18]–[20] sensor functions to detect humidity. The output of oxygen concentration, flow rate, temperature, and humidity is then processed by the ESP32 microcontroller[21] into the ADC pin. Furthermore, the microcontroller will translate the digital data and then display it on a 4x16 LCD[22][23].

In this study, after the design was finished, the results of the measurement of oxygen levels and oxygen flow were tested with settings for oxygen levels [24], [25][26], [27]of 21% in free air, 95% in oxygen cylinders, while for oxygen flow with settings of 0-10 L/min in oxygen cylinders. In each setting, the output of the oxygen cylinder was calculated to validate the results of this study.

A. DATA ACQUISITION

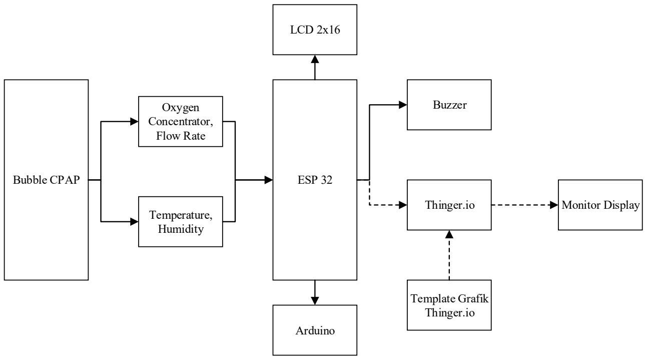

FIGURE 2. System Block Diagram

Based on FIGURE 2 When the module gets voltage from the battery, it will activate all circuits and sensors. When the "ON" button is pressed, the oxygen gas sensor (OCS 03F) and humidity sensor (DHT22) detect oxygen gas and humidity flowing from the Bubble CPAP output. the output of the oxygen concentration and humidity sensor is then processed by the ESP32 microcontroller into the ADC pin. In this section, reading the ADC value can occur if the ESP32 has been entered by the program using the Arduino IDE application. The data that has been processed from analog sensor data into digital data on the ESP32 is then sent to the https://thinger.io site using the internet network via the wifi module contained in the ESP32 module build-in as shown in the picture.

In addition, it is not only sending digital data from OCS-3f and DHT22 sensor readings to be displayed on the Thinker IO template using the internet network via the ESP32 build-in wifi module but also sending message information via telegram if the output of oxygen and humidity concentrations is outside the setting limits. Furthermore, the data on the internet network through the IoT platform namely Thinger IO which provides a web-based interface will be managed and then displayed on a monitor screen in the form of graphics.

B. DATA PROCESSING

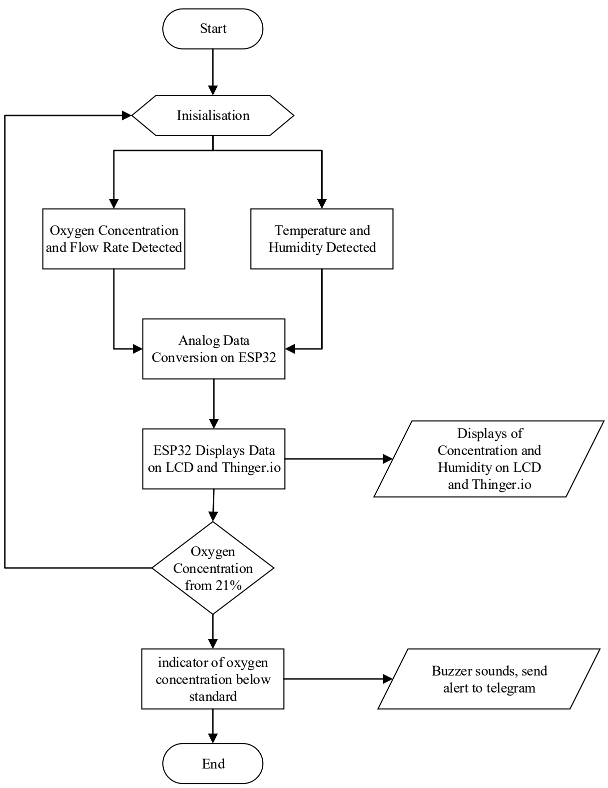

FIGURE 3. **System Flowchart**

FIGURE 3 When the module is turned on, the microcontroller will initialize. Then the reading of the sensor will be carried out. Analog output from oxygen gas sensors (O2) and humidity will be converted into digital data so that it can be recognized by a microcontroller. After the central gas pressure value has been converted into digital data it can be recognized by a microcontroller. Furthermore, the microcontroller will translate the digital data and then display on LCD 4x16. Furthermore, when the concentration of oxygen gas reaches a value below 21%, the microcontroller will activate the buzzer and send information through the telegram which indicates that the oxygen gas cylinder will run out soon.

C. DATA COLLECTION

After making the module, the author collects data. This activity was carried out at the Airlangga University Hospital using CPAP with specifications for the SLE brand, type SLE1000, Serial Number: 016-002-003, and from the Neonate Room shown in FIGURE 4.

FIGURE 4 . **Front View Of The Module**

Oxygen concentration measurements were carried out 5 times at CPAP settings of 21%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 95%. After that, the measurements were carried out with the following steps:

1. Prepare the module that has been created.
2. Prepare the CPAP tool that will take the data.
3. Perform measurements on the CPAP output oxygen.
4. Record data.

D. DATA ANALYSIS

The measurements of each parameter. The average value of the measurement is obtained by using the mean or the average by applying the equation (1).:

E. $$\overline{x} = \frac{x1+x2...+xn}{n} \quad (1)$$

where x denotes the mean (mean) for the n-measurements, x1 denotes the first measurement, x2 denotes the second measurement, and xn denotes n measurements. Standard deviation is a value that indicates the degree (degree) of variation in a data set or a measure of the standard deviation of the mean. The standard deviation (SD) formula can be shown in the equation (2):

F. $$SD = \sqrt{\frac{\sum(xi-\overline{x})^2}{(n-1)}} \quad (2)$$

where xi indicates the number of desired values, x indicates the average of the measurement results, n indicates the number of measurements. Uncertainty (UA) is a doubt that appears in each measurement result. The uncertainty formula is shown in the equation (3):

G. $$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

where UA indicates the uncertainty value of the total measurement, SD indicates the resulting standard deviation, and n indicates the number of measurements. % error indicates a system error. The lower Error value is the average difference of each data. Errors can indicate deviations between the standard and the design or model. The error formula is shown in the equation (4).

$$\%ERROR = \frac{(x_n - x)}{x_n} \times 100\% \quad (4)$$

where xn is the measured value of the machine calibrator. X is the measured value of the design.

III. RESULT

TABLE 1. Oxygen level measurement table

O_2 level	Result (%) 1	2	3	4	5	Mean	Eror %
21%	21	21,1	21	21,1	21	21,04	0,19
30%	30	30,1	30	30	30,1	30,04	0,13
40%	40,1	40,4	40	40,6	40,1	40,24	0,6
50%	49,9	50,3	49,9	50	50	50,02	0,04
60%	60,1	60,2	60	60,2	60	60,12	0,16
70%	70,3	70,1	70,3	70,1	70,3	70,26	0,28
80%	80,2	80,3	80,3	80,2	80,2	80,24	0,3
90%	90,8	90,5	90,8	90,7	90,7	90,7	0,7
95%	94,8	93,7	94,8	93,8	93,8	94,18	4,6

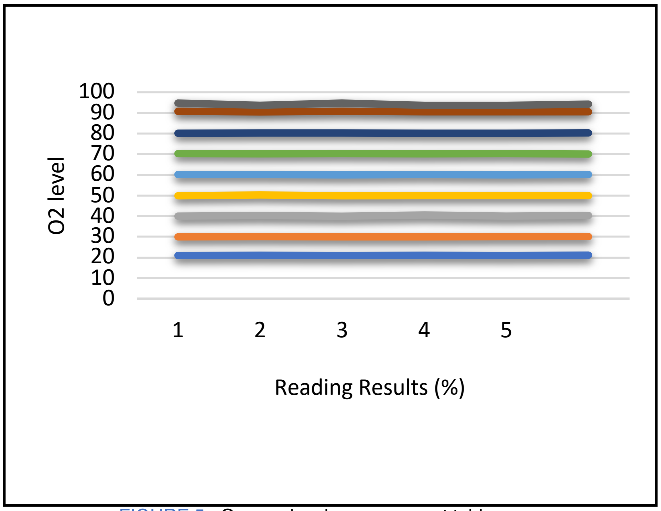

FIGURE 5. Oxygen level measurement table

TABLE 1 shows that the largest error value obtained is 4.6% and the smallest is 0.04%. FIGURE 5 shows the oxygen level measurement from 5% of the reading result

IV. DISCUSSION

In 2019 Suci Rahmadya conducted a study entitled "Monitoring oxygen concentrations in bubble CPAP devices" says that Bubble CPAP works by using oxygen input and compressed air that is mixed by a blender machine to produce oxygen concentration, there is chamber humidity as a producer of air which optimally warm and humid, bubble chamber to adjust the depth of PEEP as exhalation. Many parameters are set for this CPAP bubble tool, namely oxygen pressure, compressor pressure, percentage of oxygen concentration (FiO2), flow meter, and PEEP depth. however, this tool does not have a digital result display, making it impossible to monitor the correctness of the desired setting. One of them, such as the absence of display media for the oxygen concentration level given. the user makes the baby's condition an indicator of achieving the desired concentration setting in the success of therapy.

This module consists of an OCS-3f as a sensor for detecting oxygen concentration and DHT22 as a sensor for detecting humidity that is used to find out how to read the baby's temperature value contained in the bubble CPAP. The output from the sensor will be connected to the ESP32 to finally send the temperature value via wifi with the IoT system. The system starts working when the appliance is on (on). The ESP32 microcontroller will initialize the connected hardware including the thermal camera and Wifi for delivery. Thermal camera functions to measure temperature values in °C units. The ESP32 microcontroller processes the sensor readings and sends them to a PC using WIFI. In this module to display the results of temperature readings, the Thinger.io application is used which is located on the Personal Computer. Delivery from the ESP32 which has read the temperature value from the sensor is done using Wifi with the IoT system. Realtime data transmission on Thinger.io every 1 second, and there are notifications via telegram. To ensure the stability of concentration levels, oxygen flow rate, temperature and humidity in a humidifier that a doctor wants for CPAP therapy for patients with respiratory failure.

Testing the function of this module is done by comparing the reading of the temperature value on the module with the reading of the temperature value on a calibrated comparator. To determine our tools' precision level, we must compare this tool with a more accurate and calibrated comparison. At oxygen levels, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 95%where each measurement was made 5 times. More stable modules read oxygen levels when oxygen levels are 20%, 30%, 40%, 50%, and 60%, For oxygen levels 70%, 80% 90%, and 95% obtained reading values in the module with an error value of 0.325%. The results of the analysis of flow rate and temperature measurements show that the manufacture of CPAP measuring instruments can run well.

The limitation of this research is Limited Sample Size: The study's sample size might be relatively small, as it states that measurements were made 5 times for each oxygen level setting. A larger sample size could provide more robust and reliable results. The study's implications show promising potential for advancing neonatal care and enhancing respiratory therapy with the help of an IoT-based monitoring system for Bubble CPAP devices.

IV. CONCLUSION

The proposed research is to develop and validate an Internet of Things (IoT)-based monitoring system for Bubble Continuous Positive Airway Pressure (CPAP) devices used in neonatal care. The system aims to monitor critical parameters such as oxygen concentration, humidity, temperature, and flow rate continuously in real time. By utilizing IoT technology, the system enables remote monitoring and data transmission, allowing healthcare professionals to have access to important patient data and receive timely notifications

From the analysis results, it can be concluded that the tool. This has advantages compared to research – research previously, there were additional parameters used. After testing and taking data as much as 5 times the data, an average error value is obtained in the measurement of oxygen levels of 0.421504%. Further research and improvements based on the study's findings could lead to more widespread and impactful adoption of such systems in healthcare settings.

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