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Monitoring the Occurrence of Alarms in High Flow Nasal Cannula (HNFC) Using IoT-Based Thinger.io Platform for COVID-19 Isolation Room

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ABSTRACT Disadvantages of the old HFNC device design include oxygen flow can only be monitored manually making it vulnerable to aerosol transmission from HFNC to patients and staff, besides that leaking errors in HFNC devices often occur due to leaks in the hose or mismatching the oxygen flow setting value with the output given to the patient. The development of HFNC is equipped with an alarm if there is a decrease or increase in the flow of oxygen and a remote monitoring system is needed when continuous oxygen therapy is given to patients. This study aims to analyze errors in HFNC which cause a decrease in oxygen flow using a flow sensor as sensor to detect leaks or other flow errors from the HFNC output hose and overcome if there is a blockage through IoT in the form of notifications. This research method uses a pre-experimental with the After Only Design type where the independent variable in this study is the HFNC error condition and the dependent variable in this study is the data stream read by the sensor, IoT notifications, and device status showing error leaks. The tool module design uses the MPX5700GP pressure sensor and the SEN0343 Differential Pressure sensor as an oxygen flow sensor. This study has been tested at a pressure setting of 30-60lpm and the average error result when a leak occurs is 89.225%, the error value before a leak occurs is 4.325% which indicates the stability value of the module before a leak occurs. With this research, it can reduce the burden on medical personnel in treating Covid-19 patients, it can also minimize transmission between officers and patients due to high aerosol production by HFNC devices, this is because HFNC device monitoring alarms can be monitored in the nurse's room via the internet technology.

INDEX TERMS HNFC, Flow Fault, IoT

I. INTRODUCTION

The High Flow Nasal Cannula (HFNC) is a non-invasive ventilation system that has been shown to provide a lot of promise in a number of patient conditions requiring emergency respiratory assistance.[1]. However, it is feared that the aerosol produced by HFNC will have a high impact on transmission to other patients, especially medical personnel treating these patients.[2]. So wearable technology, telemedicine with the IoT system play an important role in minimizing the risk of contracting health workers because it minimizes closeness to patients[3][4].

The workload of medical personnel in handling COVID-19 is quite high due to limited manpower so medical personnel who are taking a break are tasked with always being ready with additional working hours thereby increasing the physical and mental burden. Exposure to infection for nurses causes instability in the number of workers[5]. Close monitoring and clinical monitoring of the use of HFNC is necessary during therapy for patients with poor saturation[6]. When HFNC is not able to provide sufficient support, the patient will be in a dangerous condition in the form of respiratory failure, so that monitoring is not simple/specific during the use of this HFNC.[7]. We know that HFNC (High flow Nasal Cannula) is a method of administering supplemental oxygen to patients with acute respiratory failure.[8][9]. The use of HFNC in recent years has been highly recommended as a solution to provide supplemental oxygen to patients[10][11]. This is because in recent years there has been a virus that attacks the lungs and causes patients to experience respiratory system failure, namely a condition where there is fluid or softening in the patient's lungs, making it difficult for the body to maintain oxygen concentration in the lungs. blood, the virus is COVID-19[12]. Covid-19 has become a virus that has become a world pandemic and this virus has caused mass deaths because medical personnel have difficulty treating patients when oxygen levels in the blood have fallen to critical levels. Several solutions to increase oxygen in the blood have been successfully carried out, including the use of a ventilator[13][14]. However, because the number of patients continues to increase, the availability of ventilators is very limited to be given to all patients who need it. Therefore, several studies were conducted to provide a solution to this, one of which was recommended in this study was the use of HFNC to support the body in maintaining oxygen concentrations in the blood, so that patients do not enter a critical period. Point.[10][11].

The use of HFNC is considered to be able to help patients to increase blood oxygen levels, although there is still debate about the side effects of aerosols given to patients.[2]even though I have used the mask properly[15]However, HFNC has been shown to increase oxygen levels in the blood, and ease lung performance[16]. Administration of HFNC to COVID-19 patients begins at a flow range of 30-50 LPM with an oxygen concentration of 92%[11]. Humidity will also have an effect when the airflow velocity in HFNC increases[17]The use of HFNC must be closely monitored by the nurse because if the patient is in the same condition or worsens, the nurse is required to increase the flow rate given to the patient, this monitoring is carried out every hour so that the nurse can find out the results of the examination. HFNC administration and if the patient's condition remains then the flow given to HFNC will be increased[18][16]Therefore, during the administration of oxygen therapy using HFNC it must be monitored carefully, so that the dose of oxygen administration to the patient does not decrease or does not stop.[19].

In the HFNC device there are several errors that occur in the administration of therapeutic oxygen, including leak errors where there is a leak in the hose or a mismatch between the HFNC setting and the output given to the patient.[20]. which causes the oxygen flow to the patient to decrease, when this condition occurs the device will provide information and an alarm to the nurse so that the nurse will immediately respond to provide corrections to the device, but in current conditions there is a condition where the patient increases, nurses sometimes do not know the alarm and warning given by the device, therefore it is necessary to continuously monitor oxygen delivery which can provide direct notification to the nurse if an error occurs so that the error does not worsen the patient's condition

Some of the research used as reference material in this research is the creation of a portable mobile real time oxygen monitoring auto ventilation system[21], this designed tool functions to ensure that the flow of oxygen supply to patients can be monitored in real time, thus facilitating the process of monitoring oxygen therapy to patients, in this study the researchers concluded that mobile monitoring applications can improve services to patients and can speed up handling when something goes wrong. . In addition, the design of an Arduino and website-based fluid flow monitoring and control system was also carried out, the tool designed has succeeded in determining the number of successful monitoring of fluid flow and controlling valves, and no errors were found to use the website as a medium for storing and displaying data. flow,[22], this study aims to test the use of piezoresistive as a substitute for flow sensors to measure microfluids with the aim of cutting sensor manufacturing costs, in this study researchers succeeded in making microflow sensors using the piezoresistive concept and cutting sensor manufacturing costs by up to 90%, further research to examine sensors is expected add data for further use of this sensor.

Air flow sensors can be used to measure flow rates in heating, ventilation and air conditioning systems. The transducer requires a device material that is strong and flexible. Due to the interaction with the fluid flow, the transducer generates a signal that can be measured electrically[23]. In addition, the air flow sensor can also detect flow velocity with high accuracy and resolution[24]. Micro-type air sensor produces a determined airflow velocity by measuring resistance changes with high sensitivity results[25].

The HFNC precision flow system incorporates a vapor transfer module, oxygen analyzer, oxygen analyzer, blender and electronic mass flow sensor. Precision flow systems use a unidirectional gas flow which the analyzer calibrates prior to testing in each flow[26]. Thermal airflow sensors use the difference between exhaled and ambient air temperatures to estimate airflow and detect mouth breathing[27].

Patient Management in Intensive Care Units utilizing IoT devices seeking to collect physiological data is a critical care treatment to improve timeliness and quality of care through the provision of IoT-based healthcare[28].

Wearable technology the IOT system plays an important role in minimizing the risk of contracting health workers because it minimizes closeness to patients, one of which in this case is patients with HFNC oxygen therapy devices.[3]thereby reducing mortality, especially for geriatrics[29]and reduced nosocomial effects in studies of transmission effects on coughing distance[30]. Monitoring with IoT technology is also very necessary for monitoring to identify failures on HFNC devices due to the low risk of intubation, nosocomial infection and patient comfort.[1].

Based on the background and review of previous research, we raise the following title "Monitoring Alarm Occurrence in IoT-Based HFNC With Analysis of Signal Drop Before Leaking and Different Flow Errors (Parameter Flow)" which will analyze several faults in HFNC that cause a decrease in flow delivery in HFNC, this analysis will aim to be able to provide notifications and warnings to nurses before an increasingly fatal error occurs, therefore researchers will create a tool to monitor oxygen therapy to patients and provide notifications in the form of telegram messages to notify nurses directly when something happens . errors, so that nurses can provide direct treatment before the patient's condition worsens due to these errors. This research aims to analyzed faults in HFNC that cause a decrease in HFNC flow.

II. METHODOLOGY

This research was conducted at Bhakti Dharma Husada Hospital in Surabaya using HFNC. The research design used in making the module is Pre-experimental with the After Only Design type. In this design the researcher only uses one group of subjects and only looks at the results without measuring and knowing the initial conditions, but there is already a comparison group.

The independent variable in this study is the error condition in HFNC. the dependent variable is the pressure data read by the pressure sensor. and the variable being controlled is the microcontroller board used, namely ESP32.

A. DATA ANALYSIS

Measurement of each parameter, flow from 30 – 60 LPM, and pressure were all repeated 5 times. The average measurement value is obtained using the mean or average using equation (1).:

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

where represents the mean (mean) for n-measurements, x1 represents the first measurement, x2 represents the second measurement, and xn represents the n measurements. The 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 formula (SD) can be shown in equation (2):$\overline{x}$

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

where xi denotes the number of desired values, x denotes the average of the measurements, n denotes the number of measurements. Uncertainty (UA) is the doubt that arises in every measurement result. The uncertainty formula is shown in equation (3):

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

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

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

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

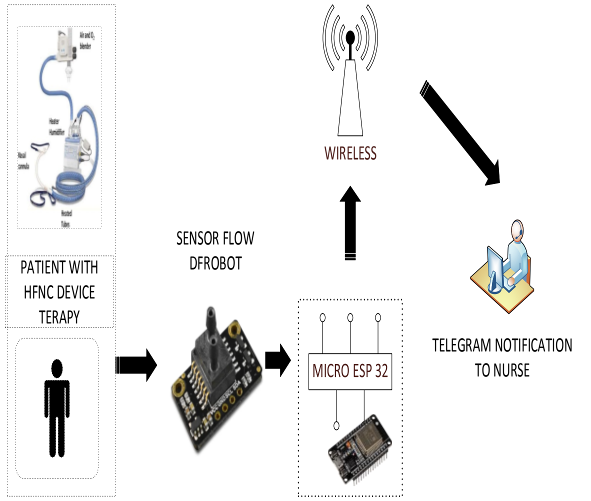

FIGURE 1. **Block Diagram of HFNC Module**

The block diagram above in Figure 1 has 3 main parts, namely the input and output processes, the input consists of the Differential Pressure Sensor SEN0343 which is the input data source on the microcontroller, the process part consists of the microcontroller which functions to receive data from the sensor and process it so that the sensor value can be calculated. displayed on the display, in the output process there is a display and notification of data via IoT.

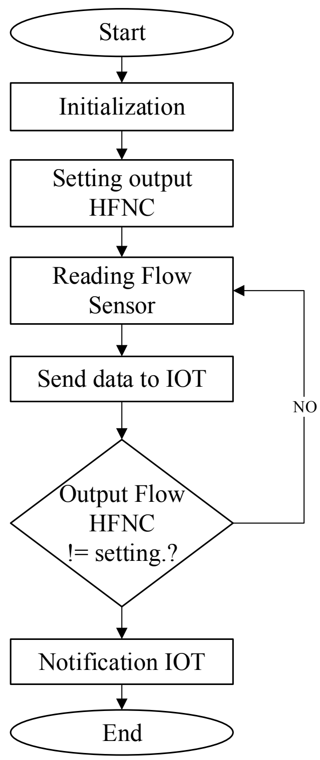

FIGURE 2. **Flow Chart of HFNC Module**

III. RESULTS

In this study the module has been tested. Module design is shown in Figure 3.

FIGURE 3. The Design of HFNC Module

The digital part consists of the ESP32 microcontroller which is the main board of the device and the DFROBOT Flow sensor. Where is the design of this module as seen in Figure 4.

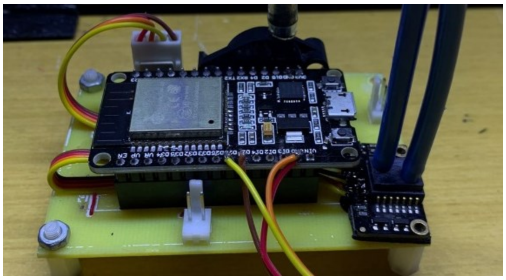

FIGURE 4. Hardware HFNC Module

Retrieval of module data at Bhakti Dharma Husada Surabaya Hospital using the HFNC device. In collecting this data, settings are used for Flow parameters 30, 40, 50, and 60 LPM.

TABLE 1.
Error Comparison Value of Each HFNC Setting with the Condition Before and After Leaking

Flow Settings	Flow Before Error	Flow In Process
30	2.0	88.0
40	1.5	89.0
50	0.8	89.6
60	1.0	90.3

From the module test, the error value is obtained from the difference in the actual value compared to the measured value of the pressure parameter with the Leakage Error condition. It can be seen in the table below that the lowest error value during flow before processing is when setting flow at 50 lpm with a value of 0.8%. While the lowest error value when flow is in progress is when setting flow at 30 lpm with a value of 88%. then for the highest error value during flow before processing is when setting flow at 30 lpm with a value of 2.0%. While the highest error value when flowing in the process is when setting flow at 60 lpm with a value of 90.3%. This can be seen in TABLE 1 which explains the comparison of the Error Value for Each HFNC Setting with the conditions before and after the leak.

The standard deviation obtained from measurements with the HFNC module has a good value because the standard deviation value does not exceed the average value of the HFNC module measurements and the standard deviation value for each parameter has the same value for each parameter, namely 0.548. The standard deviation above proves that the standard deviation value of the entire device is at the flow setting of ±0. This can be seen in TABLE 2 which conveys the standard deviation comparison value for each flow setting before leaking.

TABLE 2
Standard Deviation Comparison Value For Each Setting Flow Before Leaking

Flow settings (lpm)	SD stream before error (lpm)	SD flow in process (lpm)
30	0.548	1817
40	0.548	2,702
50	0.548	1924
60	0.548	2,864

Flow measurement results on leaking error conditions. Where the experiment was carried out for 5 repetitions at each flow setting of 30 – 60lpm. In the experiment with a flow setting of 30lpm, the average value of the output flow before the error was 30.6, the average value of the pressure in the process was 3.6 and the average value of the pressure after the error was 0. The average value of the error time was 1.46 seconds with an average time telegram notification 1.3 sec. In the telegram notification and the condition of the tool shows the condition of the leaking error. As shown in Figure 5.

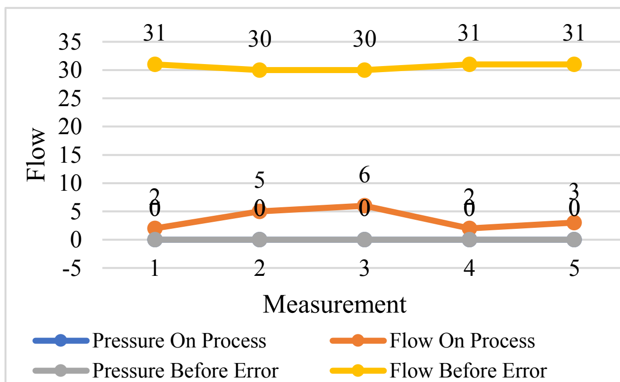

FIGURE 5. Flow and Pressure Measurement Results in 30LPM Leak Error Conditions

In the 40lpm flow setting, the average output flow before the error is 40.6, the average pressure in the process is 4.4 and the average pressure after the error is 0. The average error time is 1.52 seconds with an average notification time. telegram 1.38 sec. In the telegram notification and the condition of the tool shows the condition of the leaking error. This can be seen in Figure 6.

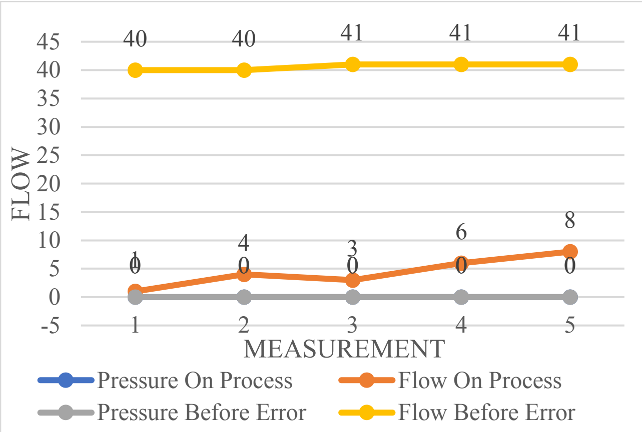

FIGURE 6. The Results off Flow and Pressure Measurements at 40lpm Leaking Error Conditions

In Figure 7 is the result of pressure measurement in the leak error condition at 50lpm setting. At a flow setting of 50lpm the average value of the output stream before the error is 50.4, the average value of the pressure in the process is 5.2 and the average value of the pressure after the error is 0. The average value of the error time is 1.6 seconds with an average the average telegram notification time is 1.5 seconds. In the telegram notification and the condition of the tool shows a leak error condition.

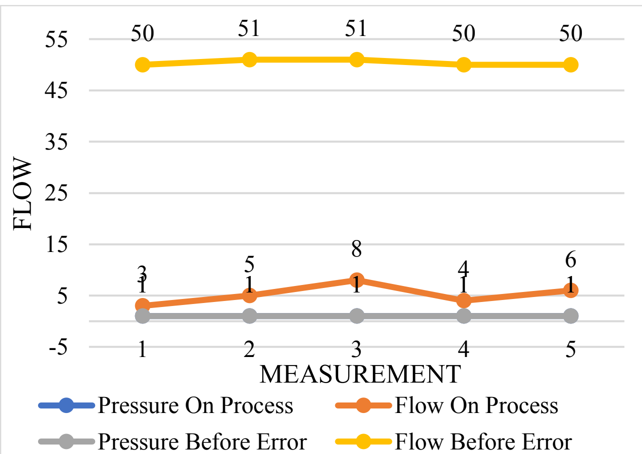

FIGURE 7. Results of Flow and Pressure Measurements in 50LPM Leaking Error Conditions

In FIGURE 8 is the result of pressure measurement in the leak error condition at 60lpm setting. At the 60lpm flow setting, the average value of the output stream before the error is 60.6, the average value of the pressure in the process is 5.8 and the average value of the pressure after the error is 0. The average value of the error time is 1.64 seconds with an average the average telegram notification time is 1.9 seconds. In the telegram notification and the condition of the device shows a leak error condition.

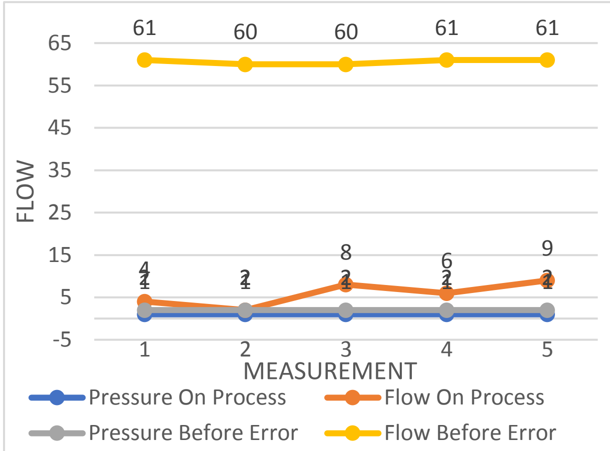

FIGURE 8. Results of Current and Pressure Measurements in 60LPM Leaking Error Conditions

Figure 9 and Figure 10 are Graphs of Analysis of Decrease in Flow Signals and Pressure Signals before leaking, during the leaking process and after leaking at 60 Lpm Flow Setting. Here it can be seen that when Error Leaking, both flow and pressure, the shape of the signal is reduced in the same way.

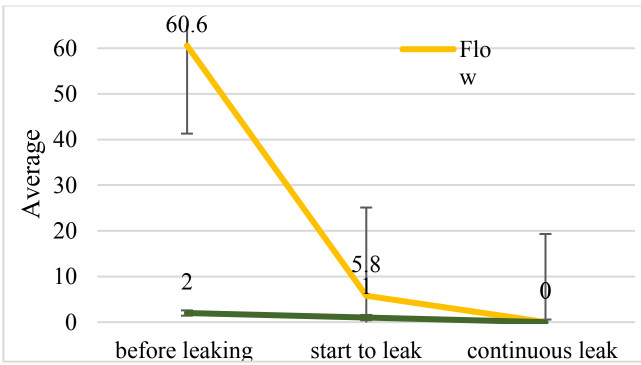

FIGURE 9. Graph Analysis of The Decrease in Flow and Pressure Signals During Leakage Errors

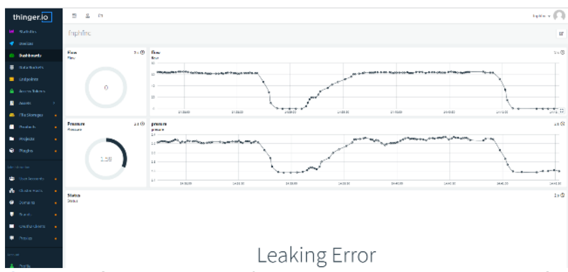

FIGURE 10. Graph Analysis of Decrease in Flow and Pressure Signals at the Time of Leakage Error on Thinger Io

IV. DISCUSSION

After testing the results, data collection and analysis was carried out to determine the accuracy of the output value of the MPX5700GP pressure sensor and the SEN0343 Differential Pressure sensor as a flow sensor.

After conducting experiments on research to get the pressure value and flow value before the error, during the process, and at the time after the process. then the results obtained in the module are as follows:

In the 30lpm experiment, the error value when a leak occurs is 88.0%, the error value before a leak occurs is 2% which indicates the stability value of the module before a leak occurs. The error flow value in this large process causes leakage. In the 40lpm experiment, the error value at the time of the leak was 89.0%, the error value before the leak occurred was 1.5% which indicated that the module value was stable before the leak occurred. The error flow value in this large process causes leakage. In the 50lpm experiment, the error value at the time of the leak was 89.6%, the error value before the leak occurred was 0.8% which indicated that the module value was stable before the leak occurred. The error flow value in this large process causes leakage. And in the 60lpm experiment, the error value at the time of the leak was 90.3%, the error value before the leak occurred was 1.0% which indicated that the module value was stable before the leak occurred. The error flow value in this large process causes leakage. And if analyzed, it can be concluded that when there is a decrease in the flow value during the process and a decrease in pressure before the error and pressure during the process, the HFNC and the module will issue a leak error notification.

The implications of this study can be concluded that the Alarm Occurrence Monitoring tool on IoT-Based HFNC With Signal Derivation Analysis Before Leaking and Different Flow Errors (Parameter Flow) has been successfully created and can be used properly. This means that the tool can apply the use of Flow sensors and the Telegram application in monitoring the occurrence of alarms when there is a signal drop in Leaking Error conditions.

Due to various factors, the modules made by the author are still far from perfect, both in terms of planning, manufacturing, and how the module works. So that there are several shortcomings that have been analyzed from the tool that the author made. The resistance of the flow sensor to humidity has not been known after using a humidifier. The stability of the flow sensor is unknown when the leak process begins. So that the selection of sensors that are resistant to high enough humidity produced by this HFNC tool should be carried out

IV. CONCLUSION

The purpose of this study is to monitor the occurrence of alarms on HFNC via IoT by analyzing signal degradation before leaks and different flow errors. At the time before the leak, the module had good and stable results when compared to the setting on the HFNC tool. Which means the module can run properly and can be used. When a leak occurs and is not immediately handled by the officer, the flow value will decrease at a certain point so that the HFNC tool will sound an error alarm, and the module will immediately send a notification to the telegram that a leak error has occurred.

This module has fairly good accuracy, but future research should select flow and pressure sensors that have high resistance to humidity produced by water vapor from this HFNC humidifier.

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