Multi-Parameter Sensor Device to Provide Continuous Indoor Environmental Monitoring in Hospitals

E. Johnson, P. Hergert, T. Appelhans

Department of Mechanical Engineering, Northern Illinois University, Dekalb, IL

FACS | 21228 Cabot Blvd, Hayward, CA

Abstract—**This paper describes the functionality of a device that is equipped with multiple environmental sensors that collect particulate, temperature, humidity, and differential pressures in a hospital setting in a small package. Data is transferred via a National Instrument microcontroller to a cloud database to be continuously monitored for root-cause analysis to protect public health interests.**

I. Introduction

In the medical field such as hospitals or operating rooms have a need to protect the health and safety to all inhabitants residing in the buildings. To accomplish this, the facility monitors the indoor environmental qualities with upmost scrutiny. Air qualities that are monitored are but not limited to are the amount of particulate matter in the air, temperature, humidity, and air pressures within any given area.

The systems that are available in today's world are either bulky in physical size, expensive, inconsistent or a combination of all three. What is not currently available is a multi-sensor singular package that has a smaller physical footprint with accuracies that conform to current hospital standards which can also monitor in real-time and can be produced in an inexpensive manner.

In this paper, we describe a new device that can take mechanical components which measure a physical measurands such as airborne particulate, pressure differentials, humidity, CO2 levels, and temperature. These mechanical components need to then be transduced to an electrical component such as resistance, current, or electric potential to be measured to correspond to the physical property measured. The data is packaged in a singular format that is sent to a cloud database continuously to be easily read by the user for environmental information wherever the device is installed. The sensors incorporated into the device are a particle counter, temperature and humidity sensor, differential pressure sensor, and a CO2 level sensor that can completely 'paint a picture' of the given environmental surroundings.

II. Materials and Methods

Through the many ISO standards for particulate counters in a health care setting like the ISO 14644-1 [1], USP 797 [2], and much input from Forensic Analytical Consulting Services (FACS), the best company for the sensor was found. After finding Particle Plus, much discussion was taken with the company to get a custom OEM Particle counter that was capable of measuring particulate in varying size from 0.3μm – 25μm using laser scanning through a pump inlet funnel. Since Particle Plus did not have an OEM version of this sensor, they supplied a custom unconstructed version of their very common and proven Model 8306 handheld particle counter. This sensor was ultimately chosen because of its ability to measure up to 6 different channels of particulate size, its OEM capabilities for production use, and its compliance with ISO 22501-4 [3] calibration methods with its built in Pulse Height Analyzer.

There are no ISO standards for pressure differential monitoring, but there was much input from FACS to the level of accuracy they required and range of measurement. The unit of measure that is used in hospitals for pressure differential between 2 separate areas is inches of water column (W.C.). The way that the sensors measures differential is the same as a manometer. While there is not a manometer inside the sensor, the sensor works from a flexible capacitive diaphragm inside the sensor that is exposed to the separate pressure ports on either side of the diaphragm. As pressure builds on either side of the charged diaphragm, the current that exits the sensor is either increases or decreases due to the increase in capacitance. This output current is read at a high precision 250 ohm +/- 0.05% resistor as a voltage. This voltage at the resistor is then measured and converted by the controller to inches of water column. The Setra Model 264 pressure differential sensor was chosen due to its simple design, high accuracy, and ease of calibration with a potentiometer on the side that is accessible with a small flat head screwdriver.

Many other environmental conditions were discussed to add to the unit like sound levels, tempurature, motion, relative humidity, and CO2 levels. The Sensiron SCD30 sensor was chosen because of its low price, ease of operation with Modbus communication, and low inlet current and voltage draw. This sensor is capable of measuring Tempurature, Relative Humidity, and CO2 levels. Motion and Sound monitoring were excluded from the unit due to privacy concerns in hospital settings.

When designing a sensor package that will be used in a healthcare setting, many requirements must be followed. The packaging needs to be made of materials that are not susceptible to corrosion, will not deteriorate from common hospital cleaning products, are entirely free of sharp edges or burrs, and will not have any openings to potentially high current circuitry on the inside of the unit. The unit is designed to be mounted on the wall of any hospital area. It needs to be secure to the wall and not stick out normal to the wall past 3.5 inches. The packaging design and components selected were chose with this dimensional tolerance in high regard.

For the purposes of controlling and measuring all software functions of the unit, the National Instruments My-RIO Model 1900 controller was selected due to its easy to use programming environment, WiFi capabilities, extremely durable design, and large number of I/O pins in a multitude of voltage and current ratings. Labview is a National Instruments program that is used to program and control all the company's controllers. Labview uses blocks interfaces and virtual interface programming instead of lines of code. As the code runs, the flow is tracked, and errors are shown in real time as the code runs to make debugging and troubleshooting the code extremely easy.

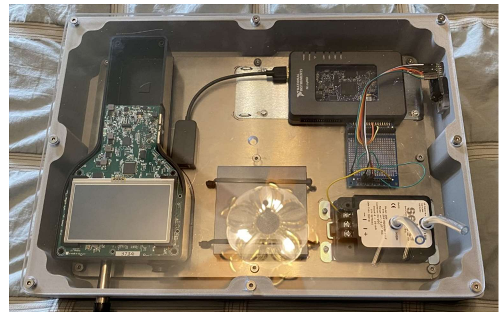
This unit will be running 24/7 and continuously monitoring data at a rate that can be defined differently for each hospital based on their individual requirements. Based on this, the storage and analysis of the data must be very robust and easily integrated to many different applications. InfluxDB is an internet cloud-based server that can be configured to read, scale, and graphically display large amounts of data for analysis and real time monitoring. Below is the graphical representation for Tempurature, Relative Humidity and CO2 Levels:

The server for this unit was configured to display the data for all 5 outputs as a rolling average to be graphically displayed. Essentially, the data is being continuously monitored and stored, but the only thing that is displayed on the graphs are the average for a certain window of time (last 5 minutes, 10min, 15min, etc). This window will be configured for each hospital based on their needs. The rolling average approach makes small 1-2 second spikes in condition levels that do not cause as high of a spike in the overall monitoring. The information being displayed on the InfluxDB interface are the particulate levels for all 6 particulate sizes, pressure differential, Tempurature, Relative Humidity, and CO2 levels.

III. RESULTS AND DISCUSSION

A. *Data Analysis Verification*

The system successfully transduced the physical measurands of particle counting, temperature, CO2, and humidity into electrical aspects. These electrical aspects are then, through Labview code, correlated back into recorded measurements. These recorded measurements are sent to a cloud server in excel format to download for data analysis. The packaging of the unit was designed in such away that it met all hospital requirements and did not distort the data in any way as seen below:



IV. CONCLUSION

V. An all in one sensor package was designed for the use in hospitals. Particulate is evaluated for the entire range as specified in the ISO 14644-1 [1] and USP 797 [2] standard for hospital particulate monitoring. Pressure differential is monitored through highly durable flexible plastic tubing with a range of +/-0.25 inches of water column to a tolerance of +/- 1.0%. Inside the unit is also a senor card that monitors tempurature, relative humidity, and CO2 levels. The packaging design is made of materials that will not corrode over time, is free of sharp edges and burrs and fits within 3.5 inches of the walls surface. With the InfluxDB cloud server analysis tools, the data that is exported from the National Instruments My-RIO Model 1900 controller is stored and displayed in an easy to read manner for the greatest ease of use for hospitals.

ACKNOWLEDGMENT

David Brinkerhoff and John Martinelli from the industry sponsor Forensic Analytical Consulting Services (FACS) provided all funding for the project. FACS also provided design requirements that were used and continuously updated through the lift of the project that drove the design of the unit.

Dr. Monsour Tahernezadi and Fahad Alqahtani met with the team every week to ensure that progress was being made on the project and supplied support when needed by the team.

Javier Arellano was a great resource for coding in Labview. His years of experience with Labview and the My-RIO controller through his career at Collins Aerospace proved to be a huge asset to the project.

Thomas Grillio from Particles Plus was a technical representative for the Model 8306 particle counter.

Dick Pansire from Setra was a technical representative for the Model 264 Pressure Differential sensor.

REFERENCES

[1] ISO Standard for Cleanrooms and Associated Controlled Enviroments, ISO 14644-1,2015.

[2] USP Pharmaceutical Compunding – Sterile Preperations, USP 797, 2018

[3] ISO Standard for Determination of Particle Size Distribution, ISO 21501-4, 2018