# Agilent Engineering Excellence Program Intelligent Monitor and Trigger System (I)

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*Abstract*— **Base on the industrial problem surrounding the maintenance of the negative pressure in isolation wards, the project aims to take up the challenge of solving the industrial problem and at the same time investigate the change profile of the atmospheric pressure in response to the changing position of the pressure sensor. With the help of Agilent Technologies, a control programme has been written using Agilent VEE Pro 8.0 to monitor the pressure readings and trigger off the various alarm systems when needed, implementing the online trend-based detection method. Agilent DAQ card U2353A allows the readings to be taken from a thermal chamber which is used to simulate as the isolation ward. Although the change profile of the atmospheric pressure is established in the case of simulating the opening of the door some time into the start of experiment, detailed study of the change profile in extracting the properties such as the rising time and settling time is not possible due to the turbulence created both by the fan as well as the action of opening the door and leaving the door open.**

## I. Introduction

The project is based on an existing industrial problem in an isolation ward to investigate the behaviour of pressure change with respect to the positioning of the pressure sensor through the use of a thermal chamber and a DAQ card and at the same time, to formulate a solution to the existing industrial problem through the investigation.

### *A. Background*

Isolation wards are special wards used to house patients suffering from communicable diseases. The wards are equipped with special facilities and one of them is a pressure sensor that monitors the atmospheric pressure of a ward. The atmospheric pressure inside the wards are maintained at a level which is lower than the atmospheric pressure outside the wards such that when the door is opened, air from outside the ward will rush in as air flows from a region of higher atmospheric pressure to a region of lower atmospheric pressure, thereby preventing the air inside the ward carrying the infectious germs from escaping to infect other patients in other parts of the hospital. Such lower atmospheric pressure inside the ward is termed as "negative pressure".

However, the pressure sensor does not provide a feedback to the ventilating system when the atmospheric pressure inside the ward starts to rise beyond a critical level. Instead, an alarm is sent to alert the facility management unit of the hospital, which will then be deployed to investigate the fault.

### *B. The Industrial Problem*

A fault is considered valid and genuine when the atmospheric pressure inside the ward rises above the critical level when the ward is in an enclosed condition with all the windows and door being closed. However, most of the alarms raised are false and the vast majority of the false alarms are due to doors of the wards being left ajar for various reasons such as after a visit by medical students, when the ward is not in use.

### *C. The academic aspect of the project*

The project will also investigate the profile of the change in the atmospheric pressure due to the change in the position of the pressure sensor and through the study of the change in the profile, derive a solution to the above mentioned problem.

### *D. Agilent Technologies*

The project is well supported by Agilent Technologies by providing a model U2353A DAQ card module and the accompanying software VEE Pro 8.0. In addition to the equipment, a one-day lesson has been conducted prior to the start of the project and a list of help has also been made known. The helpdesk also provides adequate support. The project will also demonstrate the use of the Agilent Technologies products in real application in the industrial as well as in the field of academic studies.

With the above motivations behind the commencement of the project, the main objectives of the project are:

- To investigate how the change in the air pressure varies with the position of the pressure sensor
- To improve the existing pressure change detection system that detects the genuine alarm, thereby reducing the number of false alarms
- To demonstrate the use of Agilent Technologies products in real application in the industrial and academic field.

The objectives of the project can be met by further defining the sub-objectives which will aid in further defining the tasks that need to be done.

- To design an experiment setup that models after an isolation ward.
- To design the necessary electronic circuit and to integrate it with the DAQ U2353A provided by Agilent Technologies
- To design all the software using the provided

Agilent Technologies VEE Pro 8.0

- To design a software that will assist in the experimental control and data processing and analysis
- To design a software that will bridge an existing email and SMS system to form the alarm system

## II. Control Programme

### A. Overview

With all the hardware been built and modified, there is a need to design a programme that will perform the following:

1. control the rate of rotation of the fan via the control of the current flow to the fan
2. record the measurement taken from the sensor via the DAQ card and analysis the readings
3. integrate with the alarm system.

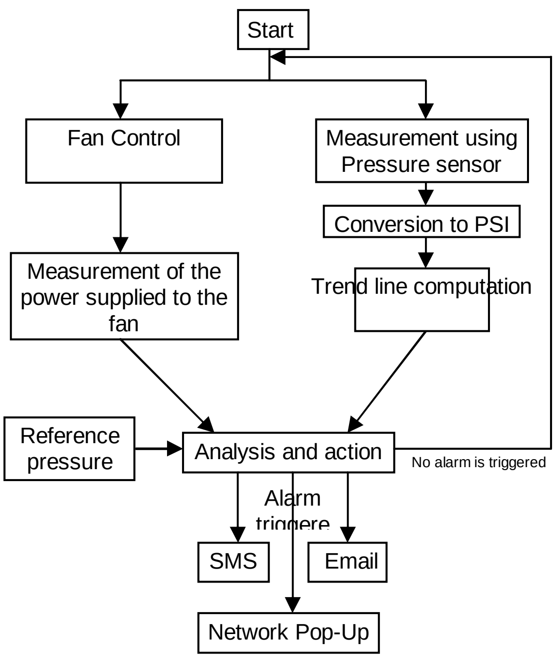



Fig. 1: Overview of the control programme

The control panel contains three plots for monitoring purposes, alarm message screen for the alarm system and control buttons for controlling the experiment setup purposes. The plot labelled "Measurement" will show the actual signal readings taken from the DAQ card, while the "Temporary Current Trend" plot will show the current trend as suggested by the latest readings taken from the DAQ card. The "Pressure Plot" shows the overall trend of the readings, excluding the most current trend. The two alarm lights sandwiched the alert message box, in which an alarm message text will shown when the alarm system has been triggered. The "Cooler" alarm light reflects the status of the fan. If the power supply to the fan is too low for the fan to move, it is considered as a failure and the alarm will turn red. The "Pressure" alarm light reflects the measured atmospheric pressure in relationship to the reference atmospheric pressure, which is usually the normal atmospheric pressure. If the former is higher than the latter, it will turn red. The "Pressure" alarm light works when the alarm switch is on. When turn off, the alert text message will not be shown as none of the alert system is triggered. Multiple mobile numbers can be input into the mobile no. field box and the alert messages will be sent.

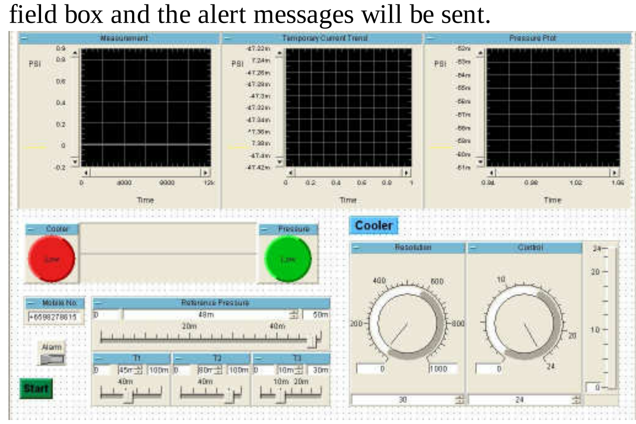



Fig. 2: Control Panel of the Control Programme.

### B. Working Principle of Fan Control Method

The method to vary the speed of the fan is through varying the duty cycle of PWM. The amount of power that can be sent to the fan can be controlled by varying the duty cycle. The method will produce a square wave where its duty cycle is modulated, resulting in the variation of the average value of the resulting waveform.

### C. Readings and Data Analysis

The reading of the measurement is done continuously with the help of an external "Break Until" loop. This loop will also reflect any changes to the settings such as the fan control or the threshold values by the user during the running of the control programme. The reading of the measurement from the DAQ card is done using the "Direct I/O" object with the SCPI commands written into it.

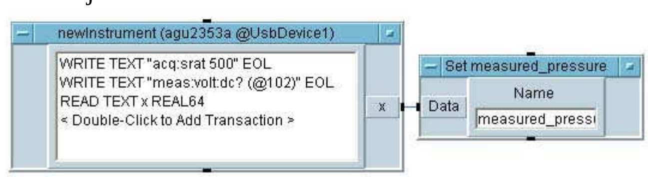



Fig. 3: SCPI commands written in Direct IO object to obtain measurements from DAQ card

The readings taken are analysed and graphs are plotted using online trend detection. The algorithm to carry out the online trend analysis is based on the article "A trend-based alarm system to improve patient monitoring in intensive care units” by S. Charbonnier, S. Gentil.

The main steps involved in the detection and the algorithm are as follows:

1. grouping of readings into linear segment online
2. classification of the latest segments into 7 temporary categories: steady or flat, increasing, decreasing, increasing/decreasing or decreasing/increasing transient and positive step or negative step.
3. transformation of the of shapes based on the 7 temporary categories into semi-quantitative episodes
4. assembling of the current and previous episodes of the same shape to form the longest possible episodes.

Every calculated value of the atmospheric pressure based on the current trend will be plotted onto the “Temporary Current Trend” plot. When a new linear approximation needs to be established, the plot will refresh itself and the beginning ordinate of the new segment will be the plotted after the ending ordinate of the previous segment is plotted. Strictly speaking, what is being plotted is the current segment, and the assembling of segments of the same type forms the trend. However, the plot is termed “Temporary Current Trend” as it gives an indication of where the atmospheric pressure is possibly heading currently, suggesting the current trend. It also shows the relationship between the current segment and the previous segment. The “Pressure” plot is only plotted when there is a need to establish new linear approximation when the cumulative sum error exceeds T1. When that happens, 2 points will be plotted. The first point is the calculated atmospheric pressure of the last point of the previous trend while the second point is the newly calculated value. This method of plotting makes use of the fact that the “XY plot” of the Agilent VEE Pro 8.0 will join the 2 points with a straight line and the previous trends are then plotted and displayed on the plot. Hence the latest plot on the graph is the previous trend.

The need to plot 2 points is to better reflect trends that are considered to be steady. This is because when the current and previous segments are classified as steady, the trend is not plotted until there is a change in the trend, but the ending ordinate of the steady trend is updated. If only a point is plotted, which is the beginning of the new trend, the XY plot will then join the ordinate of the new trend with the beginning ordinate of the previous steady trend. Such plot will display the steady trend as either an increasing or decreasing trend instead of a steady. Therefore, there is a need to plot 2 points and in the case where the previous trend is a steady trend, the first point plotted will reflect that the previous trend is a steady one as it is the ending ordinate of the previous trend, while the second point is the beginning ordinate of the current trend. For cases of from an increasing trend to a decreasing trend or vice versa, or from an increasing or decreasing tread to a steady trend, the first point will be what was previous plotted as the second point, hence plotting the same point twice but at different times.

### D. *Integration of Control Programme with Alarm Systems*

The last component of the control programme is the integration of the control programme with the alarm systems. This is part one of the aims of the project, which is to tackle the industrial problem. When the criteria to trigger the alarm systems are met, the “alarm” variable will reflect the event and through the “If/Then/Else” selection box, all the components of the alarm systems will be activated. The Control Panel Sound Alarm, which will produce a “Beep” sound to sound out that the alarm systems have been triggered off, and the Control Panel Alert Message, which will display that alert messages had been sent at the time according to the system time. Email, SMS and network computers pop-out warning messages are the rest of the alarm systems in sending out alert messages.

### E. *Discussion on the trend base algorithm*

The ideal pressure plot is desired as it makes the reading of the reading easy. However, the actual plotting of the pressure plot is far from ideal, showing more variation than it is desired. An investigation was carried through the study of the readings obtained so far and the conclusion that the ideal plot cannot be done was arrived.

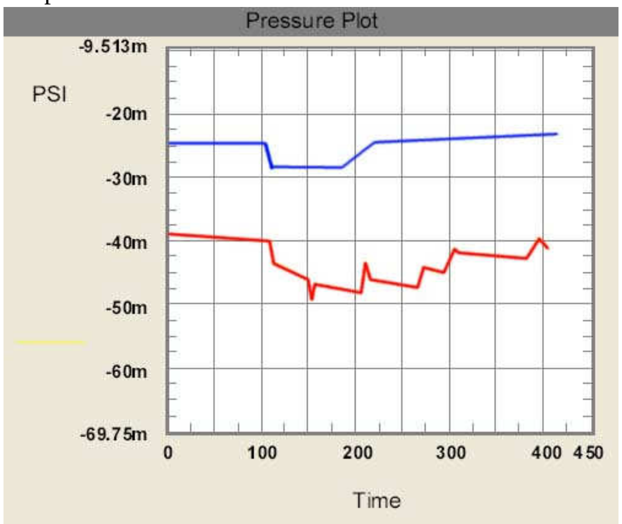



Fig. 4: Ideal and actual pressure plot

Bearing in mind that the plotting is done live, while it is possible to identify when there is a change in the trend, it is difficult to identify that at the instance of receiving the data. A reading that is lower than the current trend may not suggest that the trend has changed and is decreasing. Extending this idea when considering the relationship between the segments, when the current segment started off at a lower value than the previous segment, T3 plays an important role in deciding if the segments can be considered to be of the same trend or is a totally different trend, as a result of such fluctuation. The trend during the steady state, when the fan is off, fluctuates around 3 mPSI from the range between 40 to 50 mPSI, while the fluctuation of the trend during the steady state when the fan is on is greater, about 10 mPSI from the higher end of the 40s to 50 over mPSI. For the trend graph to accommodate the steady or flat segments, especially during the steady state, to establish a flat or steady trend, T3, which is the threshold that determines if the current segment is of the same type as the previous segments and is crucial in establishing extended steady trend, needs to be set at a high value. This high value should be around 10 mPSI, the fluctuation of the trend during the steady state when the fan is on. Any value less than that will result in fluctuations to be observed in the trend during steady state when the fan is off. However, the difference between the steady state trends is about 10 mPSI, implying that high T3 will be able to accommodate the steady or flat segments that differ from each other, calculating the difference between the ending ordinate of the previous segment or trend and the beginning ordinate of the current segment, by a large value, including the drop or rise from one steady state trend to another. In other words, high T3, in this case, will cause the trend to be adaptive, meaning that the trend is able to tolerate the changes in the atmospheric pressure and produce a straight line plot that is relatively flat. However, due to the design of the algorithm of plotting the previous trends and not plotting the current trend until it has concluded, the pressure plot will produce no plot. The ideal plot can be achieved when the fluctuations of the trends during the steady states are smaller than the changes between the trends during the steady states, illustrated below.

## III. Change Profile Results and Discussions

The academic aspect of this project is to study the change profile of the atmospheric pressure inside the thermal chamber with respect to the position of the pressure sensor. Since the pressure plot is not able to produce the ideal plot which will make the analysis of the changes in the atmospheric pressure inside the thermal chamber easy and the actual pressure plot is not really helpful in analysing the changes due to the fluctuations which makes it difficult to identify when the transient has started, separate readings have to be taken from the Agilent Measurement Manager v1.3 and analysed to come to any conclusive results. The readings at taken 500 sampling rate and the average of every 2500 points, or 5 second worth of readings, are then plotted as a graph to represent the trend.

During the experiment, a plastic cover with a rectangular hole on one end is put over the opening of the thermal chamber such that it will be sandwiched between the closing lid and the thermal chamber. The rectangular hole is placed on the opposite side of the fan and simulates as the door opening in a room. A total of 3 run of the experiment is done. For every run of the experiment, the fan is left running at 30 V, which is the maximum voltage that can be supplied for the fan, for sometime with the lid close so as to create a negative atmospheric pressure environment within the thermal chamber. After which the readings are taken for 20 seconds before the lid is open to simulate the opening of the door. The position of the pressure sensor various with every run and the positioning is shown in fig. 5 below. Readings are then taken with the pressure senor facing the fan and away from the fan or upwards facing the hole, which is only done is P4 in fig. 5. Initially, the size of the hole is 2.5 cm by 3.5 cm and in the second run, the hole increases in size to 7 cm by 8.5 cm. The last run is done with the plastic cover removed, simulating a huge door or a very small run. The diameter of the hole where the fan is seated is about 6.2 cm.

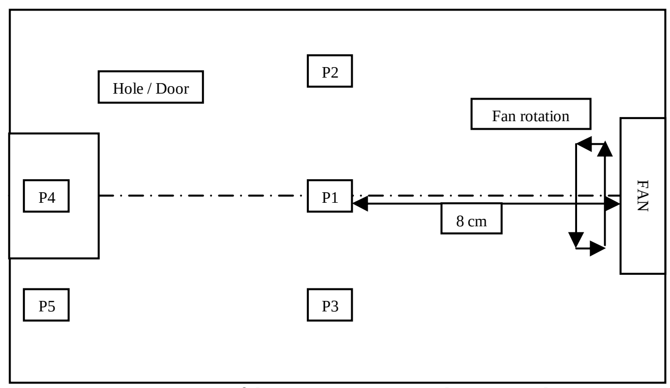
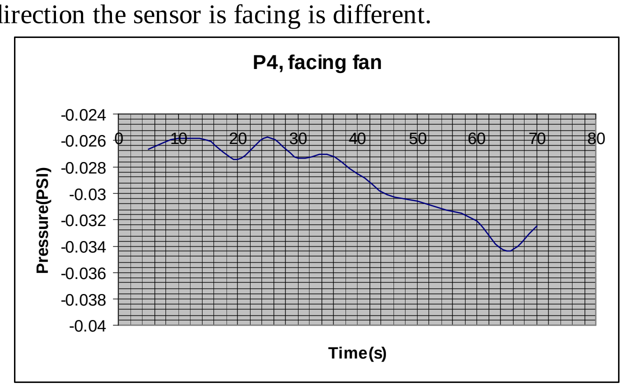


Fig. 5: Positioning of the pressure senor, not drawn to scale

The results are organised in the following manner for discussion with the aid of selected graphs plotted base on the readings from the Agilent Measurement Manager v1.3. Please refer to appendix for the rest of the graphs

### *A. How the direction of the pressure sensor affects the readings taken*

Referring to selected graphs in fig. 6, which shows that the readings suggested the same downward trend but the direction the sensor is facing is different.



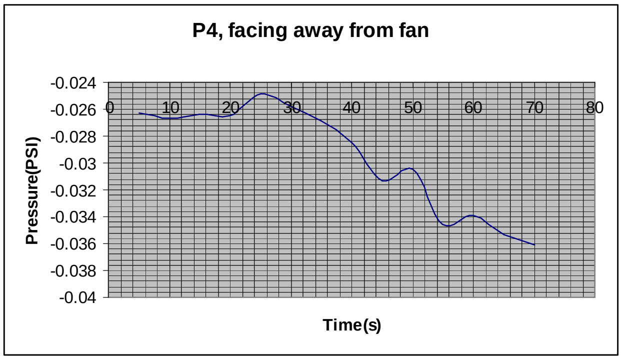
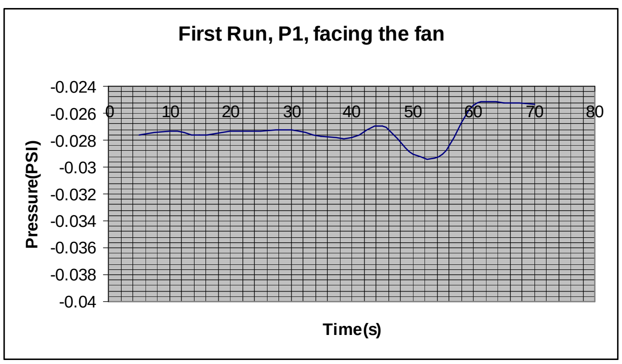
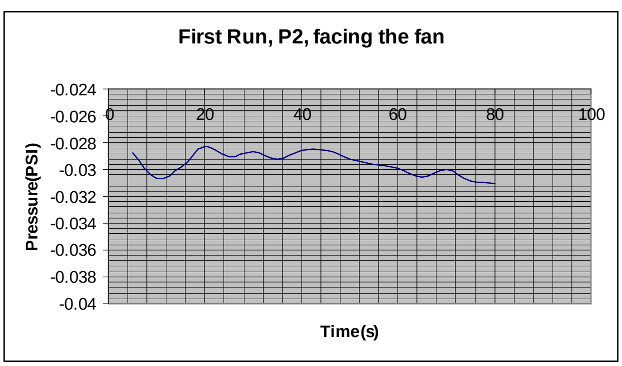


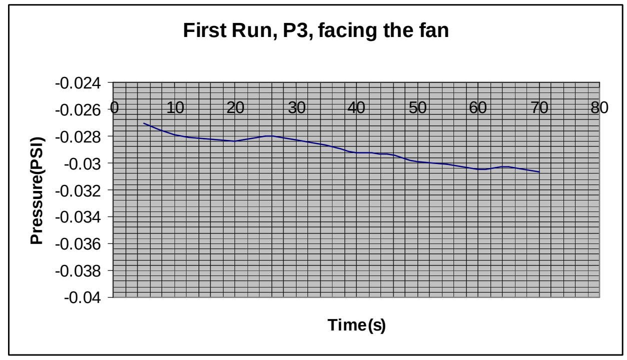

Fig. 6: Graphs showing same downward trend while the sensor faces different direction.

With that in mind, the second run is done with the sensor facing the fan. The aim of this run is to achieve more readings to establish the relationship between the size of the door opening and the trend. Also the trends displayed by the graphs at P2 and P3 are the same, hence in the third run of the experiment, the pressure sensor is placed only on one side of the thermal chamber.

### *B. Observing the trends at different position with hole size 2.5 cm by 3.5 cm*



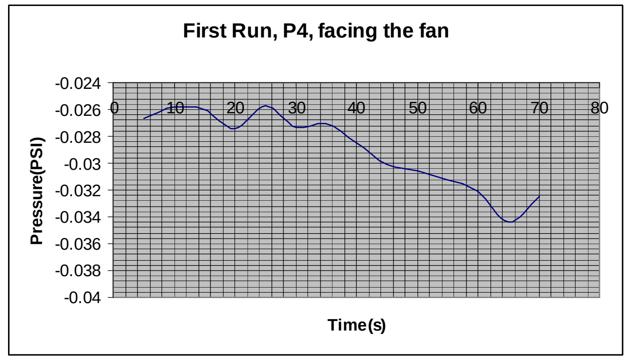




Fig. 7: Trends at various positions in the first run where hole size is 2.5 cm by 3.5 cm

From the first three plots of the fig. 7, the trend is about flat while the last graph shows a drop in the pressure reading near the end, with the end value of P4 is lower than the end values of P1 to P3. All the lids are opened at t = 20 seconds, while P1 to P3 are at positions closer to the fan while P4 is at the opening. The opening size is about 30 % of the hole where the fan is seated. The conclusion drawn here is that atmospheric pressure in a room near the fan remains relative constant and experience little change when the door is opened. However, the atmospheric pressure near the door will experience a drop when the door is opened. The reason behind could be that the fan is powerful enough to maintain the overall atmospheric pressure inside the room when the size of the door opening is relatively small. Hence the atmospheric pressure at positions near the fan is relatively constant. When the door is opened, there is airflow from the opening towards the fan, and the increase in airflow creates turbulence in the area near the opening, resulting in a drop in the atmospheric pressure at P4. The second run of the experiment at P4 with a bigger opening size also display a drop in the atmospheric pressure while the trend from P1 to P3 is steady.

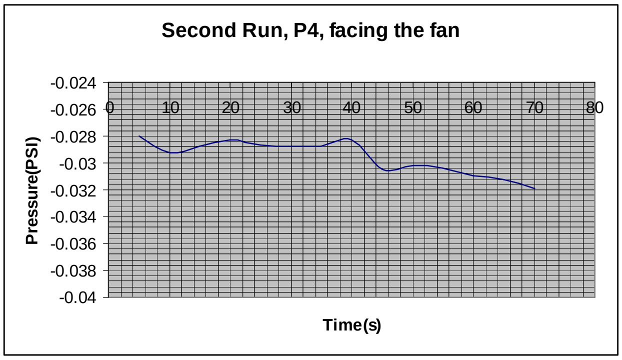
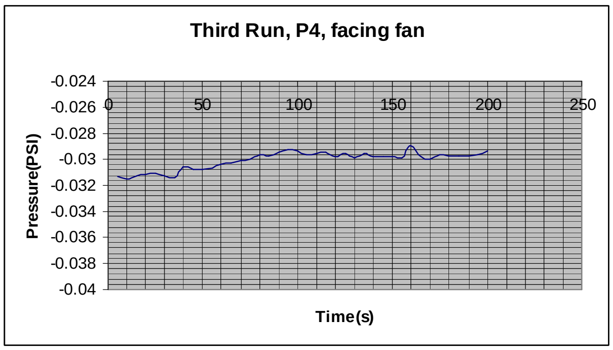
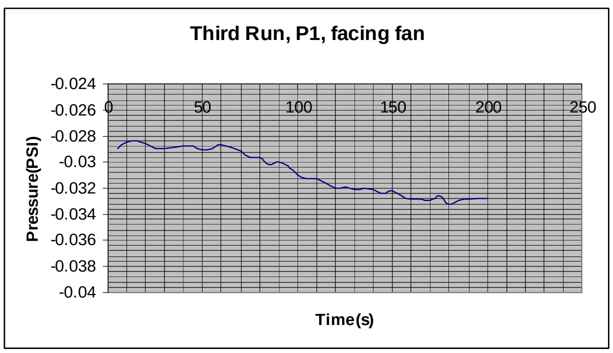
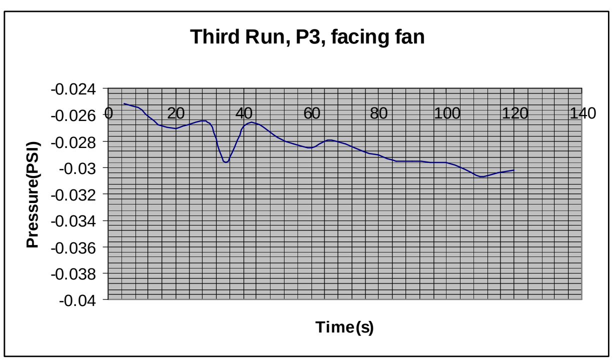



Fig. 8: Second run at P4 with opening size 7 cm by 8.5 cm

### *C. Observing the trend when the opening size is much greater than the fan hole*



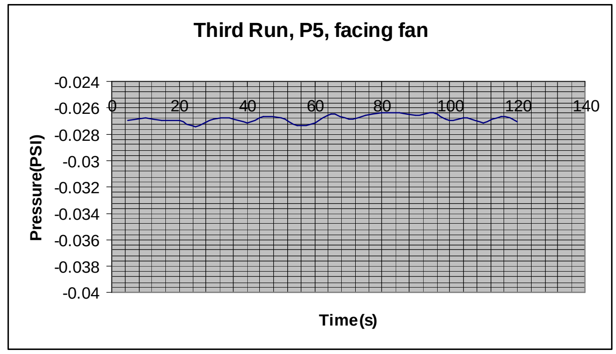




Fig. 9: Trends at various positions when the plastic cover is removed in the third run

From fig. 9 above, the second and third plot shows that the atmospheric pressure near the fan at P1 and P3 drops while the atmospheric pressure further away at P4 increase when the door is opened. The opening of the door of larger opening size is suspected to have created greater turbulence especially in the region near the fan, resulting in the lower atmospheric pressure. The conclusion which can be drawn is that for a large opening, the further the sensor is away from the fan, the readings from the sensor reflect better the changes in the room pressure induced by the atmospheric pressure of the outside environment.

## IV. Conclusion

It seems like a possible solution of improving the existing room pressure monitoring and alarm triggering for isolation ward has been produced and that is to place the sensor close to the fan and away from the door to prevent the sensor from being subjected to much changes to the atmospheric pressure of the external environment when the door of the isolation ward is opened. However, the pressure sensor is used more of detecting the turbulence that is created by the fan. Without the turbulence created by the fan, in which it can be faulty or in non-existence, the atmospheric pressure readings will be more consistent and the increase in room pressure will be detected, generating a genuine case of a fault.

The results are inconclusive in terms defining the properties of the change profile of the atmospheric pressure of an isolation ward or any room. The main cause is the turbulence created by the fan and the opening of the lid in the experiment. Turbulence, which is the unpredictable airflow, may affect the atmospheric pressure readings taken for this experimental setup. In order to study the properties of the change profile, reliable readings need to be taken, under the condition that the turbulence created must be minimised or studied and determined. For this experiment setup, the fan might be too powerful that creates much turbulence within the thermal chamber. At this stage, it can only be said that turbulence will affect the airflow and may affect the change profile within the thermal chamber but any study, formulae and theories associated with turbulence is beyond the scope of the project.

The objectives of the application aspect of the project have been met and the application has been successfully implemented into a working system through the use of provided Agilent DAQ card and VEE Pro 8.0, which incorporates the control of the setup, the monitoring of the room atmospheric pressure analysed using online trend-based detection method, the various alarm system, namely SMS, email and network computer pop-out warning message, and the alarm triggering mechanism..

## ACKNOWLEDGMENT

Special thanks for my supervising professor, Mdm Tan Woei Wan, for her patience and guidance.

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