Design and construction flow sensor for ventilator

BY

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ABSTRACT

Covid19 is the pandemic from coronavirus caused by fever, dry cough, tiredness, difficulty breathing, and risk of deaths. In 2020, Covid19 was spreading worldwide. Most of the patients need a machine for helping to breathe, which is called a "Ventilator." A ventilator is a machine that allows the patient who cannot live by themselves by delivering the air from the device to the patient's lungs. The ventilator has many functional parts, such as an emergency alarm, flow sensor, flow control valve, humidifier. This project is about a flow sensor in the ventilator, which detects the airflow from the lung to the ventilator to measure the patient's airflow. Then the ventilator computes the flow value and provides the air to the lung correctly. Therefore, the methodology is the pressure sensor to detect the airflow in the venturi tube. Then the microcontroller, Arduino, receives the data from the pressure sensor and computes the data to be the flowrate. Accordingly, the organizer would like to develop the flow sensor by design the new venturi and interface the flowrate graph in the computer. This part of the ventilator can support the Covid19 patient who has difficulty breathing and gives more time for the patient to recover from this disease.

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Symbols/Abbreviations	Terms
ATS	American Thoracic Society
BiPAP	Bi-level Positive Airway Pressure
BME	Biomedical Engineering
CPAP	Continuous Air Pressure
DPIs	Dry powder inhalers
ERS	European Respiratory Society
FEV1	Forced expiratory volume in one second
FRC	Active residual volume
FVC	Forced vital capacity
MDIs	Metered dose inhalers
MIP	Maximum inspiratory pressure
MVV	Maximum voluntary ventilation
PDI	Transdiaphragmatic pressure
pMDI	Pressurized metered-dose inhalers
PFTs	Pulmonary function tests
R.V.	Residual volume
TLC	Lung capacity

CHAPTER 1
INTRODUCTION

1.1 Problem statement

In 2020, the world had a new pandemic called "Covid19" that comes from coronavirus. It is caused by fever, dry cough, and tiredness, according to the severe acute respiratory syndrome, which is very dangerous for life. Covid19 is the most caused that increases death more than another disease this year because It is easy to infect a healthy person, and the patient who is already infected has the probability of death. Even the Covild19 is the leading cause of the increasing amount of death, it is also the cause of the problem of economic which effect to increasing unemployment, increasing the cause of the mental disorder such as panic, and the problem of communication between student because they have to study all of the online courses for preventing Covid19. So, organizers are interested in researching the solution that solves the problem of Covid19 by using the knowledge of the biomedical department, so the project started at summer training in June 2020.

1.2 Objective

1.2.1 Design and construction flow sensor for ventilator

1.2.2 To produce and develop the current flow sensor by using overall knowledge in this department for supporting the COVID19 patient

1.3 Hypothesis

The flow sensor can measure the flow rate in the exhalation.

1.4 Scope of the thesis

To design and produce the medical device that can measure flowrate by record the signal data in the computer and change the analog signal to the digital signal by Arduino program by using C++ code. Show the flowrate signal in the computer to calibrate the flow sensor and develop the flow sensor in future work.

1.5 Expect benefits

1.5.1 Available to write the code and the flowrate signal available in the computer

1.5.2 Available to using the flow sensor with the current ventilator

1.5.3 Available to support the COVID19 patient who has the failure in breathing

1.6 Definition

1.6.1 Flowrate is the maximum flow that the ventilator delivers a group tidal volume breath.

1.6.2 A flow sensor is the part of the ventilator that detects the airflow delivered from the lung to the ventilator to measure the patient's airflow. Then the ventilator computes the flow value and delivers the air to the lung correctly.

1.6.3 A ventilator is a machine for helping patients who cannot breathe by themselves by delivering the air from the machine to their lungs.

1.7 Report Outline

The review of this report organizes including:

Chapter 2 reviews the theory refer a flow sensor for ventilator

Chapter 3 defines the design and application of the ventilator flow sensor

Chapter 4 demonstrates how ventilator flow sensor performed in testing

Chapter 5 reviewing the work undertaken and concludes with critical parts of the process that undertake.

CHAPTER 2
REVIEW OF DESIGN AND CONSTRUCTION FLOW SENSOR FOR VENTILATOR

2.1 Introduction of Lung

The lungs are a few organs in the thoracic cavity that facilitate gas exchange. They need oxygen in the blood to exchange oxygen and be part of the respiratory system. The lungs work with the musculoskeletal system to aid in sniffing and exhaling, although they are a significant source of gas exchange.

2.1.1 The respiratory tract

The human respiratory system is alternating and carrying gases. It begins with the mouth and nose through which air enters the respiratory tract. The main entry point for the nose with nasal features creates moisture, temperature, and filtration as air passes.

2.1.2 Anatomy

Lung anatomy is a sponge-shaped organ that uses a thoracic cavity. They connect to the trachea and heart through the vessels of the lungs and central bronchioles and freely block the pleural membrane. Each lung using the mediastinum contains the appropriate hemithorax. They differ in shape when they appear in pairs. The structural difference between the right and the left lung indicates the weight of each organ. The pleural cavity is the potential gap between the visceral and parietal layers. The pleura is a convex membrane that covers the lung. Each membrane comprises a parietal layer that repairs the inner thoracic wall and a visceral layer attached to the lungs, the mediastinum, the costovertebral region, the lower cervical vertebra, and the diaphragm. The hole fills with fluid, allowing visceral and parietal layers to float on top of each other during respiration; therefore, a reduction in respiratory energy may result from the force generates within the area.

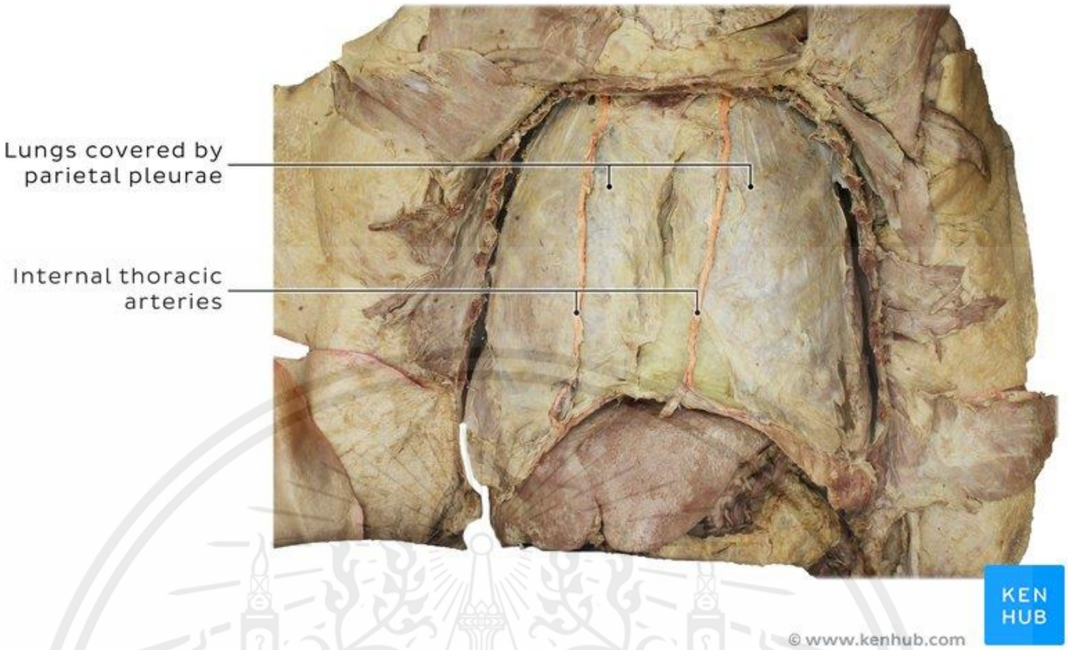


Figure 2.1 The natural lung anatomy
(Source: https://www.kenhub.com/en/library/anatomy/the-lung)

In the cadaver, the parietal pleura includes sharp folds in areas where the costly pleura connects the mediastinal and diaphragmatic parts. The parietal pleura crosses the abdominal wall, although the visceral pleura crosses the lungs. According to them, there produce an area that may contain an amount of a lubricating liquid. However, it may be associated with pleading between the two pleading layers during cadaveric isolation, resulting in disease processes.

Each character is long with its title and base, high projects of large thoracic opening, and the diaphragm's primary area. Alternatively, we can describe the lungs as three areas separated by three boundaries.

The limbs are almost the same size and divide by cracks in the lobes. Thus, the left lung has one spine and two lobes, but the right lung has two cracks and three lobes. The lobes divide into bronchopulmonary segments. Between the lobes, there are areas between the lungs that separates by cracks. The apex is the lung's maximum point which extends in the thoracic inlet. It is a medial third of the clavicle and lung dome-shaped part that projects above the first costal cartilage. An intervening subclavian artery separates both lungs from the ipsilateral scalenus anterior muscles. It only courses toward the first rib as the vessel passes over the suprapleural membrane and along the anterior surface.

Each apex connects the stellate ganglion, the superior intercostal artery located on the T1 ventral rami. The right lung medial area connects to the brachiocephalic trunk, the right brachiocephalic artery, and the trachea. Instead, the left lung medial surface connects to the left subclavian artery and the left brachiocephalic artery. Both organs are associated with a treatment of the ipsilateral scalenus medius muscle.

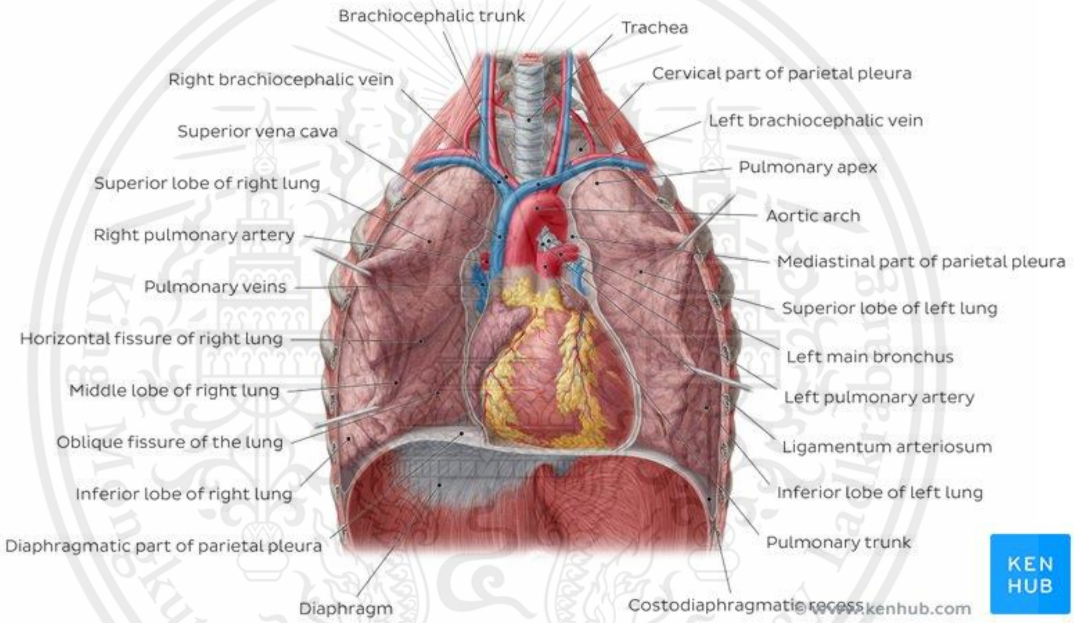


Figure 2.2 The lungs in-situ

(Source: https://www.kenhub.com/en/library/anatomy/the-lung)

The medial lung surface is a part that contains the medial, facing a mediastinum and the vertebral regions. Also, the interior has several features left by nearby buildings that touch another lung. The medial ventral aspect is a study of the medial inner part, whereas the dorsal half aware of the posterior vertebral element. An inner lining points to its relationship with the mediastinum. The resilience resides in the appearance of the heart. The posterior part of the vertebral can locate near their related intervertebral discs and thoracic vertebra.

From the costal part, it is a circular back border that divides part of the center surface. The posterior border is a symbolic stripe that corresponds to the heads of adjoining ribs. In the parietal pleura that shows the junction of the mediastinum and the expensive cartilage, medial lung, and costal structures connect to the inner border, a narrow and sharp border that joins the pericardium extending to the area. While a boundary is almost vertical to the right, it has a flexible course on the left. It stays in the four most expensive cartilage but becomes more irregular than the heart note.

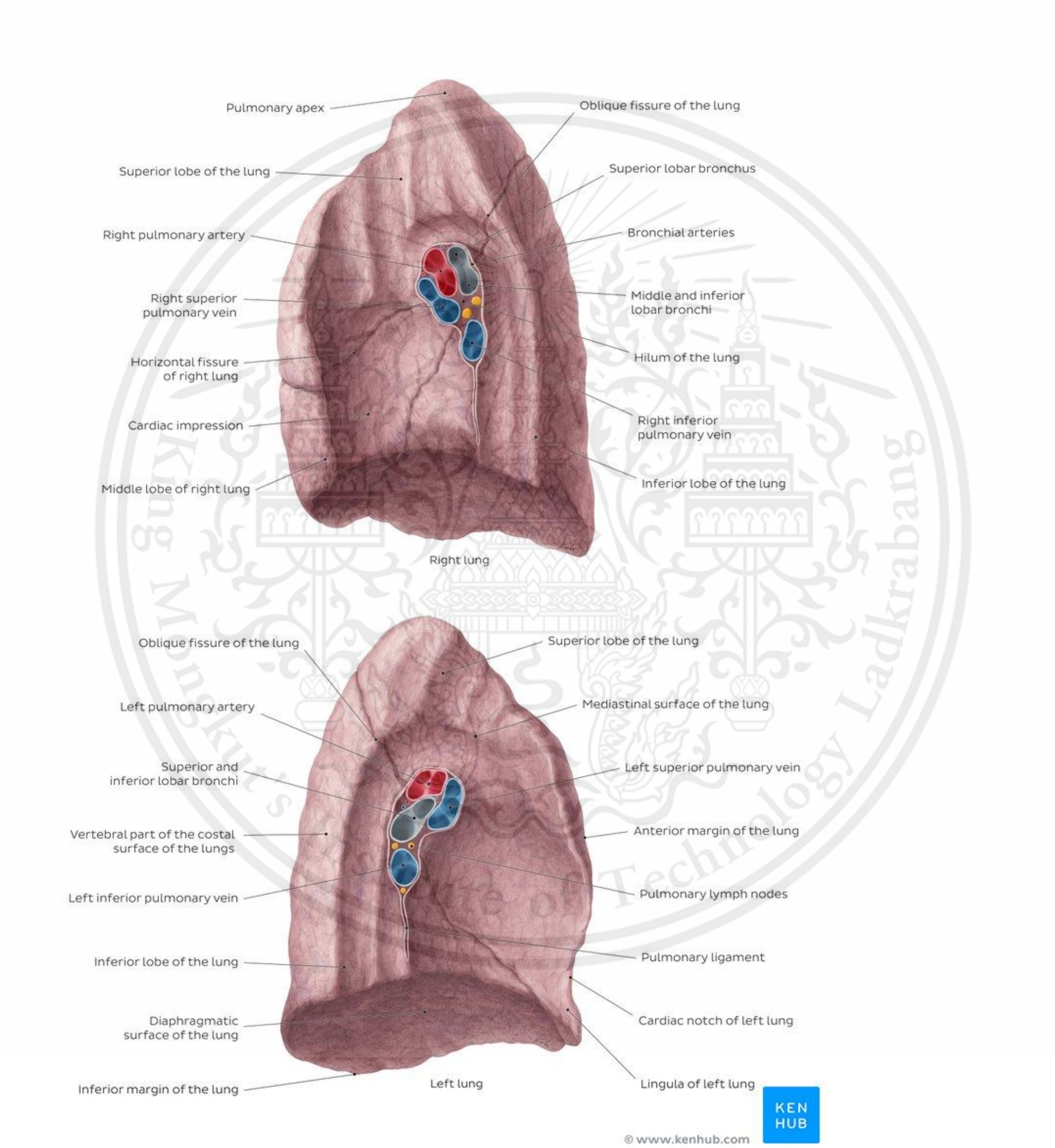


Figure 2.3 The medial surface of the lung
(Source: https://www.kenhub.com/en/library/anatomy/the-lung)

Nevertheless, anything that produces the interior is different from the hilum's reference (pl. Hila). Hila is a root of the lungs across the airways. The nerves of the blood vessels arrive and leave the lung parenchyma. It offers a point of contact between the lungs and trachea, and the heart for medical connections. Structures discover in the hilum of both lungs are similar. However, the communication with each other is very different. All of their structures cover the pleural membrane. Each hilum, the properties are available:

- Tissue connections
- Independent Pulmonary plexus
- Lung
- Lymph nodes and vessels
- Primary bronchus
- Two pulmonary arteries
- Bronchial vessels

Several other buildings attach near each hilum which is very important to provide. Previously, the anterior pulmonary plexus, the phrenic nerve, and the pericardiophrenic vessels go to their target structures. The lower is the pulmonary ligament, and behind it is the vagus nerve and posterior pulmonary plexus.

The base, the area of the lungs, separated, rests on the thoracic portion of the diaphragm. The left diaphragm divides the spleen and abdomen from the lungs base. The right one divides the lungs from the liver. It is shorter than its counterpart, and it has a deep basal blur while related to the left lung. The reason is that the right hemidiaphragm is lower than the left hemidiaphragm, which contains the liver.

The lower boundary is the base of the lungs which divides from the coastal surface. Inside where it comes from, the border appears to be where it occurs between the two places. Still, it gets thinner and sharper as it rushes into the expensive vacation. The expensive face of the lungs is more impressive than the middle face. Evidenced by an appearance of grooves and extra ribs of appropriate cracks.

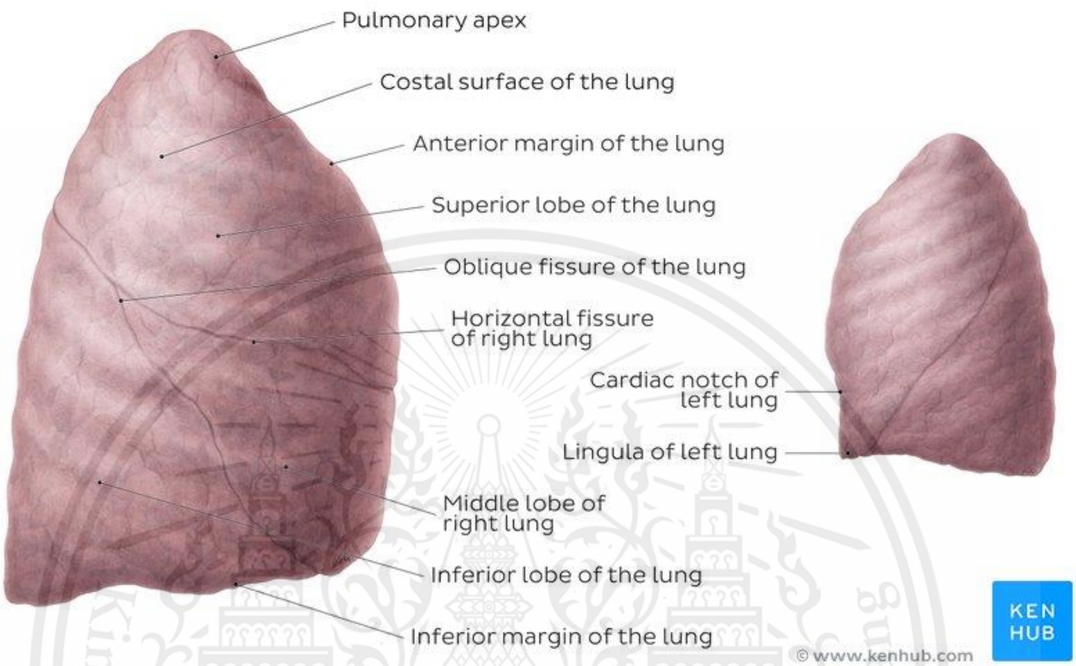


Figure 2.4 The lateral view of the lungs
(Source: https://www.kenhub.com/en/library/anatomy/the-lung)

2.1.3 The left Lung

This lung has fewer tissues in the organ anteromedial region to contain the left side of the heart. A left lung oblique rupture separates the organ from the upper and lower lobes. Thus, the left lung appears to be different in shape from the lungs in that it has a single rupture and one lobe.

2.1.3.1 Fissure of the left lung

The distinction between the oblique cracks of the opposing face and a left lung is pretty subtle. The different methods used to define the traditional point and eliminate space-related to lung hilum that a course of the left oblique fissure has compared to the right oblique fissure. On the left, oblique cracks occur from 10 p.m. and only at 5 p.m. Therefore, the left oblique fissure is marginally lower than on the right one.

2.1.3.2 Lobes of the left lung

Instead, the lower lobe is posteroinferior concerning the oblique fissure; the upper lobe is higher than the fissure. The lower lobe is larger than the upper lobe. It has a large left lung, the most important part of the posterior border, and the lower back of the posterior and internal areas. Indifferent, the upper lobe encloses the subject and many central and coastal areas, with the entire inner border. The upper lobe contains the heart notch and the corresponding lingula found in that area.

2.1.3.3 Hilum of the left lung

This hilum is external and below a thoracic aortic and aortic arch, individually. The pulmonary artery is a highly developed structure inside the left ventricle. Underneath it is the main bronchus—the upper artery is located within the main bronchus and anteroinferior to the pulmonary artery.

2.1.4 The right Lung

The left lung is marginally longer and smaller than the Right Lung. It knows that the right one is marginally shorter and broader. These changes cause a liver below the left hemidiaphragm - the placement of the heart. Overall the left counterpart is less critical than its right Lung. In addition, the two grooves separate by three lobes. The oblique fissure is one of the trenches discover on the right lung surface, another horizontal explosion. Both of these fragments divide the lungs into lower, middle, and upper extremities.

2.1.4.1 Fissures of the Right Lung

An oblique fissure can be detected by the hilum of the right lung on the medial surface, moving inward and downward through the inner part of the lung. Shortly after that, it crosses the lower boundary and appears on the coastal surface about 7 cm away from the inner boundary. It then travels superolateral around the lung in the fifth intercostal space. Form a flat cord junction at the fourth intercostal space in the medial axillary line as it remains facing the posterior border. Oblique fissure can occur at the posterior border or below the level of the spinous process. It extends to the middle surface, connecting the posterior part of the hilum post of the right lung in the first hour. The horizontal fissure has a much smaller course than the oblique fissure, which begins in the medial line between the fourth intercostal space. A horizontal plane can find in the fourth costochondral plane at the inner border. It suddenly turns around in the middle of the lungs and continues toward the hilum at nine o'clock.

2.1.4.2 Lobes of the Right Lung

An upper lobe extends beyond an anterosuperior and the horizontal fissure to the oblique fissure. There contains the title, most of the upper part of the coastal area, and the interior.

The middle lobe is the tiniest of the Right Lung, three right lobes, connecting the inner and upper fissure with the oblique fissure. It includes the inner Lung and cuneiform base, the lower region of the inner border, and the lower coast.

The lower lobes form a limit on the volume of the lungs, which locates behind an oblique clip. Its lobe encloses coastal posterior parts and central regions and all lungs in the posterior fissure oblique.

2.1.4.3 Hilum of the Right Lung

This hilum is associated with the terminal azygos vein, while the posterior is linked to the right atrium and superior vena cava. The upper artery is in and out of the lower pulmonary artery and the medial and lower artery, which is the lowest contained by the left hilum. Therefore, the structures inside the right hilum arrange that the posterior bronchus is linked to the pulmonary artery.

2.1.5 Blood supply

The same blood supply refers to the systemic and pulmonary circuits. From the heart, a pulmonary circulation starts and gives blood-free air. It then takes oxygen-rich blood back into a heart to reorganize it throughout a body. Also, the circulatory system takes oxygenated blood to the parenchyma of the lungs, which can provide easy distribution. The venous arm of this region returns oxygen-deprived blood to the heart for processing.

2.1.5.1 Arterial supply

Via the pulmonary arteries, proper ventricular pumps carry oxygen to the lungs. Their vessels emerge from the lungs trunk as they erupt behind the superior vena cava to provide a single vessel in each lung. The lower right artery passes between the medial bronchus and the upper pulmonary artery before supplying the medial and lower lobes. Each pulmonary artery falls into the second phase to produce lower and upper branches. In addition to supplying these lobes, it brings a recurrent branch to increase blood supply to the upper lobe.

The upper right pulmonary artery divides supplies of the upper lung lobe. In the dividing area, the left pulmonary artery enters a lower aortic artery to enter the oblique space. The following shipping may vary. The 1st branch of the left pulmonary artery is responsible for providing the internal bronchopulmonary portion of the upper left part. There are additional branches from this boat; However, the arborization pattern is very different from their respective counterparts. The left pulmonary artery also supplies one branch to the oblique brain that supplies the lingula. Many other branches emerge from the left pulmonary artery that extends beyond the left lung to supply the remaining organ.

While the pulmonary arteries bring low lung pressure, the bronchial arteries carry oxygenated blood up to the organ at high pressures. Most entities have two ships, left and right. from the intercostobrachial tube next to the posterior intercostal artery, the right bronchial artery occurs. They act as the vasa vasorum and a nervorum of the vagus bone to provide a third middle throat with another structure.

The bronchial arteries are the shortest thoracic aorta branches. The lower left bronchial artery provides the bronchi, and the upper left bronchial artery provides the aortic arch part and the connective tissue of the hilum.

2.1.5.2 Venous drainage

Within the alveolar walls, The Capillary networks converge remotely to produce pulmonary venous circulation. Many internal vessels inside each bronchopulmonary vessel combine to form divisive arteries. Vessels between classes then merge to produce unique arteries in each case. As a result, the left side has two lobar veins, whereas the right side has three lobar veins. The middle and upper lobar veins maintain the fuse; thus, two lobar arteries come together to produce pulmonary arteries. Their low-speed vessels return oxygenated blood to the left atrium. There spreads all over the body

Although the pulmonary arteries release the parenchyma of the lungs, the pulse pulls through the bronchial arteries deep and upward, working on loads of the bronchial arteries. One bronchial artery serves each hilum. Before merging to form deeper bronchial arteries, Intra-bronchial venous plexuses move closer to the bronchi in the hilum. They notice a direct discharge from the left atrium anywhere in the pulmonary artery.

The venous subpleural channels are bronchial upstream from the main venous arteries. They feed on the vasa vasorum of the hilar lymph node, the extrapulmonary bronchi, and the pulmonary vessels. The upper bronchial arteries sink into the brachiocephalic, leaving the upper intercostal left arteries and the right azygos vein, and sink into accessory hemiazygos.

2.1.6 Lymphatic drainage

Refer to as the lower plexus, and the lymphatic vessels sink, the lungs appear below the pleura. All the upper lymphatic vessels connect to the hilum, where they flow to the superior bronchopulmonary lymph nodes. Thus, the vessel group divides into higher and deeper groups; the latter group supports the pulmonary vein, artery, and bronchi.

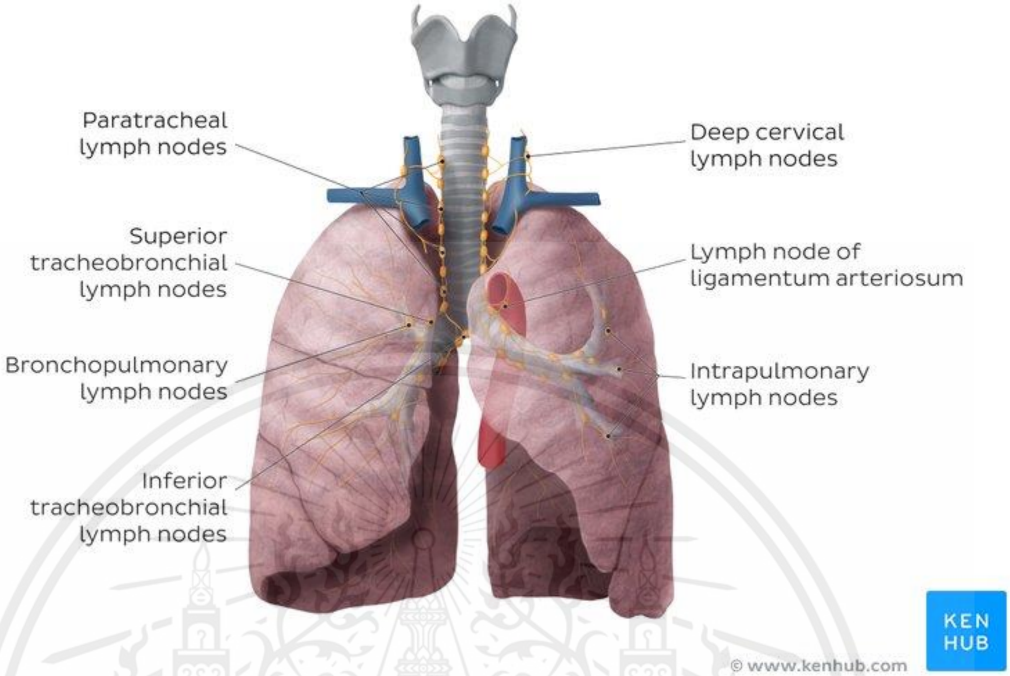


Figure 2.5 Lymph nodes of the lung
(Source: https://www.kenhub.com/en/library/anatomy/the-lung)

Gradually, there is a connection between the deep lymphatic and superficial vessels. From one system to another in lymphatic-induced pulmonary disease, connecting vessels can stretch to re-direct the flow of lymphatic fluid. Usually, the lower lung lobes deplete their lymphatic fluid in a lower tracheobronchial node. From the upper lobes, the upper tracheobronchial nodes discharge lymphatic fluid.

2.1.7 Innervation

The vagus nerve and the autonomic nervous system communicate the duty of the lungs protecting. The autonomic nervous system is blocking and widening the airway and controlling bronchial fluid. To produce the pulmonary plexus, the sympathetic branches from the coronary arteries and the branches from the vagus nerve come together. This plexus divides. Background separation according to their relationship with lung hilum. In addition, in the provision of bronchi, it also prevents visceral pleura.

2.2 Respiratory system

2.2.1 Definition

The respiratory system is a biological system that contains and structures used for gas exchange in animals and plants. The environment in which it lives. The exchange of gas within the lungs occurs in tiny, unmeasured sacs called alveoli in humans. Very small air sacs contain a rich supply of blood that carries oxygen to the bloodstream. These air sacs connect with the external environment of the airways, most importantly the trachea, which extends from the middle of the chest to the two main bronchi. It enters the lungs and upper bronchi as they enter many small tubes, bronchioles.

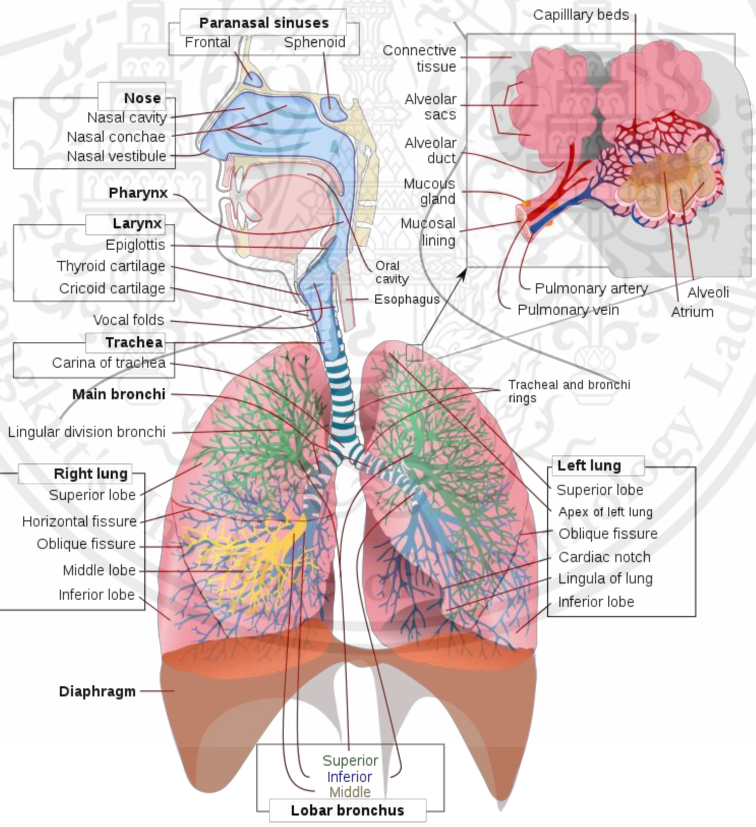


Fig 2.6 Respiratory system
(Source: https://commons.wikimedia.org/wiki/File:Respiratory_system_complete_en.svg)

2.2.2 Respiratory system mechanics

The respiratory system consists mainly of the cage of the lungs, lungs, and diaphragm (Sharma Goodwin (2006). Refer to Mittman et al. (1965), complete respiratory correction in healthy male subjects aged 24 to 78, with five more than 70 studies. However, compliance with the chest wall is low in older studies. In addition, studies associated with the lower chest wall have a high R.V., which raises the obstruction of the lung wall in the solid chest wall (Mittman et al. 1965).

2.2.3 Respiratory muscle function

The diaphragm is a very important respiratory muscle and plays an important role during the stimulation of Sharma Goodwin (2006). The exact measurement of diaphragmatic power can be limited to Vivo only. There is a piece of information on the Effect of Aging on Diaphragm contractor signals. PDI, MVV, and MIP usually measure respiratory muscle strength. MIP is an important energy source and indicator of stimulus muscle strength. The MIP is an indicator of the diaphragm power measured using a mechanical gauge with a valve closed in the mouth during the process. Studies measuring MIP are classified separately, and their main purpose is to obtain reference values instead of measuring the effect of long-term duration on diaphragmatic function. The MIP is 30% higher in men than women in any age group and reduced by 8 mm to 27 mm of H20 / year between the ages of 65 and 85, the most significant decline in age-related symptoms in men (U- Enright et al. 1994). Similar results are observed in the references by Polkey et al. (1997). The rate of decline in Pdi healthy age than healthy adolescent control was lower (13%) in a recent study, in part described by different measurement strategies (Table 1.1). The total voluntary height was reduced by aging, and one cell study showed a 12% decrease in six years in trained older athletes (McClaran et al. 1995). The possible explanation for diaphragmatic strength is reduced by age atrophy of muscle and age-related decline in fast fibers, which is charged to produce very high tension.

Study	Technique	Pdi (cm of H_20)		Reduction	p-value
		Young	Elderly		
Tolep et al 1995	Mueller	171±8	128±9	25%	<0.003
Polkey et al 1997	Sniff	136±17	119±22	13%	0.05

Abbreviations: Pdi, transdiaphragmatic pressure.

Table 2.1 Aging and respiratory muscle strength
(Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2695176/)

2.2.4 Pulmonary function tests

Interpretation of PFTs has sometimes supported comparative information estimates of an individual patient or subject by reference values supported by healthy studies. Predicted values should be obtained from healthy studies with the same anthropometric and, wherever appropriate, patient characteristics being evaluated. Most importantly, reference values are calculated on a scale based on the values observed in the sample distribution of healthy subjects in the general population. Reference ratings can also be obtained from large groups of volunteers, the appropriate distribution of anthropometric markers, and the provision of standard selection criteria for satisfaction. The principles for the definition of healthy topics were discussed in previous ATS statements by the ERS. Height and weight should be measured across the patient during the examination; experts should not rely on the height, or weight stated. Height should be measured with a stadiometer using standard techniques. Options include measuring the length or using the stated height of the hand length where the length cannot be measured, as shown in the previous document from this series and in other publications. Some suggestions for selecting reference prices for use in any lung laboratory are also discussed. It includes the following: related age, anthropometric, ethnicity, economics, and environmental factors among the subjects labeled in the lab as well as the population from which predictable statistics were taken; use of the same instruments and rules of lung function within the reference population as in the laboratory; and using the reliable values found invalid and viable mathematical models, taking into account the age-dependent lung function. For example, FVC, FEV1, and FEV1 / FVC should appear from the same referral sources. tested subjects should be asked to identify their ethnic group, and national-specific statistics should be used whenever possible. If those figures appear unavailable or unsuitable for the selected setting, a device based on discriminatory data based on published data may also use lung volumes. the employment of remedial features is not as good as racial/ethnic equality. An example of a factor in adjusting people's acquisition using standing height is the medium size, usually measuring Black topics' values by 12% TLC, FEV1 and FVC, and 7% active FRC and R.V. The 0.94 national correction factor also extends to Asian Americans, supported by two recent publications.Request promotion employment does not necessarily refer to racial/ethnic divisions in lung function.When the use of race reforms, media outreach should include reports and race reform rate. for example, spirometric reference values should be obtained from individuals such as each subject using the same tools and assessment procedures. e selections and measurements made from a sample of healthy subjects tested in each laboratory. The equation that gives the sum of the remains near zero is the most appropriate for that laboratory. However, with spirometry, the estimated number of subjects (e.g., N5100), it is important to make sure that the major differences between published reference numbers and numbers from local people are not. Therefore, the proposal does not apply to most laboratories. When using a set of clues, emphasis on more than the size and age of the subjects under investigation should be avoided. If the patient's age or height is outside the reference value limits, the release of the media within the definition should indicate that the supplement is empowering. Reference measurements should have clear descriptions of the upper and lower limits of the traditional range or provide details to allow the reader to calculate the minimum distance. for each lung performance indicator, less than the 5th percentile of distribution values measured within the reference value is less than the expected "normal range." If the reference data has a standard distribution, the lower percentile below will be estimated for a 95% confidence interval using Gaussia statistics. The lower limit should be measured by a nonparametric process, such as the 95th percentile, when skewing distribution. Using the 80% predicted as a set minimum standard is acceptable for children but can lead to significant errors in interpreting lung function in adults. This consultation focuses on the lower limit of the reference range. The upper limits are correct when the variable is usually high or low. Such variants include TLC, RV / TLC, and DL, CO. Interpretation of lung function data serves as advanced equipment and techniques for evaluating lung function, advanced mathematical models. In addition, the characteristics of most people in "normal" studies related to nutrition, health status, environmental conditions, and other factors. Consideration should be updated on daily indicator statistics, e.g., every ten years, considering the effectiveness of new indicator statistics and the impact on long-term patient follow-up interpretation. Manufacturers should need software that allows users to choose between a simple rating panel. they should also allow easy installation of the latest statistics. Reference values should record all lung function reports, the date of the principal author, and publication date.

2.3 Ventilator

A ventilator is a device that helps patients who cannot breathe on their own by bringing air from the machine to the patient's lungs. They use both patients who cannot breathe independently, breathing in or out of the operating room. The history of the ventilator begins with a variety of so-called breathing apparatus, a non-invasive ventilator style used during the polio epidemic of the 20th century after introducing the "Drinking Breathing Machine." In 1928, John Haven Emerson introduced progress. 1931, so both respirator in 1937. In 1949, John Haven Emerson formed the assistant anesthesiologist with the cooperation of the Harvard anesthesiology department. In the 1950s, ventilators began using anesthesia and medical aid. Their growth was revitalized with all the need to treat polio patients and increase muscle relaxation during anesthesia. In the U.K., East Radcliffe and Bever models are the first models.

In the past, we used the Sturmey-Archer bike gear to increase speed, and thus the last one became a car wiper motor to drive the sprays used to inflate the lungs. However, electric motors were a problem within the existing theaters at the time, as their use posed a risk of explosions between flammable anesthetics such as ether and cyclopropane. In 1952, Roger Manley of Westminster Hospital, London, developed a gas-powered respirator and became the most widely used model in Europe. It was a complex design and became a respected favorite with European anesthetics for forty years before introducing electronic-controlled models. It was not a wattage, and there was no risk of an explosion. The first Mark I unit was upgraded to the Manley Mark II, and its operating system was clear. Inlet gas flows are used to lift a weighted unit, which occasionally falls under gravity, forcing the respiratory gases into the patient's lungs. Inflation pressures can vary by sliding the weight removed over the sprays. The level of gas delivered could be variable, using a curved slide, which restricted the visit of bellows. After the expiration of the expiration time, the residual pressure was also adjusted, using a small amount of heavy arm that appears to the right of the front panel. It is a foreshadowing of the best way to put pressure on the general anesthesia of Europe.

The 1955 release of Forrest Bird's "Forrest Universal Medical Respirator" within us changed the air conditioning, and the little green box became a popular medical tool. The unit sold because it was a Bird Mark 7 Respirator and is called "Bird." it was a pneumatic tool, so it does not need a wattage source you can get. In 1965, Harry Diamond Laboratories established the military Emergency Respirator in partnership with the Reed Army Institute of Research. Its design incorporated a law that increased fluid control over air activities. The mask is made of acrylic block, about the size of a cardboard packet, with mechanically coated panels and cemented or squared. Reducing moving parts reduces production costs and durability. Therefore, current ventilators have three types: continuous air pressure (CPAP), Bi-level Positive Airway Pressure (BiPAP), and Volume-controlled volume.

2.3.1 CPAP ventilator

CPAP ventilator or continuous positive airway pressure is the ventilator used for the standard patient. This ventilator's advantage is that comfortable to use, easy to move, and the process of this ventilator is relating to ordinary people's lungs because the air volume delivers to the patient's lung is close to the standard respiration rate. So, the patient can receive adequate oxygen from the ventilator. Even this ventilator supports the patient with adequate oxygen; it is the medical device used for the Obstructive Sleep Apnea patient.

2.3.2 BiPAP ventilator

BiPAP ventilator or Bi-level Positive Airway Pressure is the ventilator used for the patient who stays at home. It has two levels of positive airway pressure (BiPAP) that this ventilator can set the difference of the positive airway pressure of the inspiration and the expiration. It uses for severe obstructive sleep apnea patients and chronic obstructive pulmonary disease patients (COPD).

2.3.3 Volume Controlled ventilator

Volume Controlled Ventilator is the large ventilator that mainly uses in the hospital. This ventilator has a process model that is more impactful than the two types above. It uses severe acute respiratory syndrome by using tracheostomy for treatment, including patients who cannot breathe independently. This ventilator controls the patient's lungs' air volume and uses the oxygen valve in the hospital. It can measure and control the concentration of the oxygen to mix with the air for the patient.

The ventilator has many functional parts, such as the flow sensor, flow control valve, humidifier. This project is about the flow sensor in the ventilator, which detects the airflow that delivers from the lung to the ventilator to measure the patient's airflow.

2.4 Flow rate

The flow rate, or high flow rate, is the maximum flow at which the group's airflow is transmitted by the ventilator, according to Warner Patel in Benumof and Hagberg's Airway Management, 2013. Heaters can provide temperatures of between 60 and 120 L / minimum. The flow rate should be titrated to satisfy the patient's motivating needs. If low blood flow is too low in a patient, it may result in respiratory failure, dyspnea, and asynchrony of the patient. The highest flow rate increases the maximum value, and the lower the air pressure means the higher the air pressure, the lower the air pressure.

60 L / min of high flow rate is acceptable for most patients. A high flow rate is required in patients with high respiratory requirements. A very high flow rate may also be required in patients with the obstructive pulmonary disease to reduce respiratory time, thus increasing respiratory time and reducing the chance of developing auto-PEEP.

The highest level of powdered stimulation in the best-selling DPIs is between 30 and 60L / min, according to Laube Dolovich, in Middleton's Allergy, 2014. From pMDI without supplementation, these flow rates end up with comparable oropharyngeal doses compared to acceptance. Lung injection from various DPIs measures in children and adults who use inhaling drug powders labeled with Radiolab and gamma imaging or pharmacokinetics. Referrals are often made in healthy subjects, and the IFR suggested by the manufacturer to be effective. All subjects were tested on healthy volunteers using the appropriate sniffing procedure. Intravenous insertion varies between devices, from 12% to 32% E. Their values are the same or slightly better than those seen with pMDIs. All DPIs require the patient to schedule a dose before inhaling, so the appropriate procedure is described within the patient information sheet or package entries. Regardless of how they sniff when they sniff, and this kind of serious error frequently occurs 86. Patients should also learn to take out space to maintain working capacity before sniffing with their DPI device. after inhaling, they should inhale strongly and honestly from the beginning of their breath to improve delivery to the lungs. The use of DPIs eliminates the need for actuation-inhalation integration that requires pMDIs. However, the inclusion of lung does not significantly improve DPI management achieved by pMDI, and the cost of many DPI drugs is much higher than pMDI.

2.4.1 Flow sensor

The flow sensor is the ventilator that detects the airflow delivered from the lung to the ventilator to measure the patient's airflow. Then the ventilator computes the flow value and delivers the air to the lung correctly. Many companies have produced the model of the flow sensor, as shown in figure 2.7. The flow sensor is essential for the mechanism in the ventilator. There has to detect airflow in many positions of the ventilator, as shown in figure 2.8. It uses for proximal flow sensor position for detecting the airflow from the patient and the machine, uses for expiratory flow sensor position for detecting the expiratory flow from the patient, and uses for inspiratory flow sensor position for detecting the airflow from the machine to be the inspiratory flow which is giving for the patient. In the last position, it is working with the humidifier in the ventilator.

Figure 2.7 the example model of ventilator flow sensor from each company
(Source: https://www.indiamart.com/proddetail/ventilator-flow-sensor-20408566112.html
Source: https://www.indiamart.com/proddetail/honeywell-envitec-flow-sensor-spiroquant-h-for-ventilator-20644348012.html
Source: https://www.medicaldesignandoutsourcing.com/single-use-proximal-flow-sensors/)

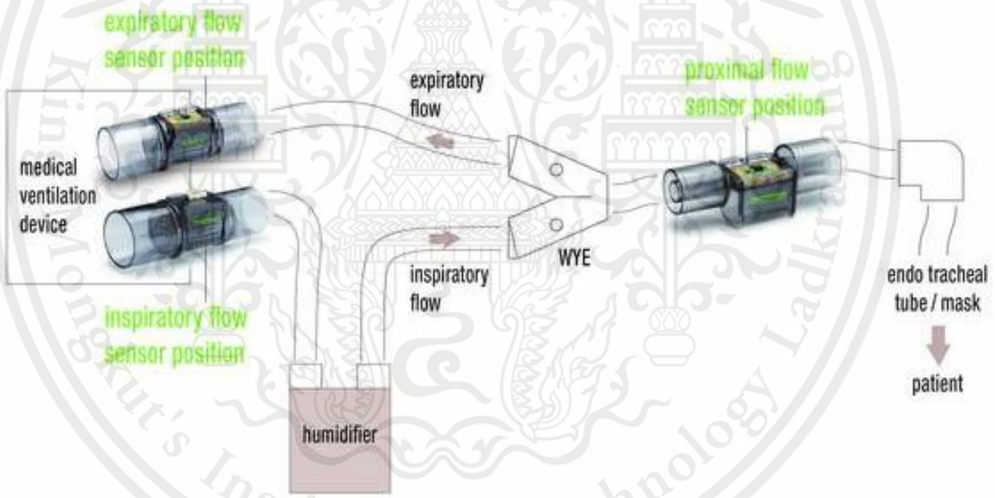


Figure 2.8 The diagram of the ventilator which is showing the position of the flow sensor
(Source: https://www.sensirion.com/en/about-us/newsroom/sensirion-specialist-articles/flow-sensor-solutions-in-modern-medical-ventilators/)

The methodology is the pressure sensor to detect the airflow in the venturi tube. Then the microcontroller receives the data from the pressure sensor and computes the data to be the flowrate. It has two parts of the flow sensor: the venturi tube part and the pressure sensor circuit.

2.4.1.1 Venturi tube

The venturi tube is a measurement device that measures both liquids and gases. It works based on the theory of Bernoulli's theorem or the principle of measuring the differential pressure. The differential pressure is the same as the orifice plate. Venturi pipes design the least amount of pressure loss. It has a cone-like shape and consists of three parts: a section 1 on the inlet side, a converging conical, part 2, an intermediate region with a constant cross-sectional area (cylindrical throat), and part 3 area on the departure side. The pipe is a diverging conical, characterized by a gradual increase or decrease in the cross-sectional area of the venturi tube. The fluid velocity changes so slowly, resulting in low-pressure loss compared to the orifice or nozzles.

The flow rate measures the differential pressure between the two points of the fluid flows. Then calculate the flow rate using Bernoulli's theory, same as the flow measurement with the orifice plate (as an equation), wherein the pressure measurement point installs, consider the two points with the most incredible difference in pressure. The giant venturi pipe (D) diameter and the point with the minor venturi pipe diameter (d).

$$Q = K\sqrt{\Delta P}$$

K is the pipe constant (m3 / s / psi).

ΔP is the pressure difference between two points at which the fluid flows (psi).

Venturi tube flow measurement provides higher linearity, precision, and accuracy than flow measurement with an orifice sheet. Venturi tubes can use to measure fluid flow in all cases where the orifice is measured. It can also use with fluids containing suspended solids without clogging. Also, they can be used to measure flow with a high flow rate. However, Venture tubes are pretty expensive; installation and maintenance are complex compared to the orifice. It is widespread to install inside smaller pipes, so venturi pipes are generally used for flow measurement in larger pipes, as shown in figure 2.9.

Fig 2.9 The figure of the venturi tube

(Source: https://www.environmental-expert.com/products/subsonic-meters-440014)

In this case, the organizer uses the venturi tube of the medical device, as shown in figure 2.9, and the flow velocity by using the equation below:

$$v_1 = \sqrt{\frac{2(\Delta P)}{\rho[\left(\frac{A_1}{A_2}\right)^2 - 1]}}$$

$$Q = A_1 v_1 \quad (1)$$

$$v_1 = \sqrt{\frac{2(P1-P2)}{\rho[(\frac{A1}{A2})^2-1]}} \quad (2)$$

(2) in (1),

$$Q = A_1 * \sqrt{\frac{2(P1-P2)}{\rho[(\frac{A1}{A2})^2-1]}} \quad (3)$$

Q = Flowrate ($^{mL}/_{s}$)

A_1 = Cross-sectional area of the part of larger tube (cm^2)

A_2 = Cross-sectional area of the part of smaller tube (cm^2)

V_1 = Flow Velocity in the part of the larger tube ($^{cm}/_{s}$)

$P1 - P2$ = The differential pressure (Pa)

ρ = The density of the air (1.839 $^{kg}/_{m^3}$ at 20 °C)

Then calculate the flowrate by using equation (3) to put the equation in the Arduino code as in

$$Q = A_1 * \sqrt{\frac{2(P1-P2)}{\rho[(\frac{A1}{A2})^2-1]}} \quad (4)$$

While $A_1 = \pi(2^2)\ cm^2, A_2 = \pi(1^2)\ cm^2$

$$Q = \pi(2^2)\ cm^2 * \sqrt{\frac{2((P1-P2)\ ^{kg}/_{cm*s^2})}{(1.839\ ^{kg}/_{cm^3})[(\frac{\pi(2^2)\ cm^2}{\pi(1^2)\ cm^2})^2-1]}} \quad (5)$$

$$Q = 4\pi\ cm^2 * \sqrt{\frac{2((P1-P2)\ ^{kg}/_{cm*s^2})}{(1.839\ ^{kg}/_{cm^3})[16-1]}} \quad (6)$$

$$Q = 4(3.14159)\ cm^2 * \sqrt{\frac{2(P1-P2)\ ^{kg}/_{cm*s^2}}{(1.839\ ^{kg}/_{cm^3})[16-1]}} \quad (7)$$

2.4.1.2 Pressure sensor circuit

The pressure sensor circuit has two modules: a pressure sensor and instrument amplifiers connect to the board.

2.4.1.2.1 Pressure sensor

The module of the pressure sensor is ten kPa Uncompensated Silicon Pressure Sensors. The MPX10 series silicon piezoresistive pressure sensors provide a very accurate and linear voltage output. It is directly proportional to the applied pressure. These standard, low-cost, uncompensated sensors permit manufacturers to design and add signal conditioning networks and external temperature compensation. Reparation techniques are simplified because of the predictability of Freescale's single element strain gauge design. In this project, the organizer uses MPX 10DP CASE 344C-01, as shown in figure 2.10, and the diagram of this pressure sensor shows in figure 2.11.

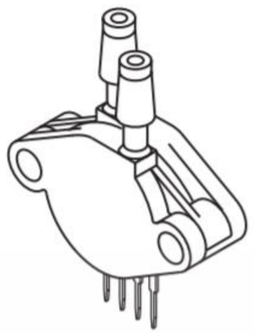


Fig 2.10 The module of the pressure sensor
(Source: https://www.nxp.com/docs/en/data-sheet/MPX10.pdf.)

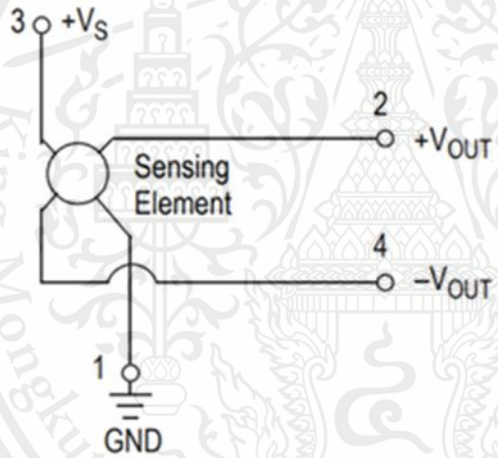


Fig 2.11 The diagram of the pressure sensor
(Source: https://www.nxp.com/docs/en/data-sheet/MPX10.pdf.)

2.4.1.2.2 Instrument amplifier

The amplifier module is INA129. INA129 low-power, standard-purpose amplifiers extend excellent accuracy. The small flexible size, which includes a 3-op amp design, makes them a model for many applications. The current supply cycle provides broad bandwidth even for maximum gain. One external opponent fixes another gain from 1 to 10,000. The INA129 benefit equation is compatible with AD620. The INA129 laser is polished with very low offset power (50µV), drift (0.5µV / ° C), and high standard mode resistance. It operates at low power levels such as 2.25V, and the quiescent current is only 700μA - suitable for battery-operated systems. Internal installation safety can withstand up to ± 40V without damage. INA129 is available with 8-pin plastic DIP, as shown in Figure 2.12, and is specified for a temperature range of 40 ° C to + 85 ° C through SO-8 surface-mount package packages.

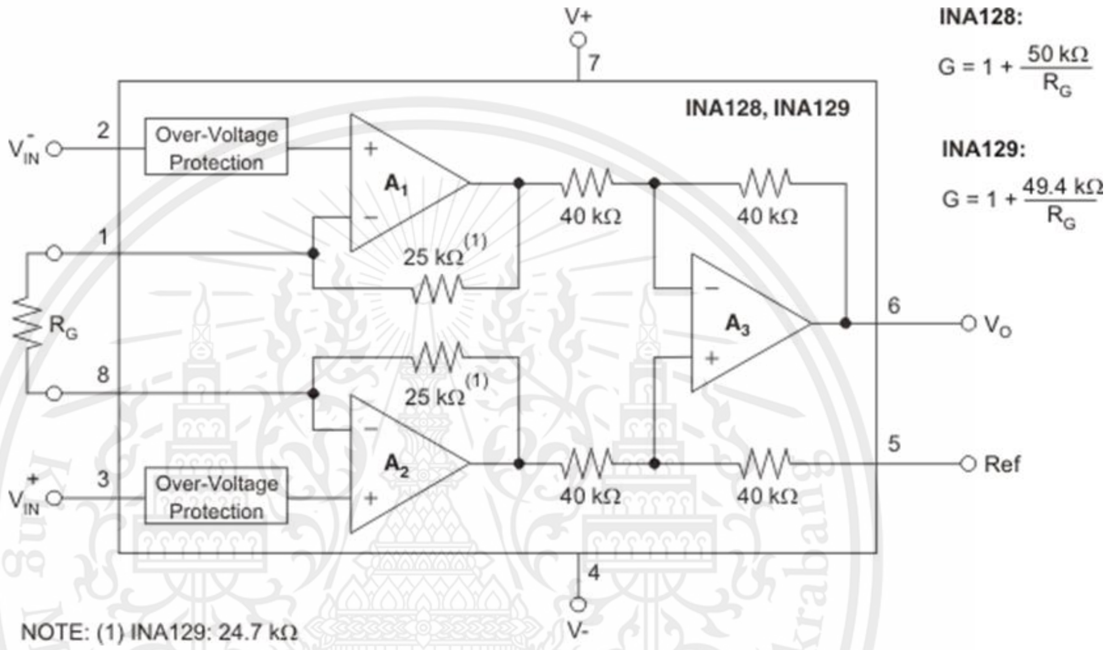


Fig 2.12 The diagram of instrument amplifier and the formula of gain (Source:https://www.ti.com/lit/ds/symlink/ina128.pdf?ts=1620276351679&ref_url=https%253A%252F%252Fwww.google.com.vn%252F.)

2.4.1.3 Arduino

Arduino is a device based on easy-to-use hardware and software. Arduino boards can read inputs and turn them into output. We use to connect the hardware part of the ECG step and the software part in this case.

Figure 2.13 Arduino UNO

(Source:https://www.semanticscholar.org/paper/Development-of-GSM-Based-Advanced-Alert-Home-Locker-Murthy-O.Jagadish/9b4000cb94304989762637344dec2eb1d6522177/figure/7)

2.5 Autodesk Inventor Professional 2021

Autodesk Inventor is 3D computer-aided design software developed by Autodesk corporation. So, the inventor's function includes 2D Sketches & drawings, creating 3D models, Advanced Surfacing to design, complex parts, Drafting and Drawing, and Assembly of components.

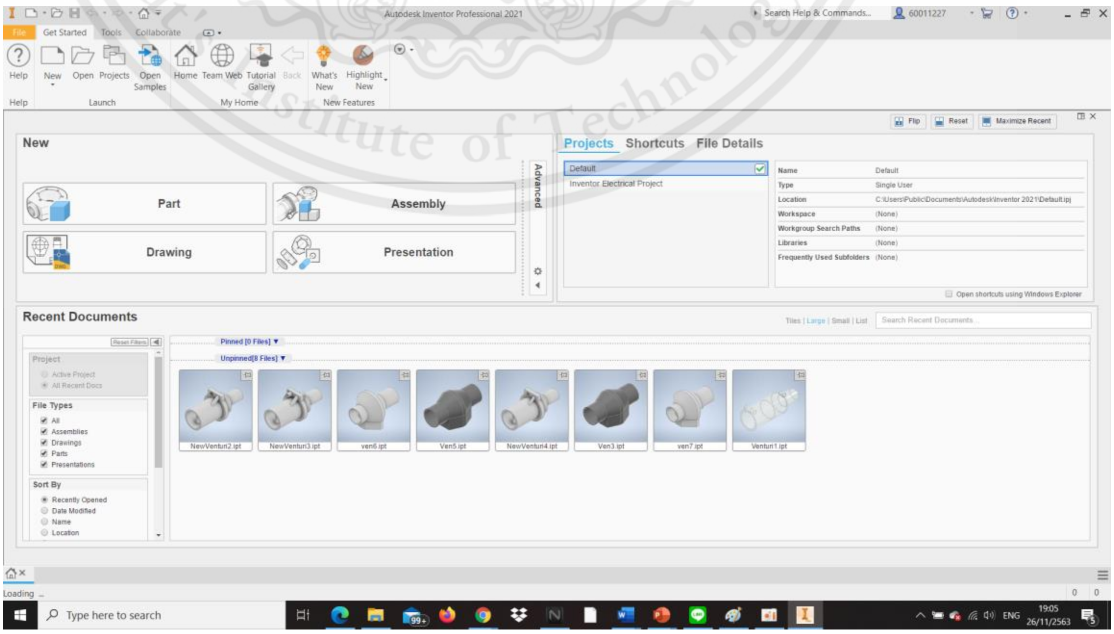


Figure 2.14 Autodesk Inventor professional 2021

2.6 Flow rate graph of another flow sensor

In this case, the Accutach™ Pneumotach Flow sensor, as shown in figure 2.15, is using for comparison with our DIY flow sensor. Therefore, the differential pressure measurement graph from pneumotach, Exhale volumetric flow rate, and exhale flow velocity as shown in figure 2.16-2.18

Figure 2.15 AccutachTM Pneumotach Flow sensor
(Source: https://bandb-medical.com/accutach-pneumotach-flow-sensor/)

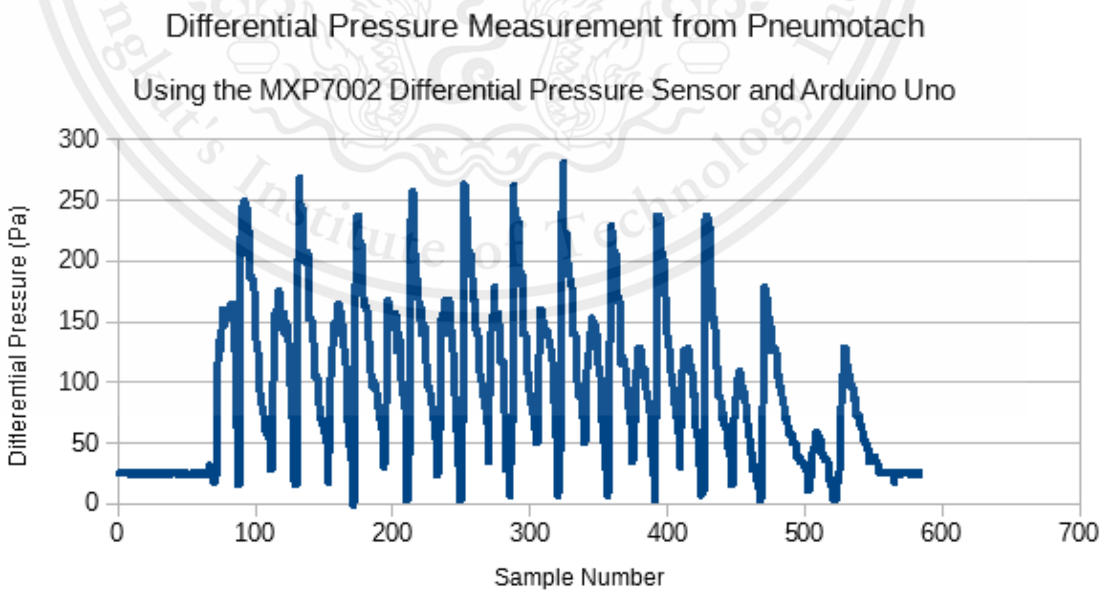


Figure 2.16 the differential pressure measurement graph from pneumotach
(Source:https://langster1980.blogspot.com/2017/04/create-spirometer-using-msp7002dp.html?fbclid=IwAR2jgHdTa1uH5H0VJ-sNsYiqmmXU99rm-jcyc28FiiAOvm6jGEFdl5SbBQA)

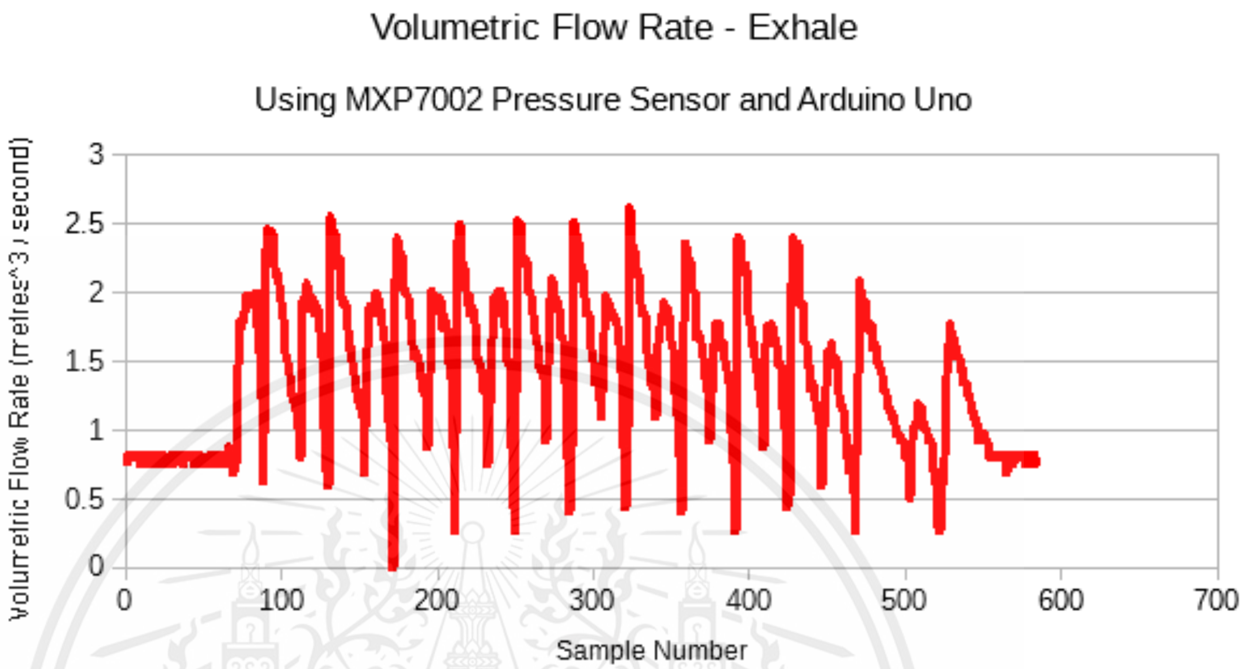


Figure 2.17 Exhale volumetric flow rate graph from pneumotach

(Source:https://langster1980.blogspot.com/2017/04/create-spirometer-using-msp7002dp.html?fbclid=IwAR2jgHdTa1uH5H0VJ-sNsYiqmmXU99rm-jcyc28FiiAOvm6jGEFdl5SbBQA)

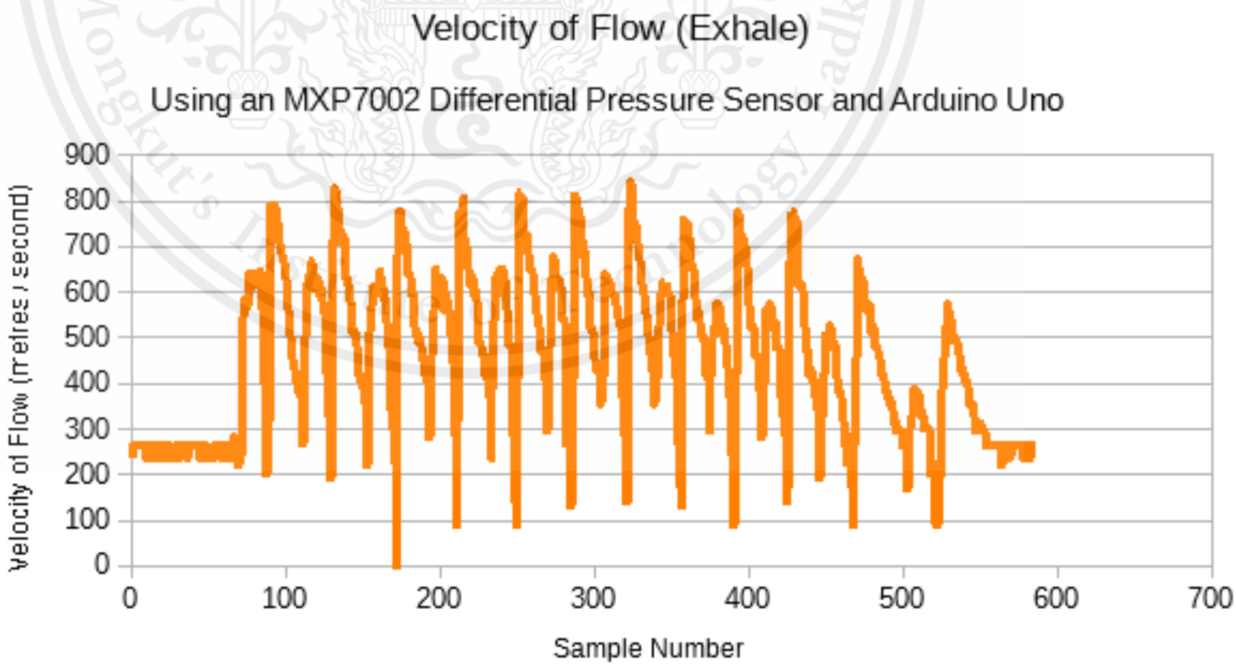


Figure 2.18 Exhale flow velocity graph from pneumotach

(Source:https://langster1980.blogspot.com/2017/04/create-spirometer-using-msp7002dp.html?fbclid=IwAR2jgHdTa1uH5H0VJ-sNsYiqmmXU99rm-jcyc28FiiAOvm6jGEFdl5SbBQA)

2.7 Chapter Summary

In Chapter 1, we proposed the introduction of a ventilator and flow sensor.

In this chapter, the state-of-the-art categorizes into the respiratory system. Observations made on the systems reviewed flow sensor including the Arduino and 3D CAD to make the flow sensor model.

The next chapter presents the design of a flow sensor, which is a system intended for venturi tubes.

CHAPTER 3
METHODOLOGY

3.1 Introduction

In Chapter 2, we identified the theory that involves the flow sensor in ventilator

This chapter describes the design of methodology, a system of the flow sensor. First, the chapter describes the project's design methodology and system requirements. A proposed solution discuss.

3.2 Design Methodology

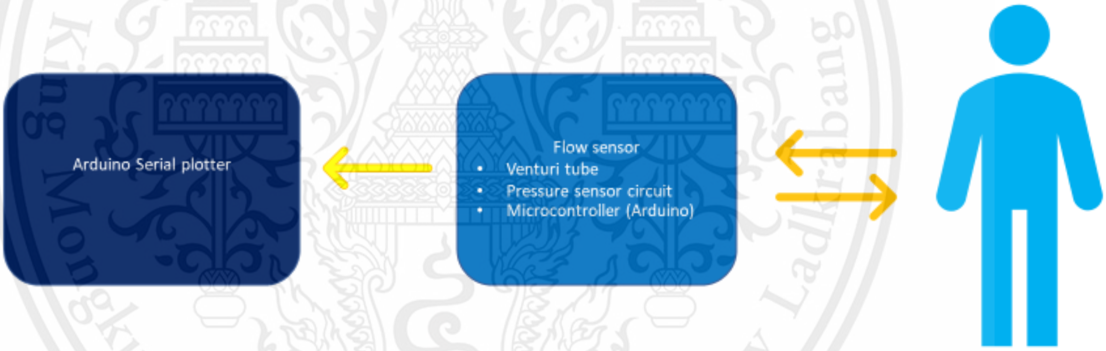


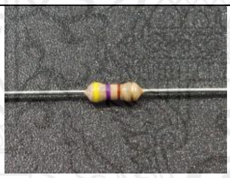
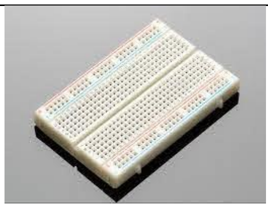
Figure 3.1 Design Methodology

The design and development of the process of the flow sensor include two parts: the first part is then part of hardware which is including the venturi tube, circuit, and microcontroller that the organizer use Arduino to be the microcontroller in this system, and the second part is the part of the software which is using in Arduino program to show the output that got from the hardware part. In this case, the signal that got from the hardware is the Analog signal. So, Arduino generates the electrical circuit to be the Analog signal and show in the Arduino program.

3.2.1 Hardware Part

3.2.1.1 Instrument

Table 3.2 Instrument

	Instrument	Figure	Function
1.	MPX10DP CASE 344C-01	 Source: https://www.gearbest.com/sensors/pp_009364903888.html	Receive the input from the airflow of the venturi tube
2.	Venturi tube		Measure the airflow of the patient
3.	INA129	 Source: https://eleparts.co.kr/goods/view?no=3409981	Gain the signal from the pressure sensor
4.	Resistor 470 ohm	 Source:https://protosupplies.com/product/resistor-470-ohm-5-14w25-pack/	Increase the gain in the Instrument amplifier
5.	Male-male wire	 Source:https://www.addicore.com/Male-Female-Jumper-Wires-40-x-200mm-7-8in-p/179.htm	Connect with the INA129, pressure sensor, and the Arduino
6.	Bread Board	 Source: https://www.adafruit.com/product/64	Board for made the sensor circuit

3.2.1.2 Methodology

- Connect the venturi tube with the sensor circuit by connecting the aquarium tube from the venturi tube to the MPX10DP CASE 344C-01 (pressure sensor)
- In the sensor circuit, connect the MPX10DP CASE 344C-01 and INA129 in the breadboard. Using the male-male wire, connect the MPX10DP CASE 344C-01, INA129, and Arduino to send the electrical. The power supply is from the Arduino to the pressure sensor and instrument amplifier.
- Then send the output to Arduino.

3.2.2 Software Part

The software part includes the sensor circuit connect with the Arduino Uno, as shown in figure 3.2, and the Autodesk inventor professional 2021 to design four models of the venturi tube. Then test with the ventilator to simulate the patient and write the Arduino code to generate and show in the program.

3.2.2.1 Arduino

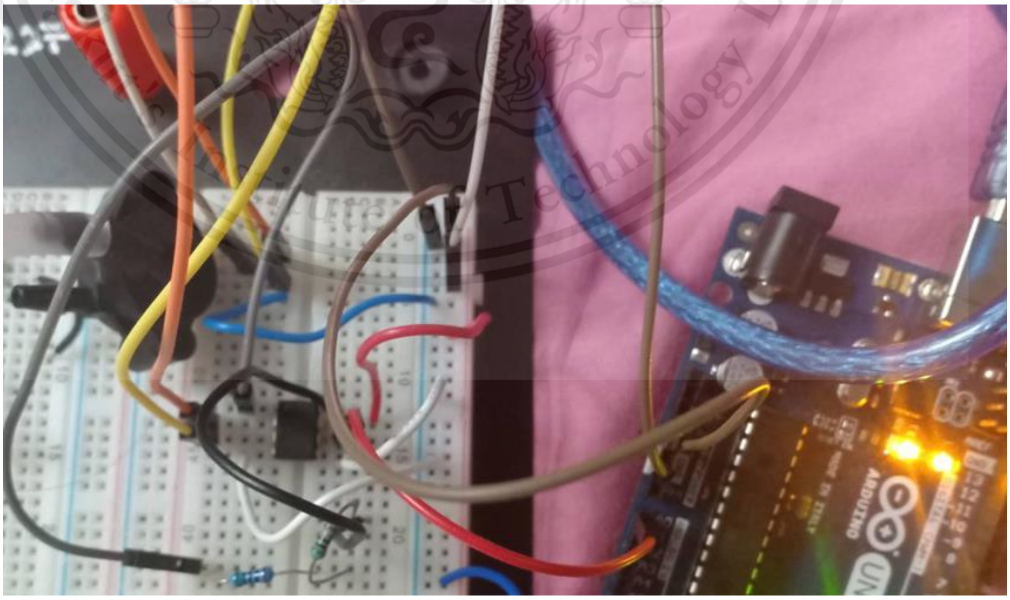


Figure 3.2 Arduino and Sensor circuit

```
int sampleNumber = 0;
int sensorPin = A0;
int sensorValue = 0;
float velocityFlowInhale = 0;
float velocityFlowExhale = 0;
float volumetricFlowInhale = 0;
float volumetricFlowExhale = 0;
float offset = 0;
float diffPressure = 0;

const float airDensity = 1.225;
const float tubeArea1 = 0.0020;
const float tubeArea2 = 0.0010;

void setup() {

 Serial.begin(9600);

 pinMode(sensorPin, INPUT);

 Serial.flush();
 Serial.println();



 Serial.print("Differential Pressure, Volumetric Flow Rate (Exhale),
Volumetric Flow Rate (Inhale), Velocity of Flow Exhale, Velocity of
Flow Inhale,");
 Serial.println();
 Serial.print("    Pa    ,  m^3/second     ,    m^3/second     ,     m/s
,     m/s    ,");
 Serial.println();

}
```

```
void loop() {

  sensorValue = analogRead(sensorPin);

  sensorValue = sensorValue - 48;

  diffPressure = map(sensorValue, 0, 1023, -2000, 2000);


  if (diffPressure < 0) {
   diffPressure = diffPressure * -1;

      volumetricFlowExhale = tubeArea1 * (sqrt((2 / airDensity) *
(diffPressure / (sq(tubeArea1 / tubeArea2) - 1))));

   //calculate velocity of flow
   velocityFlowExhale = volumetricFlowExhale / tubeArea1;

  } else {

volumetricFlowInhale = tubeArea2 * (sqrt((2 / airDensity) *
(diffPressure / (1 - sq(tubeArea2 / tubeArea1)))));


   velocityFlowInhale = volumetricFlowInhale / tubeArea2;

  }

  Serial.print(diffPressure);
  Serial.print(",");
  Serial.print(volumetricFlowExhale);
  Serial.print(",");
  Serial.print(volumetricFlowInhale);
  Serial.print(",");
  Serial.print(velocityFlowExhale);
  Serial.print(",");
  Serial.print(velocityFlowInhale);
  Serial.print(",");
  Serial.println();
  delay(100);
 }
```

3.2.2.2 3D printing

The organizer designs the venturi tube, four models, for testing with hardware part to find the best model of venturi tube as shown in figure 3.3 – 3.6

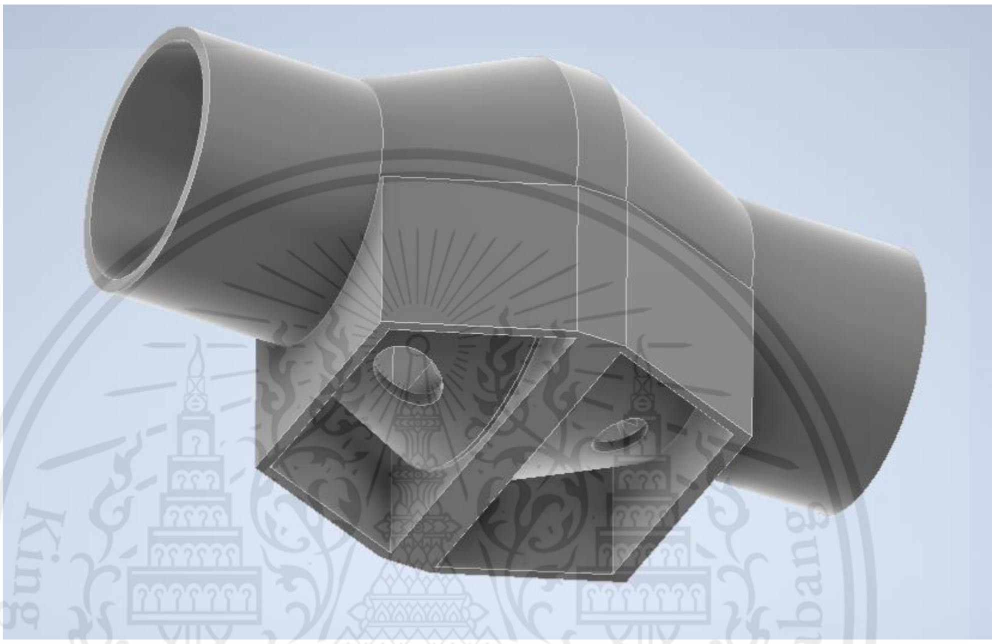


Figure 3.3 Model 1 of 3D printer

Figure 3.4 Model 2 of 3D printer

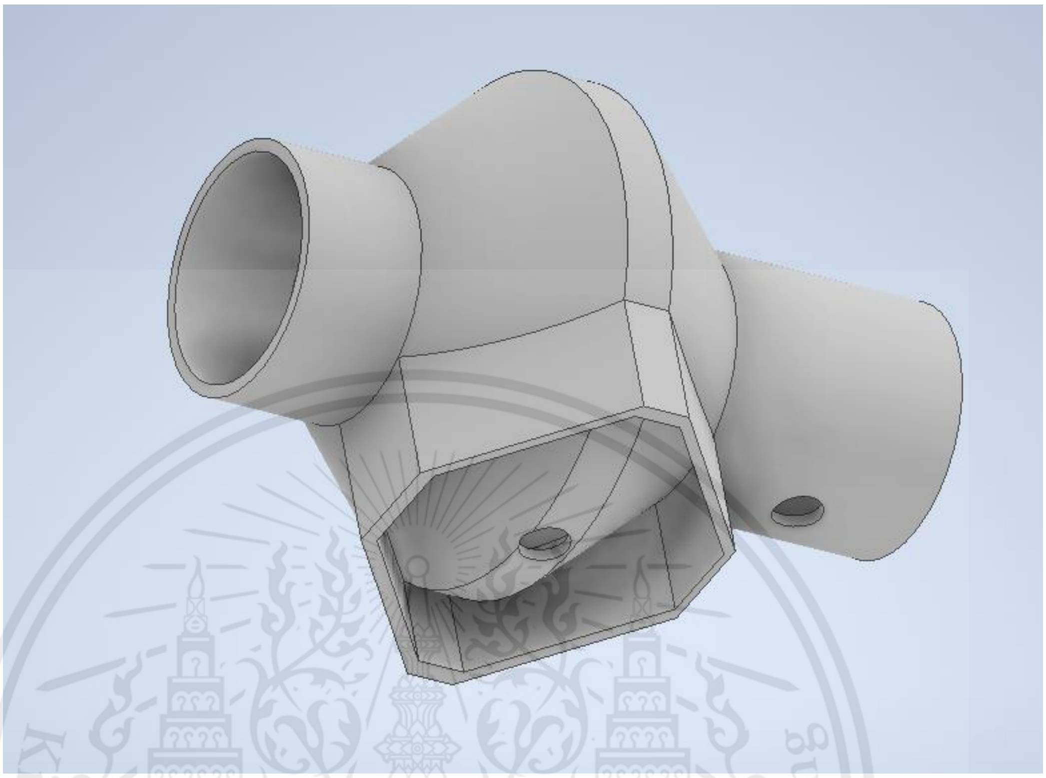


Figure 3.5 Model 3 of 3D printer

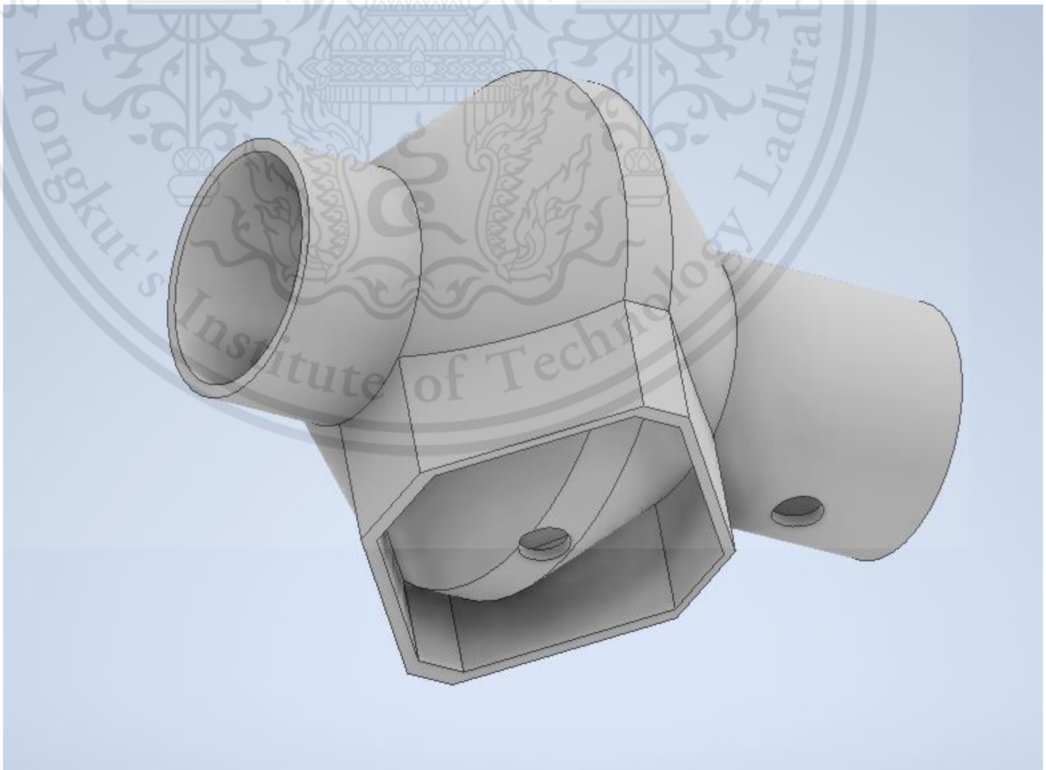


Figure 3.6 Model 4 of 3D printer

3.3 Interesting Problems

The primary purpose of the flow sensor is to get the airflow's pressure value from the value to support the Covid19 patient. So, Covid19 patient needs the ventilator to help them because Covid19 is Effect to the Lung directly if the virus spread into the lung. The ventilator helps patients save their lives, and this project does for designing and constructing the flow sensor, which is one of the ventilator systems like the DIY (Do it myself) to have my work to help Covid19 patient in Thailand.

3.4 Proposed Solution

The proposed solution is getting the flow graph that is the same as the flow graph in the ventilator and find the best design of the venturi tube and make the stable circuit.

3.5 Summary

This chapter described the high-level requirements and design of a system of flow sensors. The chapter started by describing the introduction of the methodology of the flow sensor. The proposed solution then discusses in section 3.4, followed by the methodology in section 3.2

Proposed solution cover in further detail in Chapter 4, which describes the implementation of the flow graph.

CHAPTER 4
EXPERIMENTAL RESULT

4.1 Introduction

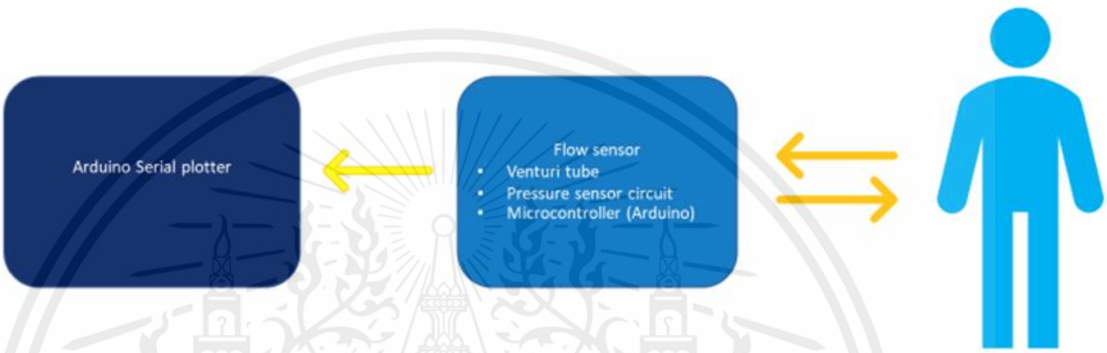


Fig. 4.1 Methodology

4.1.1 The result of the 3D printer

The 3D printing venturi model of each model shown in figure 4.1 – figure 4.4

Fig. 4.2 the 1st venturi tube model

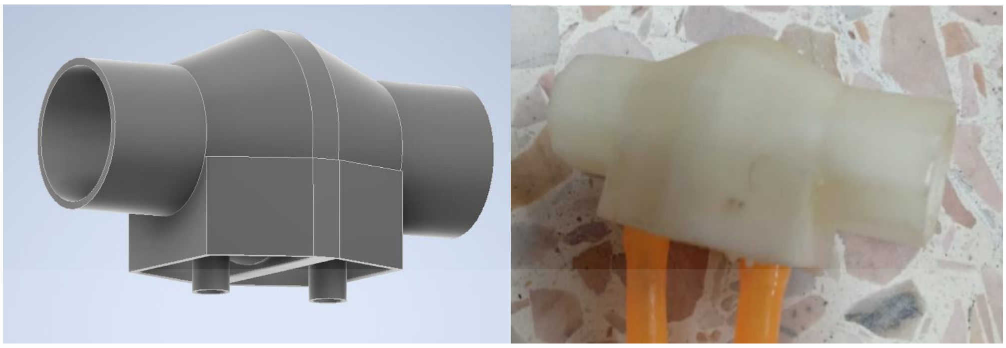


Fig. 4.3 the 2nd venturi tube model

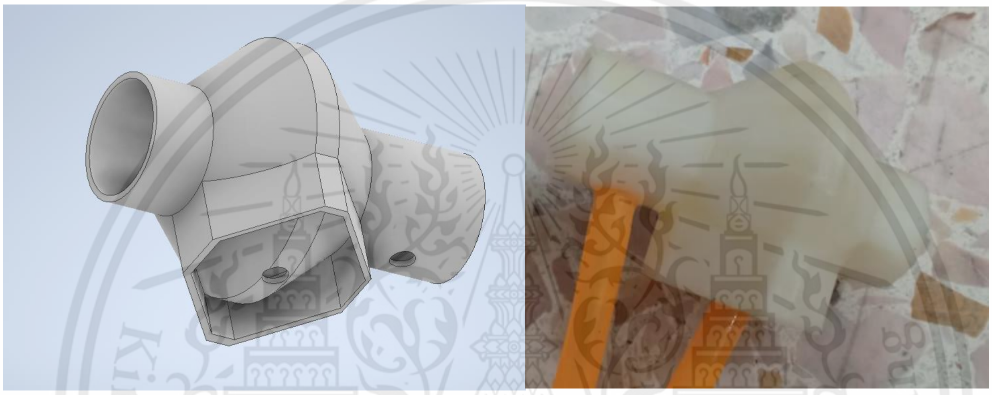


Fig. 4.4 the 3rd venturi tube model

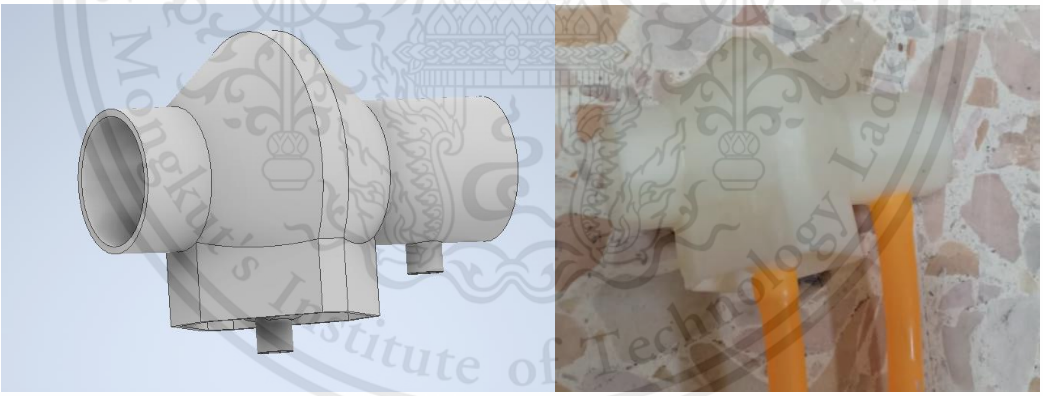


Fig. 4.5 the 4th venturi tube model

4.1.2 The result of the flow graph of each model

Each model gives the flow signal as shown in figure 4.5 – figure 4.8

Fig. 4.6 the flow signal of the 1st venturi tube model

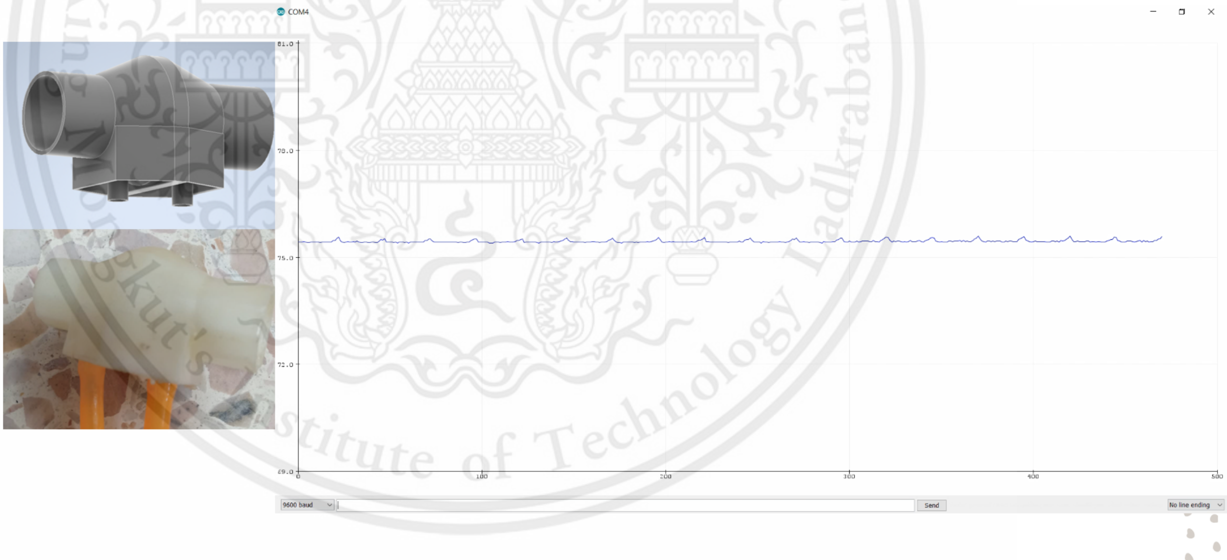


Fig. 4.7 the flow signal of the 2nd venturi tube model

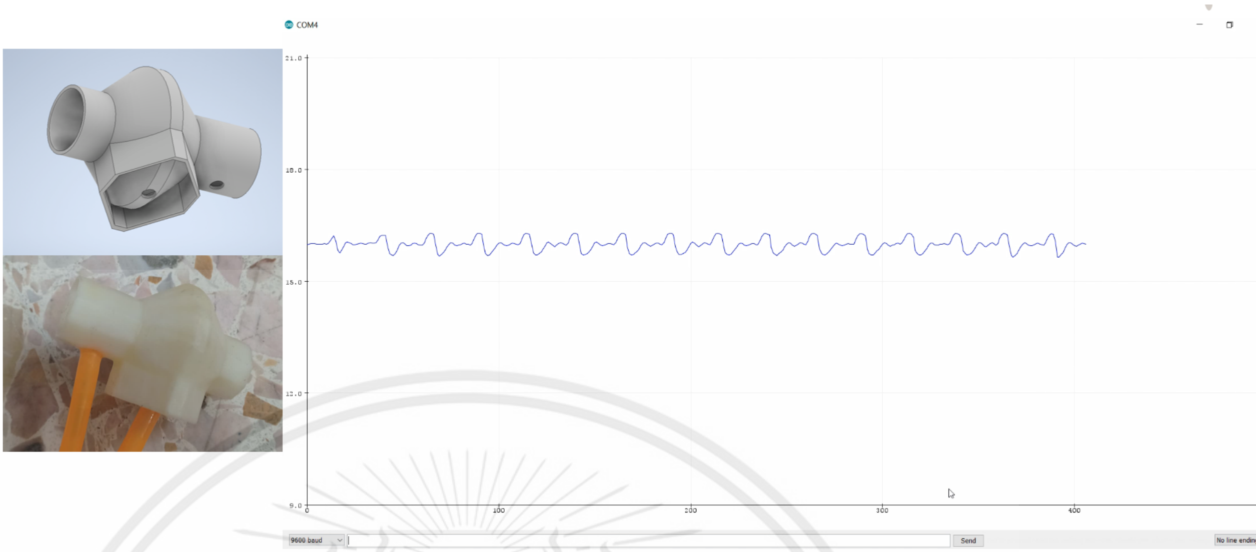


Fig. 4.8 the flow signal of the 3rd venturi tube model

Fig. 4.9 the flow signal of the 4th venturi tube model

4.2 Testing Summary

In total, over tests were executed. Each test was a flow signal, and this data then used to measure the airflow from the ventilator. The tests illustrate the best model with a good measure of the airflow from the ventilator and the patient. In the next section, this evaluation and the extent to which it supports the thesis discuss.

The third model is the best because the graph has a positive and negative graph, as shown in figure 4.9.

Fig. 4.10 the flow signal of the 3rd venturi tube model

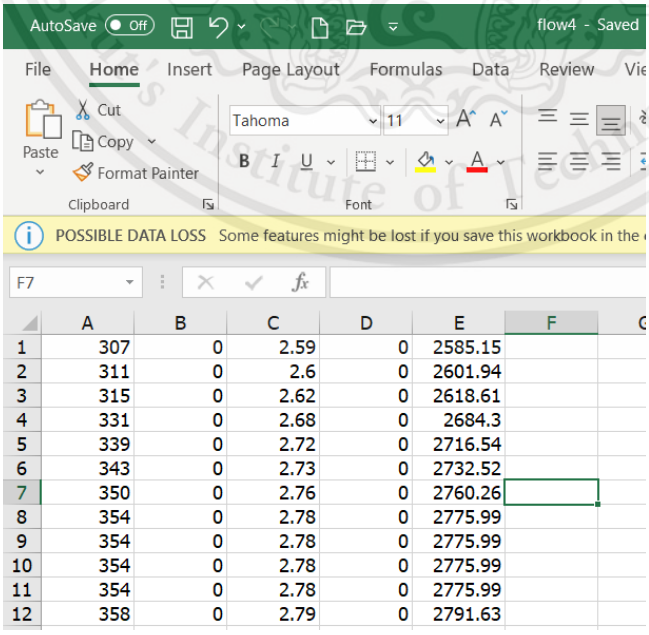
4.3 Evaluation

The testing described in section 4.3 demonstrates that the value from the Arduino while testing with the venturi tube model 3. This section evaluates the implementation and discusses issues in the underlying technologies that the implementation has highlighted.

It is the data from the Arduino signal to the CSV file. The first column is the value of the differential pressure. The second and third column is the inhale-exhale volumetric flow rate, and the fourth and fifth column is the inhale-exhale flow velocity, as shown in table 4.3 and figure 4.11. In this case, the organizer use tidal volume = 330.8 ml, as shown in figure 4.12

307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
315	0	2.62	0	2618.61
331	0	2.68	0	2684.3
339	0	2.72	0	2716.54
343	0	2.73	0	2732.52
350	0	2.76	0	2760.26
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
358	0	2.79	0	2791.63
343	0	2.73	0	2732.52
331	0	2.68	0	2684.3
323	0	2.65	0	2651.66
319	0	2.64	0	2635.19
315	0	2.62	0	2618.61
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
304	0	2.57	0	2572.49
304	0	2.57	0	2572.49
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94

Table 4.3 The value of the differential pressure, inhale-exhale volumetric flow rate, and the inhale-exhale flow velocity



	A	B	C	D	E	F
1	307	0	2.59	0	2585.15	
2	311	0	2.6	0	2601.94	
3	315	0	2.62	0	2618.61	
4	331	0	2.68	0	2684.3	
5	339	0	2.72	0	2716.54	
6	343	0	2.73	0	2732.52	
7	350	0	2.76	0	2760.26	
8	354	0	2.78	0	2775.99	
9	354	0	2.78	0	2775.99	
10	354	0	2.78	0	2775.99	
11	354	0	2.78	0	2775.99	
12	358	0	2.79	0	2791.63	

Fig. 4.11 The figure shows the output data in the Excel program

Fig. 4.12 The figure shows the flow graph output and tidal volume value in the flow analyzer

4.4 Testing and Evaluation Summary

An evaluation of the differential pressure, inhale-exhale volumetric flow rate, and the inhale-exhale flow velocity then present in section 4.3. Section 4.4 revisited the requirements described in Chapter 3 and identified the flow rate as shown in figure 4.13 -4.15. Finally, in section 4.4, the aspects of the flow graph were discussed.

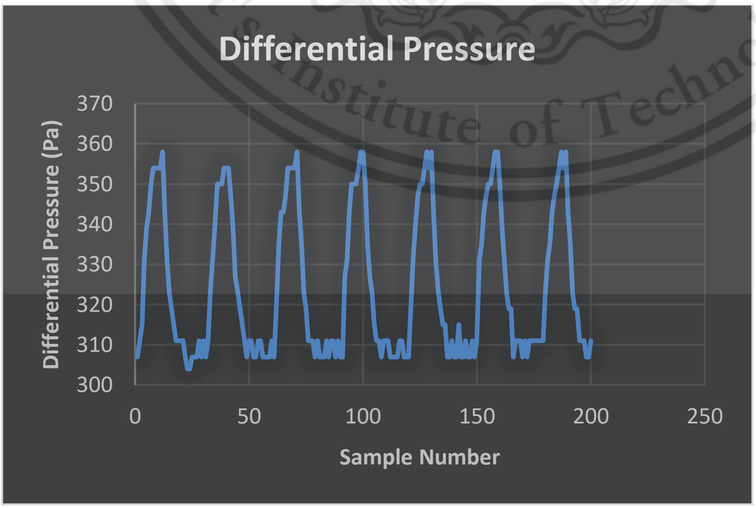


Fig. 4.13 The differential graph

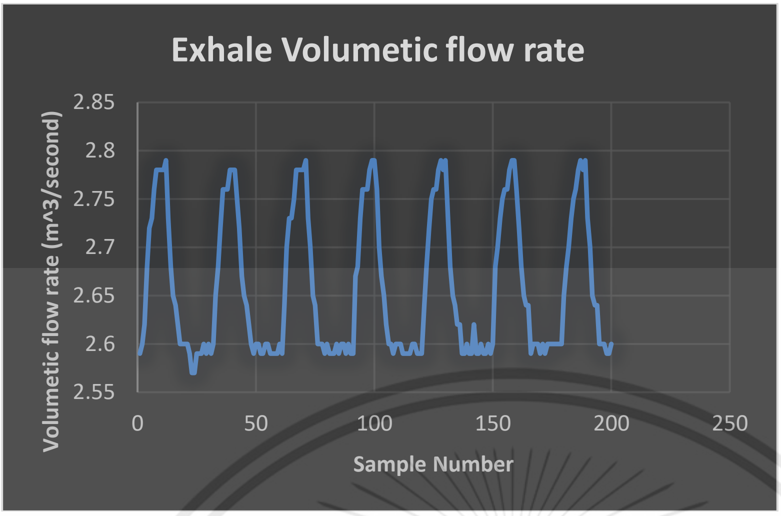


Fig. 4.14 The Exhale Volumetric flow rate graph

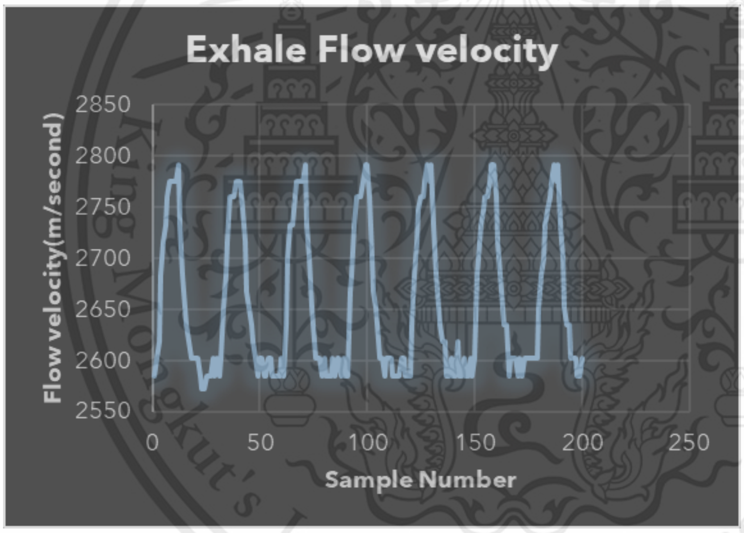


Fig. 4.15 The Exhale Flow velocity graph

CHAPTER 5
CONCLUSION

5.1 Conclusions

This project aims to flow sensor. We chose to focus on the ventilator's design and construction flow sensor for measuring the flow rate of the airflow in the ventilation and the patient's lung. It uses to support the COVID19 patient who has a failure of breathing.

The process of the flow sensor measures the flow rate signal, which is the analog signal, and changes the analog signal to be digital signal by Arduino. Then show the measuring through the computer display.

From the result, it can measure three signals by the flow sensor.

- The differential pressure of the flow sensor
- The Exhale Volumetric flow rate graph
- The Exhale Flow velocity graph

As a result, the characteristics of the three graphs show similar graphs that use the same time range, but all three graphs have different values.

5.2 Problem points and the solving

5.2.1 While using less tidal volume, the volumetric flowrate has little change.

Solving = use the efficient material to produce the venturi tube.

5.2.2 The flow sensor is not stable

Solving = Not moving the instrument and choose the more efficient microcontroller than Arduino Uno R3.

5.2.3 Have noise signal while measuring the flowrate with ventilator

Solving = Not charging while measuring the flowrate signal because of the noise signal from the power line.

5.2.4 Need to measure Inhale Volumetric flow rate and Inhale flow velocity

Solving = Use two flow sensors to measure the inhale way and exhale way. In this case, the organizer measure only exhales way of the E-ventilator.

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APPENDICES

APPENDIX A

Flowrate data

Differential Pressure	Inhale-volumetric flowrate	Exhale-volumetric flowrate	Inhale-flow velocity	Exhale-flow velocity
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
315	0	2.62	0	2618.61
331	0	2.68	0	2684.3
339	0	2.72	0	2716.54
343	0	2.73	0	2732.52
350	0	2.76	0	2760.26
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
358	0	2.79	0	2791.63
343	0	2.73	0	2732.52
331	0	2.68	0	2684.3
323	0	2.65	0	2651.66
319	0	2.64	0	2635.19
315	0	2.62	0	2618.61
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
304	0	2.57	0	2572.49
304	0	2.57	0	2572.49
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
323	0	2.65	0	2651.66
331	0	2.68	0	2684.3
339	0	2.72	0	2716.54
350	0	2.76	0	2760.26
350	0	2.76	0	2760.26
350	0	2.76	0	2760.26

354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
347	0	2.75	0	2748.41
339	0	2.72	0	2716.54
327	0	2.67	0	2668.03
323	0	2.65	0	2651.66
319	0	2.64	0	2635.19
315	0	2.62	0	2618.61
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
319	0	2.64	0	2635.19
335	0	2.7	0	2700.47
343	0	2.73	0	2732.52
343	0	2.73	0	2732.52
347	0	2.75	0	2748.41
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
354	0	2.78	0	2775.99
358	0	2.79	0	2791.63
343	0	2.73	0	2732.52
335	0	2.7	0	2700.47
323	0	2.65	0	2651.66
319	0	2.64	0	2635.19
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
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307	0	2.59	0	2585.15

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307	0	2.59	0	2585.15
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307	0	2.59	0	2585.15
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307	0	2.59	0	2585.15
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327	0	2.67	0	2668.03
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350	0	2.76	0	2760.26
354	0	2.78	0	2775.99
358	0	2.79	0	2791.63
358	0	2.79	0	2791.63
350	0	2.76	0	2760.26
335	0	2.7	0	2700.47
327	0	2.67	0	2668.03
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311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
311	0	2.6	0	2601.94
307	0	2.59	0	2585.15
307	0	2.59	0	2585.15
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319	0	2.64	0	2635.19
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339	0	2.72	0	2716.54
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350	0	2.76	0	2760.26
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358	0	2.79	0	2791.63

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307	0	2.59	0	2585.15
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307	0	2.59	0	2585.15
311	0	2.6	0	2601.94
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354	0	2.78	0	2775.99
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358	0	2.79	0	2791.63
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358	0	2.79	0	2791.63

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339	0	2.72	0	2716.54
335	0	2.7	0	2700.47
323	0	2.65	0	2651.66
319	0	2.64	0	2635.19
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327	0	2.67	0	2668.03
335	0	2.7	0	2700.47
343	0	2.73	0	2732.52
347	0	2.75	0	2748.41
350	0	2.76	0	2760.26
354	0	2.78	0	2775.99
358	0	2.79	0	2791.63
358	0	2.79	0	2791.63
362	0	2.81	0	2807.18
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315	0	2.62	0	2618.61
327	0	2.67	0	2668.03
339	0	2.72	0	2716.54
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323	0	2.65	0	2651.66
315	0	2.62	0	2618.61

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311	0	2.6	0	2601.94
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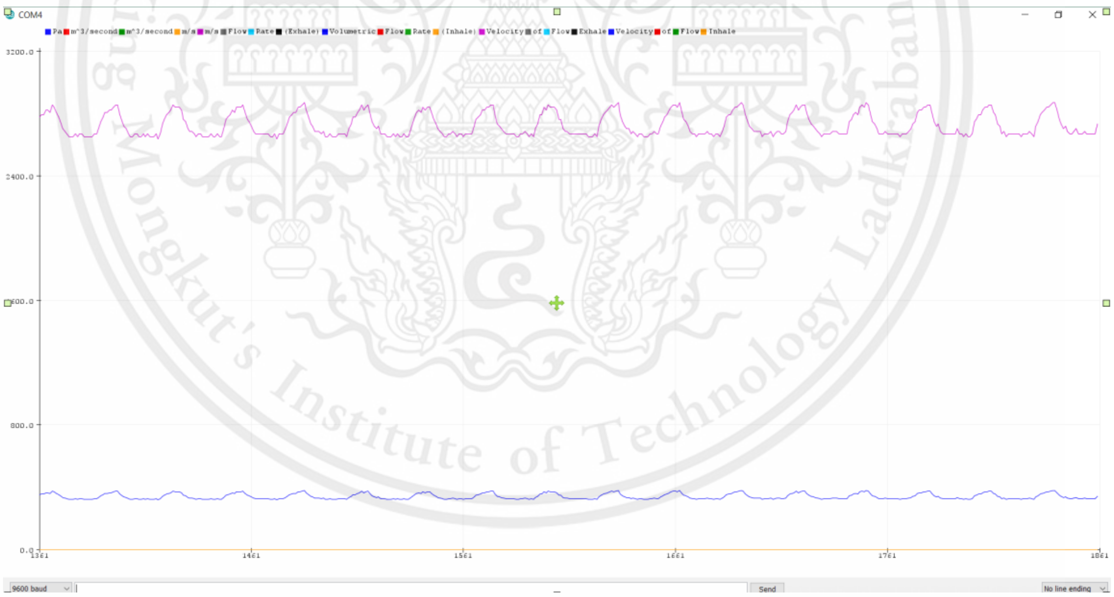
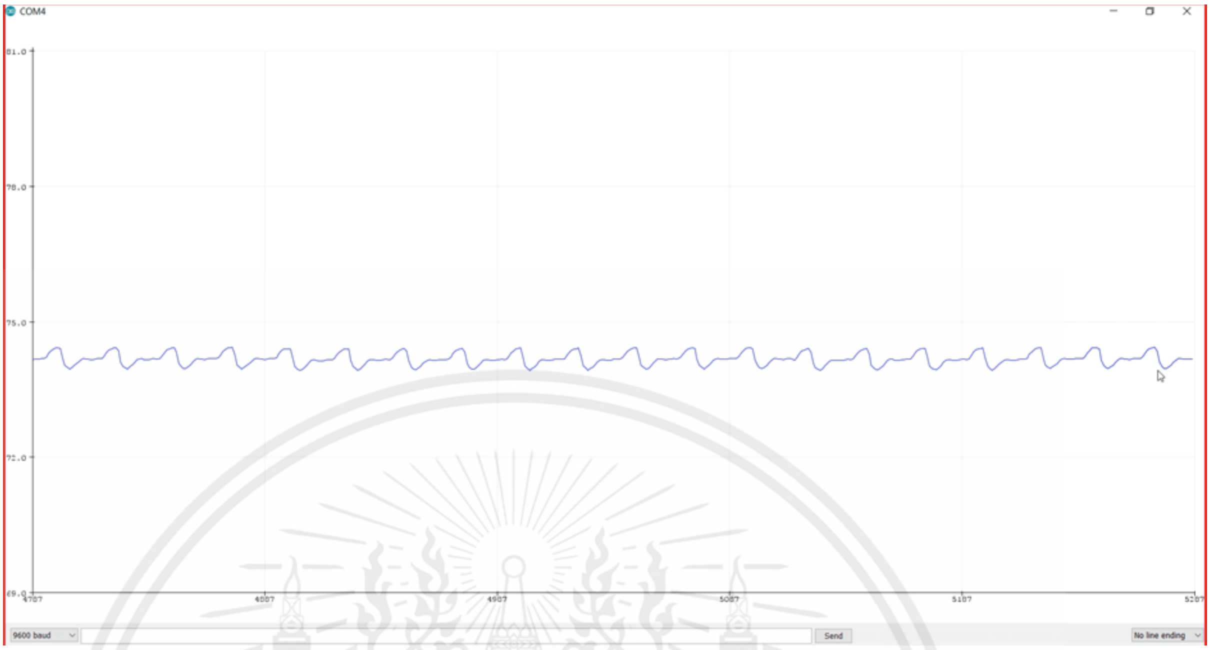
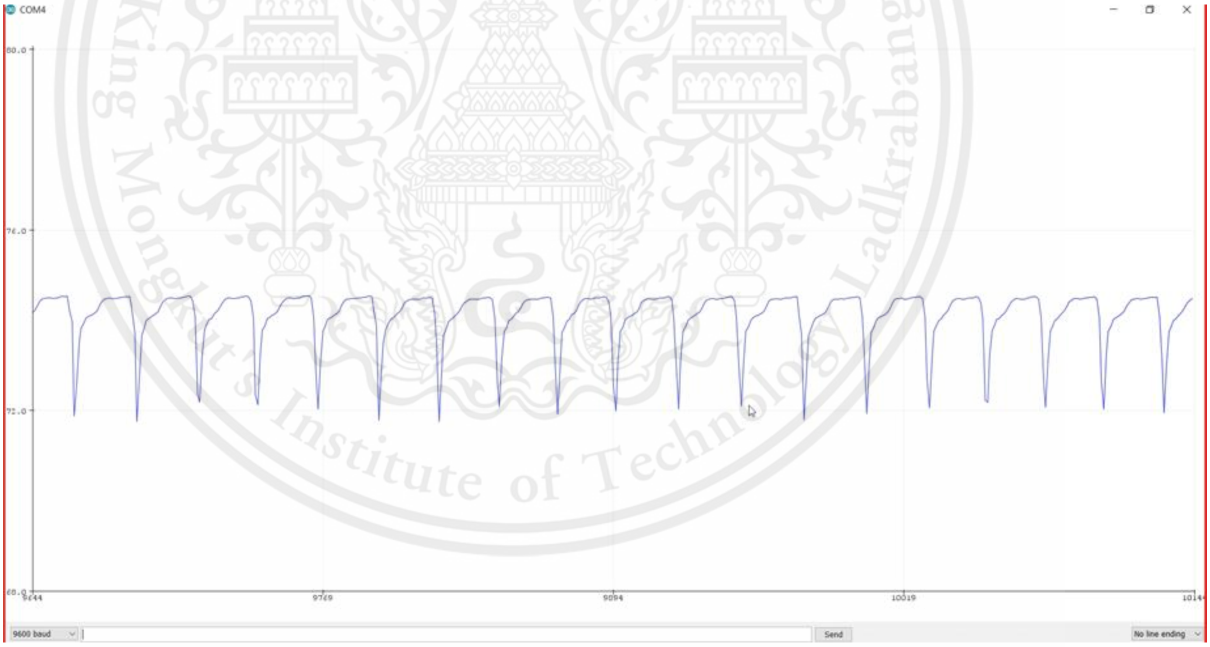
331	0	2.68	0	2684.3
343	0	2.73	0	2732.52

Figure Realtime flowgraph

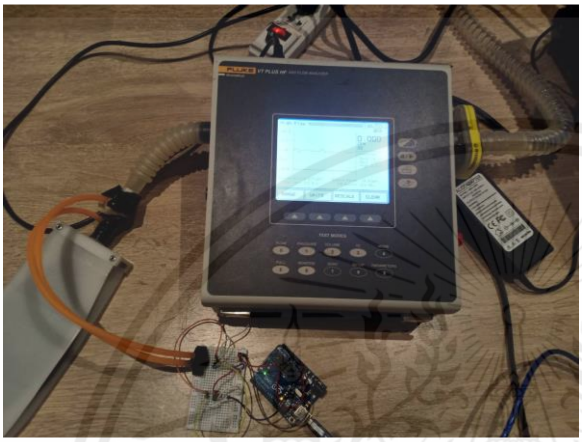


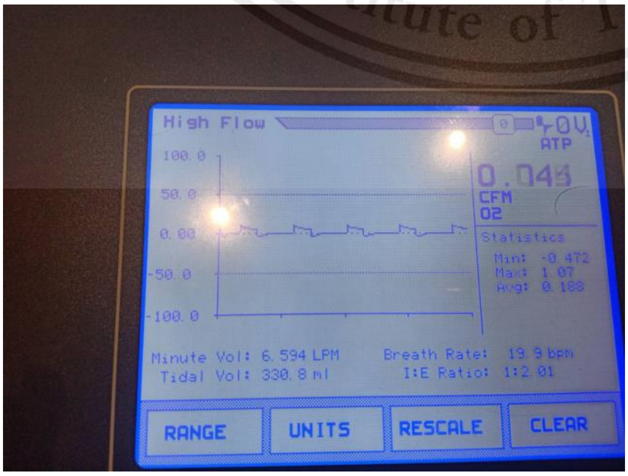


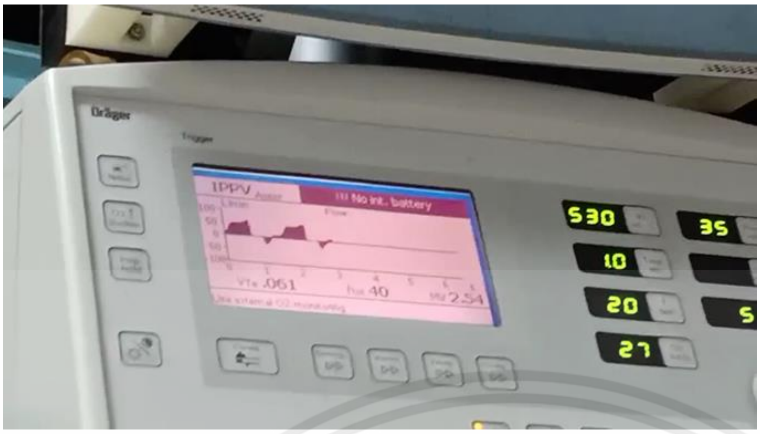


APPENDIX B

Figure during Experiment






Dräger
IPPV
No int. battery
530
35
10
20
27