DEVELOPMENT OF AFFORDABLE FULL BODY ISOLATION POD

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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LIST OF ABBREVIATIONS

HCW	Healthcare Worker
HEPA	High Efficiency Particulate Air
CT	Computerized Tomography
PPE	Personal Protective Equipment
AII	Airborne Infections Isolation
CDC	Centers For Disease Control and Prevention
HUSM	Hospital Universiti Sains Malaysia
MMA	Malaysian Medical Association
UV	Ultraviolet Radiation
TB	Tuberculosis
NHS	National Health Service
MEKP	Methyl Ethyl Ketone Peroxide

DC	Direct Current

ABSTRAK

Wabak Covid-19 telah menjejaskan berjuta-juta individu di seluruh dunia. Virus Covid-19 telah merebak dengan pantas dan membunuh hampir empat juta orang di seluruh dunia. HCW termasuk dalam populasi yang dijangkiti kerana interaksi mereka dengan pesakit yang dijangkiti. Penyelidikan ini mencadangkan penggunaan isopod berkos rendah, tekanan negatif, badan penuh. Isopod menggunakan pengambilan blower untuk mencipta vakum atau tekanan negatif di dalam ruangnya. Pengambilan blower juga dilengkapi dengan penapis HEPA untuk memastikan udara yang keluar dari isopod adalah bebas virus. Akibat tekanan negatif di dalam isopod, udara ambien diambil melalui penapis HEPA tambahan dan dibenarkan untuk beredar ke dalam pesakit. Penapisan HEPA dan tekanan negatif di dalam isopod menghalang bahan cemar daripada melarikan diri dan menyebabkan kecederaan kepada profesional perubatan yang merawat pesakit. Isopod ini mungkin jawapan untuk hospital di negara miskin yang ingin melindungi HCW daripada penyakit maut, kerana ia boleh diakses dan memenuhi garis panduan CDC.

ABSTRACT

The Covid-19 epidemic has affected millions of individuals throughout the globe. The Covid-19 virus has rapidly spread and killed almost four million people throughout the globe. HCWs are included in the infected population due to their interaction with infected patients. This research proposes the use of a low-cost, negative-pressure, full-body isopod. The isopod employs a blower intake to create a vacuum or negative pressure within its chamber. The intake of the blower is additionally equipped with a HEPA filter to ensure that the air exiting the isopod is virus-free. As a result of the negative pressure inside the isopod, ambient air is taken in via an extra HEPA filter and allowed to circulate into the patient. HEPA filtration and negative pressure inside the isopod prevent contaminants from escaping and causing injury to the medical professionals attending to the patient. This isopod might be the answer for hospitals in impoverished nations seeking to safeguard HCWs from the fatal illness, since it is accessible and meets CDC guidelines.

CHAPTER 1 INTRODUCTION

1.1 Research Background

In December 2019, an outbreak of a mysterious pneumonia of unknown origin was reported in Wuhan, Hubei Province, China. The first case in Malaysia was reported on the 25th of January 2020. On the 15th of February 2020, the number of cases had escalated to 22. Millions of people have been afflicted by the Covid-19 pandemic around the world. The Covid-19 virus has spread quickly and claimed the lives of almost four million people around the world [1]. The first COVID-19 case was discovered in Malaysia on 25th January, 2020, and it was linked to 3 Chinese nationals who had previously had intimate contact with an infected individual in Singapore [2]. With 5305 confirmed cases of COVID-19 and 88 fatalities by 18th April, 2020, Malaysia was in the midst of a dire situation.

During the installation of mobility restrictions across the nation, the government quickly launched a public health response and provided appropriate medical treatment to address the public health issue [3]. HCWs are included in the infected population because they come into touch with infected patients. In the year 2020, 1608 HCWs at hospitals have been informed with COVID-19 infection. Healthcare occupations account for 40.5% of the total, followed by medical doctors (20.8%), healthcare assistants (9.7%), medical doctor assistants (9.1%), medical specialists (3.2%), and hospital administrative assistants (3.2%) (2.8%). The majority of cases were recorded in Sabah (39.8%), Selangor (27.5%), Wilayah Persekutuan Kuala Lumpur & Putrajaya (6.7%), Sarawak (6.0%), Perak (5.6%), and Johor (5.6%). (4.7%) [4]. Being compelled to breathe the same air as sick patients while working in tight spaces like ambulances puts emergency medical staff at an especially high risk of infection. In a perfect world, isolating patients in a low-pressure setting would safeguard emergency HCWs [5]. Because infected HCW might spread nosocomial illnesses to the broader community, the safety and health of HCW is crucial [6].

Utilising a negative pressure isolation pod is one of the most efficient methods to lower nosocomial infections [7]. Due to a lack of funds in 2020, state governments lacked sufficient isolation pods as well as other PPE [8]. Due to the high cost and difficulty in obtaining isopod during the epidemic, this condition is regarded as being particularly serious [9]. In order to provide a durable barrier between HCWs and infected patients while they are being transported, this study suggests using a low-cost, full-body negative-pressure isopod. The isopod uses a blower intake to produce negative pressure, or vacuum, inside its chamber. A HEPA filter is also included in the blower intake to guarantee that the air leaving the isopod is virus-free. Since there is negative pressure inside the isopod, the ambient air is drawn in via an additional HEPA filter, allowing it to flow through the patient. Contaminants are prevented from escaping and harming the medical staff attending to the patient through HEPA filtration and negative pressure inside the isopod

The isopod can also be employed in any clinical care setting, from pre-hospital to intra-hospital transfer, as well as during emergency medical imaging, such as CT scanning and plain radiography, without compromising image quality. Additionally, the isopod can be used to transport critically ill patients whose airways are covered by endotracheal intubation, significantly lowering the chance of airborne particles being transferred to HCWs and ensuring their safety. Imported isopods have a current market value of USD 8,000 (MYR 32,000), while the one utilised in this study costs one-fifth of that. The minimal cost is achieved by utilising parts available from hardware and electronics stores. The isopod must also meet the AII room requirement stipulated by the CDC. This study examines the isopod's ability to produce and maintain the negative pressure defined by the Centers for Disease Control and Prevention (CDC).

1.2 Problem Statement

Imported isopods sell for USD 8,000 (MYR 32,000) on the open market, but the one used in this study costs one-fifth of that. Parts from hardware and electronics stores are used to keep the cost to a minimum. The AII room criteria established by the CDC must also be met by the isopod. The capacity of the isopod to create and sustain the negative pressure established by the Centers for Disease Control and Prevention is investigated in this study (CDC). There are also significant issues with the isopod, such as the interior temperature of the isopod making the patient uncomfortable, thus a study will be conducted in this study to enhance the ventilation inside the isopod.

1.3 Objectives

This research aims:

1. To develop new design of the isopod
2. To fabricate an isopod with proper methods, do will be helpful for mass production
3. To develop the air circulation system inside the isopod and make it comfortable for the patient during hot weather

1.4 Scope of Research

ISOPOD has a prototype that is now in use at Hospital Universiti Sains Malaysia (HUSM) in Kubang Kerian, Kelantan. HUSM has inspected the prototype and provided feedback. The study entails creating a second-generation ISOPOD prototype. Even though a working prototype already exists, certain changes to the structure's design will be made. The investigation will begin with the fabrication of a second prototype. The second phase is all about the isopod's ventilation system, which is based on the HUSM's evaluation. The majority of the effort will be spent assessing and programming the microcontroller. Experimentation was required as part of the assessment procedure to determine the thermal comfort within the isopod. The experiment will be done in various temperatures.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction to COVID-19

Around January 2020, the severely intense respiratory syndrome coronavirus 2 (SARS-CoV-2), the eighth human coronavirus, was identified in Wuhan, Hubei province, China, amid a recent pneumonia crisis [1][10]. Since then, the infection has spread around the globe, infecting 4,806,299 individuals and causing 318,599 fatalities as of 20th May 2020. SARS-CoV-2, SARS-CoV, and Middle East respiratory syndrome coronavirus (MERS-CoV) potentially cause pneumonia with a corresponding mortality rate of 2.9%, 9.6%, and 36% [11-14]. The other four human coronaviruses, HKU1, OC43, NL63, 229E, often induce self-limiting infections with minimal symptoms [15].

COVID-19 is an infectious illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Variable COVID19 symptoms often include fever, cough, headache, exhaustion, difficulty breathing, loss of smell, and loss of taste. [16] One to fourteen days following exposure to the virus, symptoms may manifest. At least one-third of infected individuals do not exhibit visible symptoms [17]. The majority (81%) of patients have mild to moderate symptoms (up to mild pneumonia), whereas 14% develop severe symptoms (dyspnea, hypoxia, or more than 50% lung involvement on imaging), and 5% develop critical symptoms (respiratory failure, shock, or multiorgan dysfunction) [18]. People over the age of 65 are more likely to have severe symptoms. After recovery, some individuals continue to have a variety of symptoms (long COVID-19), and organ damage has been seen [19]. The disease's long-term repercussions are the subject of ongoing investigations spanning many years.

2.2 COVID-19 in Malaysia

COVID-19 is not the first pandemic that hit Malaysia although it is the greatest one since 1981 where Spanish Flu killed 1 percent of the British Malaya's population which is equivalent for 34,644 people [20]. SARS (2993) and Nipah virus (1999) have also caused pandemic which cause to death of 2 and 105 Malaysians respectively [21]. Too far, the COVID-19 has taken the lives of a total of 35,816 people [22]. Malaysia has seen three waves of this illness. The first COVID-19 wave occurred between 25th January and 16th February, 2020, and the second between 27th February and 30th June, 2020. The third wave began on 8th September 2020 [23].

The largest cluster of the second wave, which started on 27th February, was Sri Petaling Tabligh, which accounted for 47 % of all cases in Malaysia and had an infection rate of 6.5% [24]. Due to regular exposure to and handling of COVID-19 in hospitals, HCWs are at a high risk for infection [25]. As matter of fact, 1608 HCWs was infected at hospital in the year 2020 and according to the portion nursing occupation have been infected the most (40.5%) and the most cases is reported at Sabah (39.8%) [4][26]. Since Sabah is situated in East Malaysia, which is considered a less developed region, there are minimal medical resources and services available. On 8th October 2020, the Sabah Medical Department sent MMA a letter requesting RM1.7 million in order to purchase essential medical equipment, including 60 units of Tecman Powered Air Purifying Respirator (PARP), 6 units of Mobile Negative Pressure Isolation Chamber, 22 units of High Flow Nasal Cannula Machine, and other PPEs [27]. This demonstrates the necessity for adequate PPE to lower nosocomial infections among patients and HCWs.

2.3 COVID-19 Transmission

COVID-19 is mostly spread by inhalation of droplets/aerosols and tiny airborne particles infected with the virus. These particles are exhaled by infected individuals when they breathe, speak, cough, sneeze, or sing [28]. Transmission is more probable when individuals are physically closer together. However, illness may spread across greater distances, especially within [29].

Primary infection may begin four to five days before to the development of symptoms, although contact tracing often starts just four to five days prior to the onset of symptoms [30]. Even presymptomatic or asymptomatic infected individuals are capable of transmitting the illness [29]. Typically, the peak viral load in samples from the upper respiratory tract occurs close to the beginning of symptoms and falls after the first week [31]. Current research supports a length of viral shedding and infectivity of up to ten days from the beginning of symptoms for those with mild to moderate COVID-19, and up to twenty days for those with severe COVID-19, including immunocompromised individuals [28].

Infectious particulates vary in size from aerosols that stay airborne for extended periods of time to bigger droplets that remain airborne for shorter durations or fall to the ground [28]. Moreover, COVID-19 research has transformed the conventional view of how respiratory viruses are spread. The biggest droplets of respiratory fluid do not move far, but they may infect mucous membranes of the eyes, nose, and mouth if they are inhaled or rest on them [32]. Aerosol concentrations are higher when individuals are in close contact, which makes viral transmission simpler when people are physically near [33]. However, airborne transmission may occur at greater distances, especially in poorly ventilated areas; in these circumstances, small particles can float in the air for minutes to hours [32].

The average number of persons infected by a single sick person varies, but the R0 ("R naught" or "R zero") value is around 2.5 [34]. Typically, the illness spreads in clusters that may be traced back to a single index case or geographic region [35]. In these cases, superspreading occurrences often occur, in which several persons are infected by a single individual [36].

2.4 Negative Pressure System

Negative room pressure is used in hospitals and medical institutions to prevent cross-contamination [37]. It features a ventilation system that generates negative pressure (lower pressure than the surrounding region) to allow air to enter the isolation room while preventing contaminated air from escaping, since air naturally flows from places with higher pressure to areas of lower pressure [38][39]. This approach is used to isolate patients with airborne infectious diseases such as measles, influenza (flu), tuberculosis, chickenpox, severe acute respiratory syndrome (SARS-CoV), Middle East respiratory syndrome (MERS), and coronavirus disease (COVID-19) [14][40].

A venting system that continually attempts to remove air from a room generates and maintains a negative pressure in the area as shown in Figure 1. A gap beneath the door allows replacement air to enter the space (typically about one half-inch high) [41]. The space is as airtight as it can be, with the exception of one opening. Fewer air leaks via openings surrounding windows, light fixtures, and electrical outlets. Maintaining room negative pressure may become more challenging and inefficient due to leakage from these sources. Because certain components of the expelled air, such as chemical pollutants, germs, and radioactive isotopes, would be undesirable to discharge into the neighboring outside environment, the air outlet must be positioned so as not to expose people or other inhabited locations [43]. Typically, it is discharged from the top of the structure. In biosafety level 4 rooms, for example, the air must first be mechanically filtered or disinfected by UV irradiation or chemical treatments before to being released into the surrounding environment. In nuclear power facilities, radioactive isotopes in the air are routinely screened for and filtered before being discharged down a tall exhaust duct and away from inhabited areas [42].

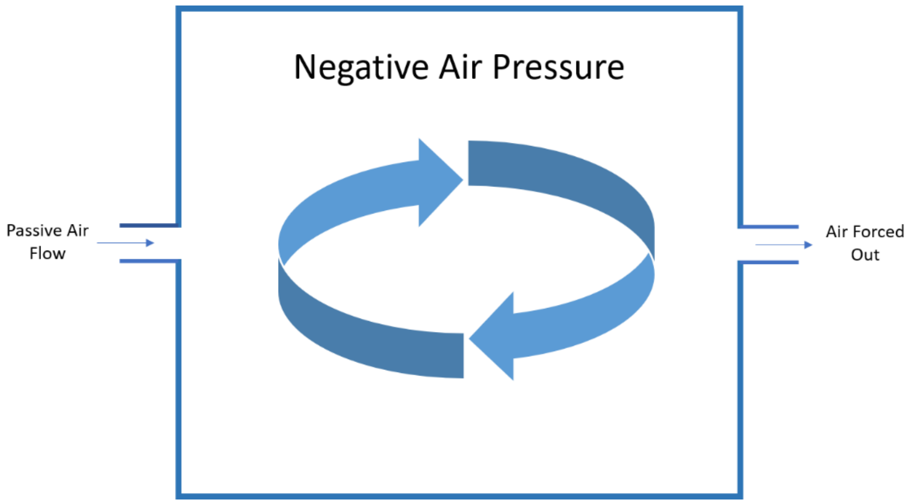

Figure 1 Negative Air Pressure Mechanism

The CDC issued infection control recommendations in 2003 that included advice on negative pressure isolation rooms [44]. Recommendations for acute negative pressure isolation chamber monitoring are still missing from the CDC. As a result, some hospitals, including the Cleveland Clinic, have created their own rules. The smoke or tissue test, as well as periodic (noncontinuous) or continuous electronic pressure monitoring, are frequently used techniques for acute monitoring. To evaluate the pressurisation, two different kinds of tests may be performed. The smoke or tissue test is one of them. To evaluate the pressurisation of the room, this test employs smoke or tissue paper. If a capsule of smoke or a tissue is put behind the door towards the bottom of the door, the chamber is under negative pressure. This test has the benefits of being affordable and simple for HCW to carry out. Both the fact that it is not a continuous test and the fact that it does not quantify magnitude are drawbacks. Even if the smoke/tissue test is positive, isolation rooms may still be under- or over-pressurized without a way to evaluate magnitude.

A 1994 CDC guideline said that while being utilised for TB isolation, TB isolation rooms should be monitored daily for negative pressure [45]. The negative pressure in the rooms should be examined periodically if they are not currently being utilised for patients with suspected or confirmed TB but may one day be. In order to continually monitor the pressure difference between the rooms, an electrical equipment with a pressure port in the isolation chamber and an isolation port in the hallway is used. An alarm will notify personnel of any unfavourable pressure changes, and the test is continuous, which is a benefit of this sort of monitoring. The drawbacks of this monitoring include the potential for particulate contamination of the pressure ports, which could result in inaccurate readings and false alarms, the cost of purchasing and installing the devices, and the need for staff training in order to properly operate and calibrate them due to the low negative pressure's requirement for the use of extremely sensitive mechanical, electronic, or pressure gauge devices [46].

2.5 Isolation Pod (ISOPOD)

2.5.1 Introduction

An isolation pod is a sort of capsule that is also used to keep a patient isolated for medical reasons. The Norwegian EpiShuttle and the United States Air Force's TIS or PBCM are two examples of airborne isolation systems [47][48]. In the 1970s, isolation devices were created for the aircraft evacuation of Lassa fever patients. HSTI pods (Figure 2) were used for the aerial evacuation of health staff during the 2015 Ebola epidemic in Guinea [49]. HCWs are completely protected in isolation pods [biosafety level-4]. Edithheathcare.in, a startup located in Ahmedabad, designed these pods to isolate infected patients during the covid epidemic in India in 2020-21.

Figure 2 A HSTI-TCOL pod used in Guinea during an Ebola outbreak [49]

According to a review of 14 relevant studies, the usage of isolation pods for the transfer of COVID-19 individuals would not be appropriate, since oxygen masks and other, less demanding methods would suffice [50]. During the COVID-19 epidemic, NHS hospitals in the United Kingdom put up separate reception rooms known as isolation pods; however, these were generally temporary accommodations like as a portacabin or tent, with no unique technical characteristics other than being positioned far away from permanent facilities [51][52].

A pod designed to isolate chemical, biological, radiological and nuclear (CBRN) risks as shown in Figure 3. There are a lot type of model and patent already exist in the market and most of them are have their own functionality. Since in this study only the development going to be done to the existing protype [12]. To enhance, we may examine the other current model and patent to have a better understanding of the structure and design. This process is vital to produce a more advanced and achieving or core objective of our study.

Figure 3 A pod designed to isolate CBRN [78]

Biosafety negative pressure portable isolation chamber is a collapsible apparatus used for avoiding unwanted contamination of harmful biological and chemical materials by HEPA filter [53]. The isolation chamber is outfitted with its own filtering system under negative pressure to guarantee optimal safety and operational safety for the contaminated individual or object as well as the medical team. The cover is accessible through a zipper. Portable Biosafety Isolation Chamber unit is the ultimate solution to preventive spread out any infection from the highly infective patients.

CTMP is a transport chamber that prevents cross-contamination between the patient and the external environment during land or air transfer [54]. The chamber may work at either negative or positive pressure. Transporting sick patients or patients suspected of biological contaminations such as COVID-19, SRAS (severe acute respiratory syndrome), or TB requires a negative pressure environment. The Adult PIC is a transportable confinement device used to transfer patients who are extremely infectious or at high risk [55]. It is mostly used to transfer extremely infectious or high-risk patients, as it is recommended for usage in disaster medicine. Completely airtight and fitted with a HEPA-filtered ventilation system, this device is airtight and airtight. It is capable of either depressurization to assure the isolation of highly infectious patients or over pressurization to protect patients from external contamination while being transported (transfer of immunocompromised patients or the evacuation and care of casualties in CBRN war zone environments). Table 1 compares the benefits and drawbacks of the previously stated medical isolation capsules.

Table 1 The Advantages and Disadvantages of the Isolation Capsules

MODEL	ADVANTAGE	DISADVANTAGE

ISOLATION CAPSULE		
Pro Pac CAPSULS Patient Isolation Unit (PIU) [56]	• High durability among models due to the manufacturing materials used (The PIU's Iso-Shell engineered plastic film shell material, pressure-seal zipper, and Iso-Weld seaming technology, together form a gas and liquid-tight envelope) • Lightest model among 5 models • Highest mobility as it can be carried around in a bag and ease of setup • Achieves negative pressure environment by a powered air exhaust at its foot end develops isolator under-pressure.	• Lowest patient comfort due to low air flow rate and having smallest chamber size • Being the smallest in size, may lead to an internal environment feeling cramped and suffocating for patients
ATA Medical, CTMP-Isolated transport chamber [57]	• Whole transparent cover is made of hard plastic material (polycarbonate) which improves strength	• Heaviest model among 5 compared models • Highest gross weight which

	and durability • Highest bearing load capacity • High initial battery life for longer operations and usage and comes with external power supply • Negative and positive pressure conditions are equipped with • Have tighter seal due to its design characteristics • Comes with a built-in control screen which is easy to use and operates automatically depending on model	makes it less mobile to be carried around • Not fully collapsible making it hard to carry around during emergency • Most expensive model
Securotec, Adult Pic-Portable Isolation Chamber [58]	• Made of clear transparent polyurethane and 840 D coated fabric double sided, grey polyurethane on arches and ends. Ground sheet and double bottom base made of 840 D double sided black polyurethane. These makes it highly and	•However, operations and handling on the unit can be limited as there are only 2 glove ports •Inflatable bottom mattress design which has high chances of air leakage over time after multiple usage •Uses an internal balloon to control the

	extremely resistant. (Water and air proof) • Comes with double O-rings for a better and tighter seals at glove ports. • High mobility as almost every component is foldable and easy to be transported • Highest initial battery life of 16 hours and equipped with self-alarm system	decrease or increase in pressure which may not be as efficient compared to a •However, operations and handling on the unit can be limited as there are only 2 glove ports •Inflatable bottom mattress design which has high chances of air leakage over time after multiple usage •Uses an internal balloon to control the decrease or increase in pressure which may not be as efficient compared to a designed control system •Expensive

2.5.2 Existing Patents

Since 1970 when the first isolation device was created, there are many types of devices where invented in order to make HCW life easier. The type that related to this research is the portable isolation device which mostly used for transportation also in hospital use is allowed. There many patents have been done in this type of isolation device and most of them are mostly identical in size and shape. In the particular niche devices, the two common types of position where patient are placed which are supine and Semi-Fowler's position as shown in Figure 4 and Figure 5 respectively. Since it is impractical to transport COVID-19 patients in the prone position, the next best posture is the supine position, which is one of the most natural positions for patients and typically permits all patient anatomical structures to stay in natural neutral alignment [62]. The vast majority of patients are able to maintain sufficient respiratory function without externally restricting the respiratory system [61].

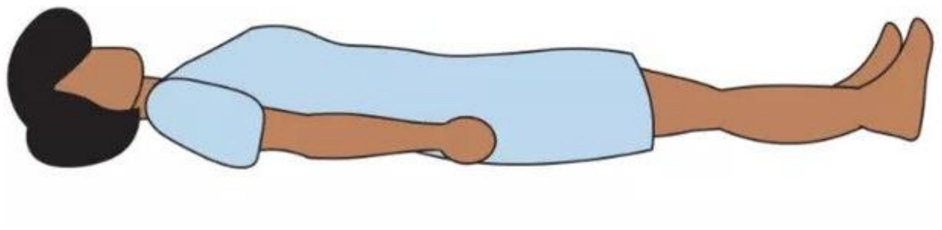

Figure 4 Supine position [59]

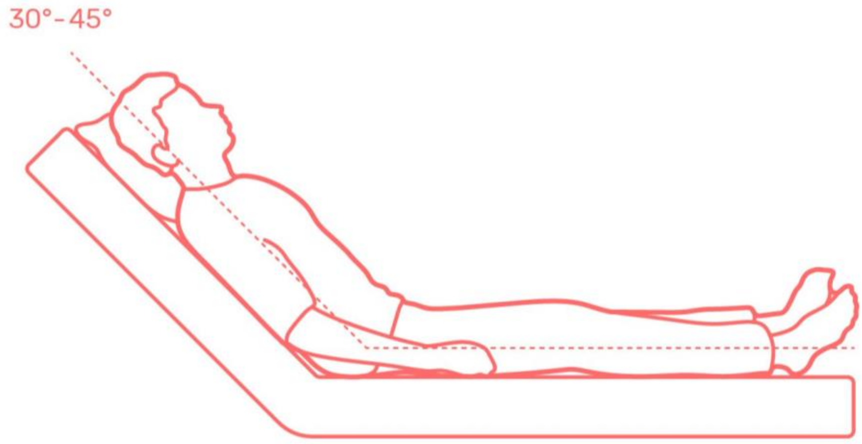

Figure 5 Semi Fowler's Position [60]

The features of the patents that are existing is almost the same where all of them have flexible and impermeable plastic sheeting that is sealable to provide a clear look for HCW to observe the patients and this is isolation apparatus is patented in WO2001005348A1 and United Kindom Patent UK 201520065 [63][64]. Since it is thin layer, they can even interact with the patients which is very useful during transportation. Next, the glove compartment is also very common in portable isolation devices where it helps HCWs to examine the patients externally without having direct contact with patient which idea rise from United States Patent US 6,003,728[65]. The glove compartment is built of conventionally constructed, medical-grade, tear-resistant gloves. The gloves include a reinforced portal and tubular sleeves so that patients may be treated without being exposed to the environment.

The potable isolation pod comes in several shapes and most of the them are semi-circular shaped or cuboid shaped. Conceptually, the latter will hold more volume of air compare to former but in a portable isolation device the volume of air need to optimum not maximum because if more air is placed inside it harder to push air outside the isopod. When the volume air is high inside, it can create stagnation area where the air circulates itself and does not exit the isopod. This causes the contaminated are exist inside rather than removed from the isopod so the semi-circular shape is used and this also gives a sense of depth to the isopod’s shape.

The barrier support system is the material that used to reinforce the clear plastic sheet in be in shape and preventing from collapsing on patient which inspired from United States Patent US 8,245,713 [66]. In this particular design, two flexible rods are crossed on the crossed to produce pyramid like shape but the problem is that it blocks some of the vision of the patient and also makes harder to transport. United States Patent US 20040111008 and European Patent EP 1202696 gives a simple solution for having supporting ribs that is very simple and elegant to design which are placing flexible or malleable material (plastic, nylon, steel, aluminum, etc.) on the thin plastic sheet without having it screw buy only slotting in like a pocket as shown in Figure 6 [67][68]. This design very practical and it was picked for this project.

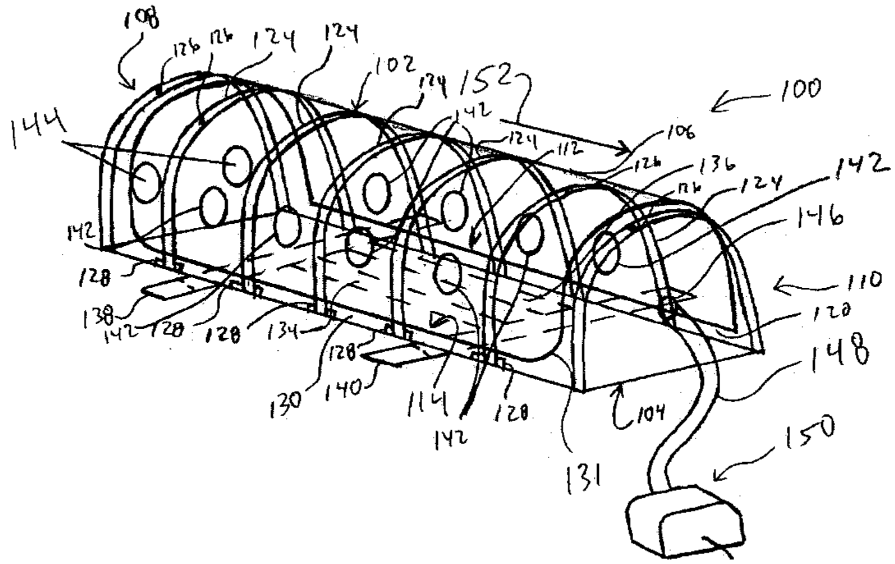

Figure 6 Design Proposed in United States Patent US 20040111008

Next, the side board is also a very popular feature in the isopod but there also designs without them as example in United States Patent US 8,245,713 and 5,950,625 [66][69]. There is downfall this kind of deign which the control or life support system usually will hanging of the pod which makes it less portable and by having the side board the will more space to give support for the control system as patented in US6969346 and TWM605084 [70][71].

The disinfection method is the one offering a purpose for the isopod because the ultimate objective of isopod is preventing the infection among the HCWs. There are several methods to neutralize or stop the infectious virus or pathogens from exiting the isopod which are using HEPA filter, UV lamps and etc. [72][73]. The particular COVID-19 is 0.1 micrometer in diameter but studies show that a basic N95 mask can block the microbe [74]. COVID-19 presents in the environment in the form of aerosol and tiny droplet which forms infected respiratory system. In both forms the diameter is more than 5 micrometers [33]. Most of the HEPA filter cartridge in the market is valid to block pathogen from 0.3 micrometer so it is valid to use for the isopod. As in for the UV lamps, it makes the isopod heavier and HEPA filter is good enough.

2.5 Conclusion

There are a lot of high-end full body isolation devices available in the market for example the EMSS Biological Isolation Chamber portable, FSI Isolation Chamber, BIOBASE Biological Isolation Chamber portable, QUANTUM EMS Isolation/Containment Chamber and etc. [76][77]. All the products above almost have the same functions but one thing that most common among them is the price. The price range for the products is from RM5,300 up to RM53,000. The design seems very simple although the price is very expensive. The amount of isolation pod design and system have been patent but the implementation to production is very less among the medical manufacturers.

CHAPTER 3 METHODOLOGY

3.1 Introduction

The majority of the effort on the development of an affordable full-body isolation pod project involved the fabrication of specific components. This developing model has a prototype as a point of reference, but it was unavailable because it was being used at the HUSM, Kuala Kerian. The majority of development was based on the feedback provided by medical personnel utilising the isolation device, as well as the suggestions of the prototype's creators. Some produced parts had prototype spares, which served as a starting point for the project's dimension reference. Additionally, we acquired from the external vendor certain components that we are unable to produce. As a disclaimer, the measurements of the final product were altered throughout the duration of the project.

3.2 Simulation

First, there are no mechanical components involved in the development project, with the exception of the DC motor attached to the fan blade that serves as the blower to regulate the airflow in the portable full-body Isopod; this will be discussed in detail in the electrical section of the article. As for the electrical components, simulation was required to determine the most suitable system for the automation component. Autodesk Tinker cad was used to model the anticipated outcome of the electrical system, allowing us to be prepared for the required components during assembly. Figure 7 displays a screenshot of the simulated electrical diagram, as well as the before and after simulation for comparison. The graph demonstrates that when the temperature rises, the fan speed increases. Typically, the temperature within an Isopod rises as a result of the internal temperature and the quantity of heat emitted by the patient; however, as the fan speed increases, the internal airflow increases and the temperature falls.

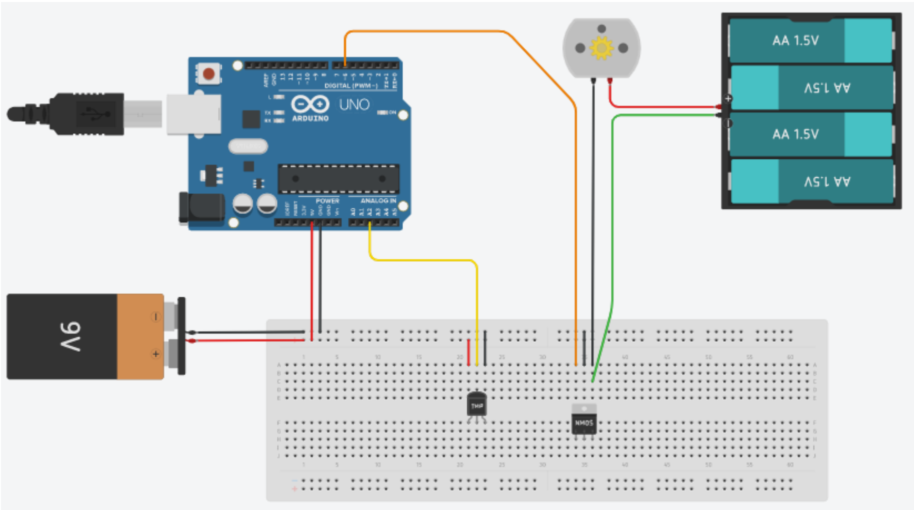

Figure 7 Simulation Circuit using Tinker Cad

Tinker CAD was used to imitate the isopod's electrical system, and missing components such as the BMP140 sensor and 5200mAh lithium-ion battery were replaced with TMP36 and four 1.5V AA batteries, respectively. Connecting the Arduino's positive terminal to the 5V power pin and the negative terminal to the GND pin commenced the simulation. The temperature sensor is then connected to analogue pin A2 and the remaining pins are linked to opposite terminals. The nMos transistor (MOSFET) was then connected to digital pin 6 along with other pins that were attached to the dc motor and negative terminal of the external battery. Finally, the motor is linked to the external battery's positive terminal. Tinker CAD provides two techniques for running simulations: block diagram and code. I utilised the coding method, and the code I wrote for the simulation differs slightly from the final code, as shown in the Appendix A, due to the variation in components.

3.3 Hardware

3.3.1 Material and Components

The glove compartment is a typical component of portable isolation equipment. This function is not limited to medical devices, but is also utilised in the chemical, weapon, and other industries. The glove compartment consists of four types of components, of which two must be produced. Figure 8 depicts two produced components whose fabrication processes are comparable. Utilising spare parts to create a mould for the parts is the first step in the procedure. As depicted in Figure 9, the components were first cleaned with acetone and then adhered to a glass surface, where they were encircled by a closure and all leaking points were sealed with hot glue. Next, 1.5 percent hardener and silicon rubber are thoroughly combined, poured over the sealed surface, and allowed to cure. Normally, it only requires 24 hours to cure, but to be safe, it was let to cure for 48 hours, and the first two attempts to create the mould failed for unknown reasons.

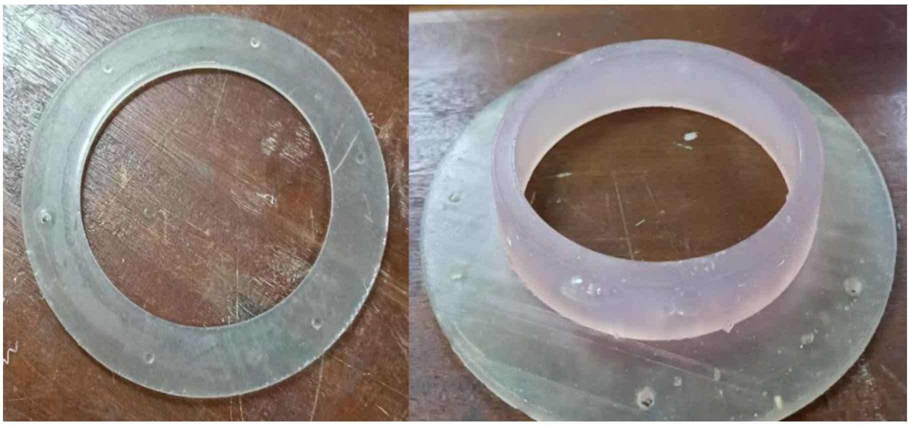

Figure 8 The Preparation for Moulding Process

Figure 9 The Circular Sleeve for Glove Compartment

The first time, the silicon never cured, and it remained sticky for a week. The second time, the mixture dried within a minute, making it impossible to pour it onto the glass surface. Later, it was determined that the measuring inaccuracy was due to a lack of sensitivity, necessitating a near-precise amount of hardener for the process to go smoothly; once this was corrected, the curing process ran well. After two days, the cured silicon mould is removed, and before moving on to the next phase, the cured silicon mould is cleaned because a significant amount of mould release wax will have accumulated on its surface.

As the silicon mould is somewhat flexible and will conform to the surface, a crooked item will be produced if it is not placed on a flat surface for the next step. Then, polyester and 1.5 percent MEKP (hardener) are combined based on the part's weight, and the mixture is put into the silicon mould. Because polyester is not as sensitive as epoxy, the percentage of MEKP can be varied according to personal liking. However, before mixing more than 2 percent

MEKP, component shrinkage must be taken into account. The percentage of MEKP required can also be affected by the temperature, with a hot day requiring less hardener than a cold day. Typically, the curing process takes around 5 hours, but during the manufacturing process, it was discovered that most of the time, the part was entirely cured in only 3 hours, which hastened the production process. Using a chisel and sandpaper, the surfaces of the cured parts were eventually polished and smoothed to provide a polished and smooth appearance. This procedure was continued until the required quantity of glove compartments had been produced.

Next, the glove compartment contains tear-resistant medical-grade gloves of traditional design and composition. The gloves have a reinforced portal and tubular sleeves so that patients can be treated without being exposed to the environment. This glove was purchased from an online retailer because it is difficult to manufacture something of this quality in a basic workshop. It must be robust enough to survive all possible hand movements, as it is one of the most vulnerable regions to puncture, which renders the portable worthless until it is replaced. This glove is expensive, so it must be used with care. If it must be replaced due to normal wear and tear, it defeats the objective of creating a less expensive portable isolation device for the entire body. The final component in the glove compartment is the screw and bolt that maintains the integrity of the previous three components. In Figure 8, there are six holes encircling the circular sleeve. The glove is inserted in between the upper and lower sleeve and the nut, and both are tightly but not excessively tightened so as not to harm the sleeve. This protects the integrity of the device and prevents the isopod from leaking from the outside.

The side board of the isopod is consist of two part which are back and front board. Back board and front board is the spine of the isopod where it gives support and helps to retain its shape. The front board is the one located near the patents head where the blower and the HEPA filter is mounted together with the electrical system. According to studies, the patient should be situated close to the air supply, as this will help flush away infectious pathogens as soon as they are produced. This is feasible when air moves from the zone with the least contamination to the zone with the most contamination [75]. The blower placement is directly above and this give the patient fresher air to breathe comfortably which also reduce the stagnant air flow areas. While the back board is placed near the patient's leg and there is also a HEPA filter is placed as the air outlet.

Each board has comparable dimensions, but the filter and glove compartment holes are positioned differently. It is simpler this way since the same technique may be used to create both boards, and these components can be manufactured without a mould. First, the fibreglass mat is measured and cut to the desired dimensions and quantity. The polyester and 1 percent MEKP are then thoroughly combined as a bonding agent between each fibreglass mat. The fibreglass mat is then put on a level glass surface and the polyester mixture is rubbed over it with a paintbrush until the necessary thickness is attained. The fibreglass was allowed to cure for 48 hours to ensure the construction of a robust framework. Initially, we intended to utilise a different material to reduce the cost of this component, but we came onto the flax composite, which turned out to be more difficult to produce. The pieces of fibreglass that had to be removed to get the component were measured and labelled. This technique was done for the second board, and sandpaper was used to give both pieces a nice finish.

The greatest component of the portable full-body isolation pod is the translucent vinyl-covered plastic sheeting that links the front and rear boards. This component, which resembles an extended tube, serves as a barrier between the exterior and inside environments. This section covers the majority of the isopod's cavity and is colourless, transparent, and airtight. It is essential that the plastic sheet be compatible with x-rays, and it is preferred that the sheet be lightweight and resistant to tears and punctures.

The most important component is selecting the optimal thickness, which typically ranges from 5 to 25 millimetres, with 5 millimetres chosen for the isopod in order to save costs and make it lighter. This thickness was ideal, and heavy-duty plastic sheet is unnecessary since vinyl sheet is fairly resilient. First, the dimensions are marked on the vinyl sheet, which is the simplest and quickest step in the production of this component. Cut larger than necessary for safety purposes, since the extra material may be removed afterwards. Since this barrier is exceedingly flexible, difficult to retain its form, and physically weak, the transparent vinyl sheet is reinforced with aluminium strips.

The vinyl sheet is inflated, so four metal strips are adhered to it to maintain its shape. The metal was bent into a semicircle that will have a curve similar to the front and back boards. By doing so, it will retain its form and prevent the vinyl sheet from falling onto the patient, since the volume of the cavity will reduce as the internal pressure decreases, therefore drawing the vinyl sheet inside.

Aluminum is used for the isopod's ribs due to its low weight, high corrosion resistance, and ease of machining. It is also nonferrous, which makes it nonmagnetic and safe for use with MRI and other diagnostic equipment (X-ray, ultrasound, etc.). The production of metal strips began by measuring an aluminium sheet and cutting it into several strips. Then, a hand grinder and power brush were used to give the polished finish. Finally, the aluminium surface was washed off with a clean towel to remove any leftover metal deposits.

As illustrated in Figure 10, the bedding for the portable full-body isolation pod is a tarpaulin sheet. Tarpaulin sheets are inexpensive, water-resistant, and lightweight. They consist of strands of woven polyethylene (PE), polypropylene, or another polyolefin material. More cross-weaves per square inch result in greater strength and longevity. Due to its water-resistance, this is merely the basis of the bedding, and patients should not have direct touch with it. Therefore, some soft and absorbent material will be put on top. The tarpaulin sheet is durable and resistant to tears and punctures, making it perfect for outdoor usage, since the isopod may be put on rough surfaces such as asphalt roads or sharp surfaces such as gravel roads. This material requires less fabrication since we purchased one that was already created and of high quality and industrial standard. Before being used for the assembly, it was simply washed with soap and water to eliminate dirt, and then dried.