University of Southern Queensland

Faculty of Engineering and Surveying

Design of a Microclimate Ventilation System

A dissertation submitted by

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ABSTRACT

Apart from commercial users, the Singapore Civil Defense Force and the Singapore Armed Forces use protective garments for protection against chemical and biological hazards. The use of protective clothing generally increases the risk of heat stress and hyperthermia by impairing the capacity for evaporative heat exchange from the body to the environment. Local studies have shown effective working time in these protective suits to be unacceptable short. Current microclimate cooling strategies adopted fall short of their objectives. Until a more suitable imported system could be used in the tropical climate with high humidity level of more than 90 per cent, there is a need for an interim solution that is highly affordable yet more effective than the current cooling systems in use.

The Microclimate Ventilation System proposed in this report was able to use with an entire family of filters and combinations of desiccant cartridges for protection against particulates, toxic gases and vapours. The conditioned air with humidity level below 20 degree Celsius was supplied to the user to provide some respite. The recommendations for further improvement and research on the design of the microclimate ventilation were also listed in the report.

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I further certify that the work is original and has not been previously submitted for assessment in any course or institution, except where specifically stated.

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Date

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GLOSSARY

Absorption	Absorption is when a substance is chemically integrated into another. When you drink a glass of water, you are absorbing it, as the water becomes part of you.
Adsorption	Adsorption is when one substance is being held inside another by physical bonds. If you spill a glass of water on your shirt, it is adsorbed as the fibers will hold the water until heat dries out the shirt.
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
Dehumidification	The removal of water vapours from the air. Dehumidification can be accomplished by cooling an air stream to below its dew point temperature causing the condensation of vapour or by desiccant adsorption resulting in removal of humidity from air in the vapour phase.
Desiccant	Generally, a hygroscopic substance such as silica gel, molecular sieve, activated alumina, etc. having the ability to absorb moisture from air and be reactivated (regenerated) by thermal or other means without loss of

	physical properties. Desiccants are used to maintain a dry (dehumidified) air stream or environment. Some salts, such as lithium chloride and calcium chloride are utilized as desiccant, these are known as absorbers.
Humidity	Water Vapour contained in air. Expressed as specific relative or absolute humidity. Common units of measure are: percent relative humidity (RH), partial vapour pressure, grains of moisture per pound of dry air (GPP), dew point or humidity ratio (W). The amount of vapour that air can hold is a function of the air temperature.
NATO	North Atlantic Treaty Organisation
Relative Humidity	It is the ratio of the mass of moisture in the air, relative to the mass at 100% moisture saturation, at a given temperature.
Laminar Flow	A laminar flow is one in which the fluid particles move in smooth layers, or laminas.
Thermosets	A special group of polymers that decompose rather than melt upon heating. They are normally quite brittle

	due to a relatively rigid, three-dimensional network structure (e.g., polyurethane)
Elastomers	Natural or synthetic plastics that are comprised of molecules with spring-like coils that lead to larger deformations (e.g., natural rubber, silicones).
Conduction	The process of losing heat through physical contact with another object or body. For example, if you were to sit on a metal chair, the heat from your body would transfer to the cold metal chair.
Convection	The process of losing heat through the movement of air or water molecules across the skin. The use of a fan to cool off the body is one example of convection. The amount of heat loss from convection is dependent upon the airflow and the water flow over the skin.
Radiation	Is a form of heat loss through infrared rays. This involves the transfer of heat from one object to another, with no physical contact involved. For example, the sun transfers heat to the earth through radiation.
Evaporation	The process of losing heat through the conversion of water to gas (evaporation of sweat).

Latent Heat of Vaporization	This takes place when sweat changes its state from liquid to gaseous.
Vasoconstriction	Is the narrowing (constriction) of blood vessels. When blood vessels constrict, the flow of blood is restricted or slowed.
Static Pressure	Is the pressure exerted by a fluid at rest.

CHAPTER 1 INTRODUCTION

1.1 Outline of the study

Military, Civil Defence, Law Enforcement and Medical personnel require high level protection when dealing with chemical and biological threats in many environments ranging from combat to urban, agricultural and industrial accidents. Current protective clothing is based on full barrier protection, such as hazardous material (HAZMAT) suits, or based upon permeable adsorptive protective garments such as the U.S. Military protective over-garments. These permeable adsorptive protective garments are usually made of low air permeability which possessed an inherent problem of excessive thermal loading. In Singapore, the problem is exacerbated by the tropical climate. The purpose and scope of this study is detailed in section 1.4 Research Objectives.

1.2 Introduction

Low air permeability protective garments have been used commercially and in the military for protection against chemical and biological hazards. Such garments are often heavily padded or made of non-porous material. Acting as a layer of thermal insulation, a “greenhouse effect” occurs within the garment whereby a build-up of ambient and body heat occurs in air pockets between the user’s body and the garment. Without an effective exhaust for this heat, the resultant thermal load would rapidly overwhelm the body temperature regulating mechanism, leading to heat stress related aliments. Work has to be suspended in order to avoid the onset of heat related injuries.

Both operators and manufacturer of protective garments continually seek solution for the removal of this heat load. Characteristically, these solutions need to offer a high degree of portability, ruggedness and lightweight qualities. There are two approaches to this:

1) Passive Cooling;
2) Active Cooling.

1.2.1 Passive Cooling

Passive Cooling: The aim of this mode of cooling would be to improve the gas permeability and more importantly, reduce the insulation factor to levels found in typical combat fatigues. Unfortunately, the suits which have met this target are recommended for wear as a jacket and trousers over combat fatigues, effectively doubling the total heat stress. Also, if water vapour were to be able to leave easily, the reverse could be possible regarding the entry of chemical warfare (CW) agents. Moreover, the effectiveness of these suits could be easily be compromised when damped with perspiration.

Passive systems generally do not need an outside source of energy to proceed. Passive microclimate control can be an excellent means of controlling humidity variations in a case. The Naval Health Research Center, San Diego

State University and University of Kentucy have investigated the effects of passive microclimate cooling, specifically the ice vest design (ICE), as a countermeasure to prevent or delay the onset of heat strain during work performed in a high heat environment. It was concluded that passive microclimate cooling maintains cardiovascular stability in the heat by eliminating cardiovascular drift.

1.2.2 Active Cooling

Active Cooling: These cooling systems reject heat from the human body using air (ambient or conditioned), liquid (ice or aqueous solutions) or phase change materials (PCM) as a working medium. This active cooling system can be further subdivided into 2 categories. The first covers the removal of heat (evaporative cooling) to a temperature not exceeding that of the ambient conditions. The second refers to artificial means of cooling air to temperatures below ambient conditions.

Active microclimate control systems almost always involve the mechanical supply of air to maintain the desired humidify limits in an enclosed space. Most systems use fans or pumps to move air within, to, or from the system's components; an external energy sources which may contain refrigeration compressors, steam generators, desiccant dryers, heaters, misters, bubblers, dampers, valve, gas, gas filters and mechanical or electronic controls. Active humidity control can be more efficient than passive methods – think of a sponge compared to a pump.

1.3 The Problem

In warm environment, a naked human body loses heat through the evaporation of perspiration off the surface of the skin. This is a highly effective method of heat removal. A large amount of this heat is lost as latent heat of vaporization. This takes place when sweat changes its state from liquid to gaseous. The loss of this heat is the main factor behind the cooling effect one gets when one perspires through the pores of one's skin. The rest of the heat loss occurs through conduction (sweat leaving the skin in its liquid state e.g. through wiping or dripping off), radiation (loss of heat over a temperature gradient) and convection (loss of heat to air moving over the skin).

Although evaporative heat loss is the most efficient method of cooling in humans, clothing worn over the skin lowers its cooling efficiency. The porosity of the clothing fabric also affects the rate of evaporative cooling. Lower air permeability protective garments, often covering the entire body and affect the evaporative cooling mechanism very significantly. This is to the extent of forcing the body to rely on the less effective mechanism of conductive cooling to lose heat.

Air pockets are inadvertently formed between the skin and the clothing worn. The presence of these air pockets forms the microclimate. In loose fitting clothing, the volume of air in the microclimate can become substantial. In the case of low air permeability clothing, this still air trapped between the body and the garment form a layer of thermal insulation, impeding the dissipation of heat from the body. Initially, a small amount of heat is lost through evaporative clothing. The evaporation of sweat is however, quickly saturates the microclimate with moisture. This renders the evaporative cooling mechanism within a short time. The body begins to sweat profusely in an attempt to lose heat through conduction. At the same time, heat is constantly radiated from the body into the microclimate. Radiant heat also enters the microclimate from the external environment. This heat is trapped by the insulative properties of the garment and diminishes the initial temperature gradient established between skin and microclimate.

The rise in temperature of the microclimate results in a corresponding increase in the body temperature of the person wearing the suit. Prolonged exposures to such conditions can result in heat stress related illnesses. As the mean body temperature of the person rises, the person will experience general fatigue. Symptoms of heat exhaustion and heat stroke develop soon after and the person becomes at risk of collapse.

To date, several studies conducted in North America, Europe and Australia have examined the effects of heat load in low air permeability protective garments on the human thermoregulatory response. These studies examined the effects of climate conditions with temperatures up to 40°C. Although this is higher than the mean temperature experienced in Singapore, it is important to note that these studies seldom considered humidity levels above 50%. However, this is not the case in Singapore, which regulatory encounters humility levels exceeding 90%. This explains why some imported microclimate cooling devices are not suitable for use in Singapore.

1.4 Research objectives

Roger Masadi, Robert F. Kinney, and Cynthia Blackwell from the US Army Natick Research, Development and Engineering Centre Operation Desert Storm (ODS) have highlighted a critical military deficiency that being the inability to perform many essential battlefield missions in hot, NBC (Nuclear, Biological, Chemical) environment. A microclimate cooling (MCC) system provides a major operational capability in a hot environment while significantly reducing heat stress related injuries and water consumption.

The aim of this research is to Design of a Microclimate Ventilation System that would be able to offer local users (Singapore) of low air permeability protective clothing some respite using the Evaporative Cooling Concept. The specific objectives are as follows:

1) To fabricate a prototype that can deliver conditioned air at an airflow rate of 7 to 8 liters per second;
2) To employ a modular concept in design;
3) It should be low weight (3 to 4 kg);
4) To overcome a static pressure of 95.4mm H_2O (to accommodate most of the NATO standard gas mask filters).

1.5 Concluding remarks

The research is expected to result in a better understanding of the current types of microclimate ventilation cooling system available in the market.

A review of literature for this research will identify which is the better cooling concept. The outcome of this study will be used for the design of a microclimate ventilation system.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter will review the literature to establish the need for the types of cooling concept, the specification requirement and the various components to build the microclimate ventilation system.

2.2 Microclimate Ventilation System

The Microclimate Ventilation System is a garment and / or device worn by the individual to reduce thermal burden associated with physical activity, temperature, solar load, humidity while on maneuvers or encapsulated in protective clothing. The advantages and shortcomings of the current methods of microclimate ventilation systems available in the market were reviewed. The cooling mechanism of the human body under normal circumstances was studied to determine the type of cooling concept to adopt for the design of the system.

Microclimate cooling systems can be categorized into 7 types: 1) Umbilical Systems, 2) Convection Cooling, 3) Chilled Fluid Systems, 4) Ice Packs, 5) Vapour Compression Systems, 6) Phase Change Material (PCM) and 7)

Evaporative Cooling Systems. At present, most microclimate cooling systems are produced in North America, Europe and Australia. To date, no single type has emerged as a front runner in the market. This is probably because each type has its accompanying advantages and drawbacks. The selection of cooling systems is often based on the demands specified by the end user.

1) Umbilical Systems – These systems can simply be described as delivery hoses transporting conditioned air to the microclimate from an air conditioning system. These are commonly employed in enclosed working environment such as in clean room facilities. The advantages of this system are a) Continuous supply of chilled fluid and b) Long duration cooling possible. The disadvantages of this system are a) Mobility limited by compressor location and the umbilical length, b) Heavy power consumption, and c) Heavy substantial combined weight of more than 10kg.

2) Convection Cooling – These systems are equipped with blower assembly that forces air into microclimate facilities. The advantages of this system are a) Highly portable, b) Relatively cheap, and c) Light weight. The disadvantages of this system are a) Limited cooling capacity (ambient and above) and b) Ineffective in hot weather.

3) Chilled Fluid Systems – These systems provide personal cooling to personnel wearing insulative protective clothing in high heat

stress environments. It usually consist of a pump assembly, which continually circulates chilled fluid (usually ice water) from a portable reservoir into hoses delivering the fluid close to the skin of the body. Metabolic heat from the wearer is transferred to the fluid and constantly recycled through the reservoir. This system becomes ineffective when its fluid has been raised to that of ambient. The advantages of this system are a) Garment can be worn close to the skin, b) Relatively long duration cooling, and c) Good heat removal capability. The disadvantages of this system are a) Condensation causes dampness and loss cooling efficiency, b) Requires replenishment of chilled liquid, and c) Substantial weight depending on volume of liquid used.

Figure 1: Chilled Fluid System

4) Ice Packs – Microclimate cooling in its simplest and crudest form exists in the form of placing packs of ice, sometimes doped with

starch, in pockets strategically positioned against the torso region. The pockets can be found on the inside of a vest that is worn close to the body. Cooling is achieved via conduction. Heat is lost from the skin surface to the icepacks, which remain at 0 ^{0}C for a brief period of time. The passive cooling ice vest reduced rectal and skin temperatures, heat rate and sweat rate. Water has a high heat capacity that allows it to absorb a lot of heat. It has a low profile, requires little maintenance and is not susceptible to mechanical problems. The advantages of this system are a) Inexpensive, b) Portable, and c) Rechargeable. The disadvantages of this system are a) May causes vasoconstriction, b) Requires additional insulation from skin, and c) Requires freezer for recharge.

Figure 2: Vested Ice Pack

5) Phase Change Systems (PCM) – These systems are made up of paraffin or ice-based materials that absorb body heat in the vest/hat/neck warp configuration. They require the use of a refrigerator, freezer, or ice chests to re-charge the phase change material. Additional, phase-change systems require a cooler to transport the phase change packets. It is an improved version of the ice pack concept; this system uses chemicals in place of water. The chemicals possess superior heat capacity properties and more favourable phase change temperatures. Due to their higher operating temperature, phase change material can be recharged more easily than ice packs. The advantages of this system are a) The chemical use is lighter than water, b) Can be activated without electricity (simply submerge in ice water), c) Lasts longer than ice (approximately 3 hours), d) Delivers constant temperature, e) Not affected by outside temperatures or humidity, f) PCM packets are durable and reusable.

Figure 3: Aquality Deluxe PC200 Phase Change Vest

6) Evaporative Cooling System – Such systems rely on latent heat loss that occurs when sweat is evaporated off the skin. The concept involves the conditioning of air by way of dehumidification. This enhances the effectiveness of the evaporative mechanism. The advantages of this system are a) Relatively inexpensive, b) Light Weight, c) Long hour of working duration; d) Modular design allows greater flexibility and adaptability. The disadvantages of this system are a) Relatively high power consumption, b) Inability to cool below ambient temperature, c) Requires supply of desiccant cartridges , and d) Little room for technological improvement.

7) Vapour Compression Systems – These systems are miniaturized, portable versions of convectional air conditioners. Vapor compression technology works like a refrigerator or air conditioner, with a compressor, condenser, evaporator, thermal expansion tube, fan and pump working to move heat to the ambient environment. In microclimate cooling, liquid is chilled and pumped through a vest lined with a network of tubing, removing excess body heat (U.S. Army Soldier Systems Center Public Affairs office, January 2006). The advantages of this system are a) Good cooling capability, b) Good portability, and c) Long working duration possible. The disadvantages of this system are a) High power consumption, and b) Expensive.

2.3 Concluding remarks

Various microclimate ventilation systems are used for different needs. As such there is no single method that is superior over the others. Evaporative cooling concept was adopted for the design of the microclimate ventilation system since it is one of the most effective means of cooling which requires a lot less energy to promote cooling than via other means.

CHAPTER 3 RESEARCH METHODOLOGY AND THEORETICAL ESTIMATIONS

3.1 Introduction

The methodology adopted is sought through literatures and review on previous studies of the microclimate ventilation system development to have a better insight of current systems available in the market.

The type of cooling concept had been chosen and theoretical estimations such as the ideal airflow, heat load within microclimate and degree of dehumidification was developed after the current cooling methods were studied in detailed. The main components and materials selection were analyzed using CAD modeling and through calculations. This project requires competence in engineering knowledge such as fluid mechanics and solid works software.

This chapter introduces the rationale behind the evaporative cooling approach. This will be followed by a description of the way certain system specifications were derived. The most commonly used indicator of thermal comfort is air temperature – it is easy to use and most people can relate to it. But although it is an important indicator to take into account, air temperature alone is neither a valid nor an accurate indicator of thermal comfort or thermal stress. Air temperature should always be considered in relation to other environmental and personal factors.

The six factors affecting thermal comfort are both environmental and personal. These factors may be independent of each other, but together contribute to a worker's thermal comfort.

3.1.1 Environmental factors

The environments factors are:

- Air temperature
- Radiant tempertaure
- Air velocity
- Humidity

3.1.2 Personal factors:

The personal factors are:

- Clothing Insulation
- Metabolic heat

3.2 Reasons for choosing the Evaporative Cooling Concept

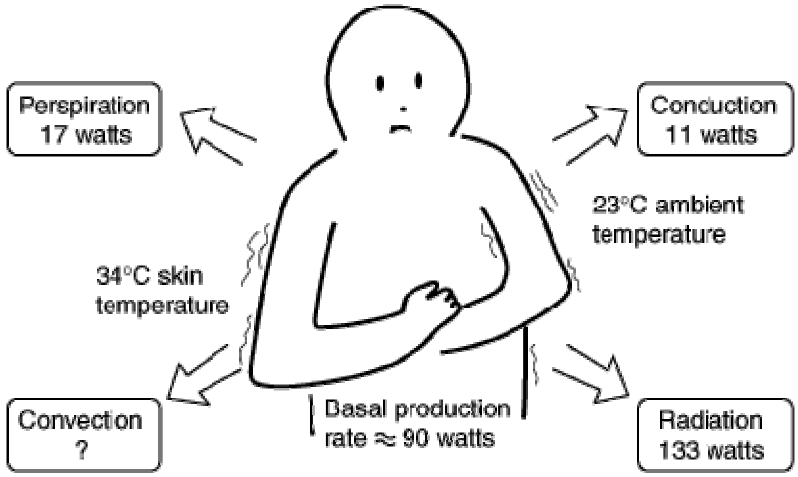


Figure 4: Heat transfer mechanisms in cooling human body

(Source of picture: hyperphysics.phy-astr.gsu.edu)

The above figure show a simplified model of the process by which the human body gives off heat. Even when inactive, an adult male must lose heat at a rate of about 90 watts as a result of his basal metabolism. One implication of the model is that radiation is the most important heat transfer mechanism at ordinary room temperatures. This model indicates that an unclothed person at rest in a room temperature of 23 Celsius or 73 Fahrenheit would be uncomfortably cool.

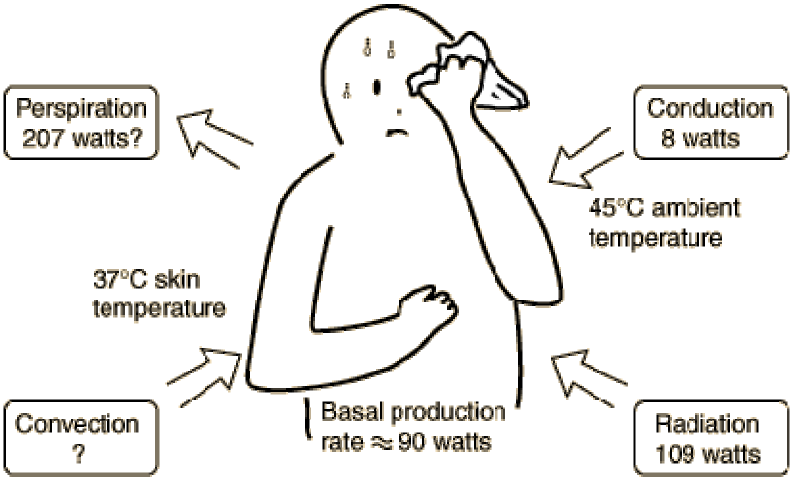


Figure 5: Heat transfer mechanisms in cooling human body above body temperature

(Source of picture: hyperphysics.phy-astr.gsu.edu)

When the ambient temperature is above body temperature, then radiation, conduction and convection all transfer heat into the body rather than out. Since there must be a net outward heat transfer, the only mechanisms left under those conditions are the evaporation of perspiration from the skin and the evaporative cooling from exhaled moisture. At a temperature of 45 Celsius or 113 Fahrenheit the evaporation process must overcome the transfer of heat into the body and give off enough heat to accomplish a 90 watt net outward flow rate of energy. Because of the body's temperature regulation mechanisms, the skin temperature would be expected to rise to 37°C at which point perspiration is initiated and increases until the evaporation cooling is sufficient to hold the skin at 37°C if possible. The cooling effect of perspiration evaporation makes use of the very large heat of vaporization of water. As part of the physiological regulation of body temperature, the skin will begin to sweat almost precisely at 37°C and the perspiration will increase rapidly with increasing skin temperature.

If part of a liquid evaporates, it cools the liquid remaining behind because it must extract the necessary heat of vaporization from that liquid in order to make the phase change to the gaseous state. It is therefore an important means of heat transfer in certain circumstances, such as the cooling of the human body when it is subjected to ambient temperatures above the normal body temperature.

Because of the large heat of vaporization of water, the evaporation from a liquid surface is a very effective cooling mechanism. The human body makes use of evaporative cooling by perspiration to give off energy even when surrounded by a temperature higher than body temperature.

As one of the basic heat transfer mechanisms, convection involves the transport of energy by means of the motion of the heat transfer medium, in this case the air surrounding the body.

Under the normal circumstances, the human body relies on the mechanism of evaporative cooling to lose heat. Evaporative cooling has been identified as one of the most effective means of cooling, physiologically speaking. It relies on the latent heat loss that results when droplets of perspiration evaporate from the surface of the human skin to cool the body. More than 70% of heat loss from the body is accomplished through evaporative cooling. Since this is a naturally occurring phenomenon, a lot less additional energy is required to promote cooling than via other means. Apart from being more economical than artificial cooling, it should also result in a lighter device, which would present a lower physiological load on the operator. Being less complicated in design and few components (with moving parts), an evaporative cooling system could be more rugged and reliable.

However, the trade off is in the extent of evaporative cooling achievable (not lower than ambient temperature). It has to be noted that the effectiveness of evaporative cooling is often referred to in the context of a naked human body. The efficiency of this mode of cooling drops substantially when successive layers and types of clothing are introduced. Ideally, evaporative cooling should occur through exposed skin but this is not permissible in any degree when it comes to Nuclear, Biological and Chemical (NCB) protection.

The challenge would be to continually condition the air quality with the microclimate by maintaining relatively low humidity levels. The low humidity would facilitate the evaporation of sweat, this encouraging the body to lose heat in the most efficient way possible. In term of the technology involved, it was a relatively low-tech undertaking, with a few barriers to overcome. A system based on the evaporative cooling concept could give the highest rate of success. Until a more suitable imported system could be used in the tropical climate with high humidity level of more than 90 per cent, the prototype based on the evaporative cooling approach would be able to offer local users of low permeability clothing some respite. Speaking in optimistic terms, further development of the prototype could also provide users in

Singapore with the option of an indigenously developed cooling system, which would have substantial cost and service support advantages.

3.3 Ideal Air Flow Rate

An airflow rate between 7 to 8 liters is commonly adopted for thermal comfort in ambient air cooling within a microclimate (Bomalaski et. al, (1995), Aviation Space Environment Medical, 66:745-750). According to the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), human thermal comfort is defined as, "… that condition of mind that expresses satisfaction with the thermal environment". This recommended figure refers to the air flow supplied to the entire microclimate including the head, torso, and limbs. For the purpose of the study, the cooling and ventilation was supplied only to the head region.

3.4 Required Static Pressure

An approximation for the total sum of the static pressure due to each of the major components was obtained. A mean figure was obtained in such a case since the prototype was selected to accommodate most NATO standard gas mask filters. Consideration was also given to the layout of ducting and connectors to be used in the prototype. The final figure obtained in Chapter 5 was 95.4 mmH_2O or 935.9 Pa.

3.5 Operating Temperature

The importance of estimating the operating temperature of the prototype is due mainly to the working temperature of the desiccant. It would be detrimental to exceed the optimal operating temperature of the desiccant. Exceeding the operating temperature opens the prospect of reversing the dehumidification process, thus contributing more moisture to the microclimate. It was expected that this temperature would only be reached within the desiccant cartridge and the blower motors. This temperature should not be confused with the temperature of the air supplied to the microclimate. Most of the heat from prototype (microclimate ventilation system) would be lost to the external environment.

3.6 Degree of Dehumidification

The degree of dehumidification could not be determined readily. The silica gel could dehumidify enclosed areas to humidity levels below 10% relative humidity. Since the method by which these values were obtained could not be established, the more expensive option of activated alumina, with its higher optimum temperature of about 60 °C was also considered as an alternative desiccant.

3.7 Dry Thermal Insulation of Clothing

The dry thermal insulation of the clothing ensemble intended for use was approximated with values from a book (Parsons, 1993). Body heat storage, which would be the majority contributor to the heat load within the microclimate, was taken as a mean figure of 120 W. Another significant source of heat would be from the solar radiation. The radiation exposure for the prototype would be set at 800 W, of which it was estimated that 30 W would be absorbed into the microclimate. This gave a final heat value of 150 W (Parsons, PIIS0003-4878(1999)00060-5).

$$E_{in} - E_{out} + E_{gen} = E_{st}$$

$$30 \quad - 0 \quad +120 \quad = 150 \text{ (W)}$$

where E_{in} represents energy input

E_{out} represents energy output (assumed nil due to thick insulation)

E_{gen} represents energy generated (by human body)

E_{st} represents energy storage (heat load)

3.8 Concluding remarks

Evaporative Cooling Systems rely on latent heat loss that occurs when sweat is evaporated off the skin. This concept involves the conditioning of air by way of dehumidification. This enhances the effectiveness of the evaporative mechanism. The approximations for air flow rate and static pressure were important for the process of blower selection. Since the working temperature of the desiccant is a main factor in estimating the operating temperature of the prototype, it is important to use a suitable type of desiccant for the prototype.

CHAPTER 4 MAIN COMPONENTS OF THE PROTOTYPE

4.1 Introduction

In keeping with the lightweight requirements of the prototype design, most of the components used were polymer-based material. Apart from the weight advantage, most thermoset and elastomer based polymers are chemically insert and resistant to corrosion due to chemical vapours. They are also thermally stable at the operating temperatures of the prototype. While keeping weight considerations in mind, efforts were made to keep the cost of non-essential parts low. For the evaporative cooling concept, the box diagram shown in figure 6 below could represent the basic design and its components. The details explanation of the components and its functions are illustrated section 4.3.

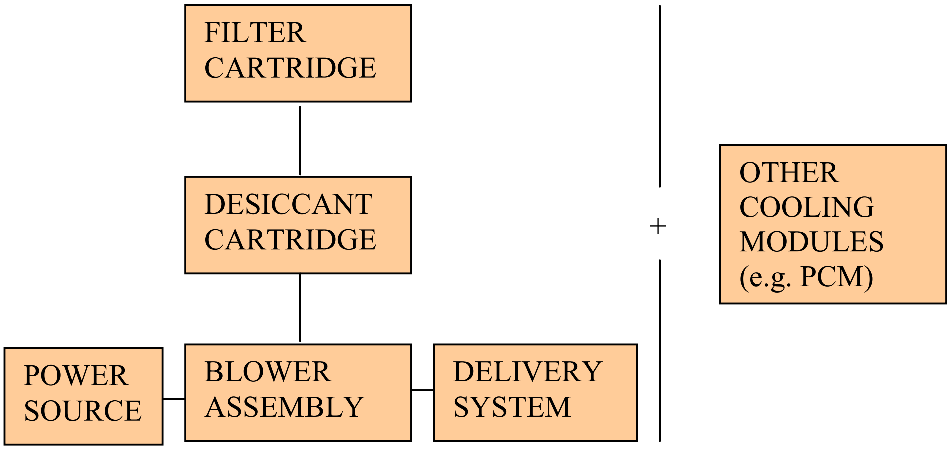


Figure 6: Box diagram of evaporative cooling prototype

4.2 Existing Microclimate Ventilation System

The existing system consists of two hoses which deliver conditioned air into the front and back of the low permeability suit. The figure 7 below shows an existing microclimate ventilation system which comprises of:

a) Filter cartridges,
b) Y-fitting joint,
c) Blower module,
d) Re-charger battery

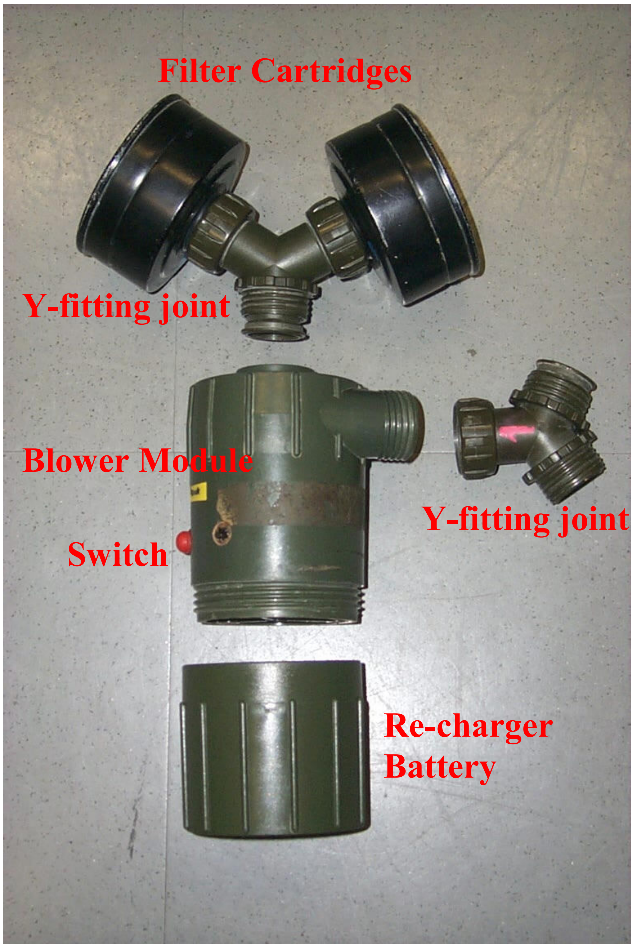


Figure 7: Picture of existing microclimate ventilation system

4.2.1 Filter Cartridges

The filter cartridges are used to protect against particulates, toxic gases and vapour, or a combination of both. A detail illustration of the function of the filter cartridge is shown Section 4.3.1.

4.2.2 Y-fitting joint

The existing microclimate ventilation system consists of two Y-fitting joint. One of the Y-fitting joint is to connect to the two filters. Since the current delivery system consists of two hoses which delivered conditioned air into the front and back of the low permeability suit, the other Y-fitting joint is connected to these two hoses.

4.2.3 Blower module

The blower module is used to blow the conditioned air through the delivering hose to the front and back of the low permeability suit

4.2.4 Re-charger battery

The battery is used to supply power to the blower. The battery lasts for 45 minutes and it can be recharged after use. There is an internal thread for the battery to fit into the ventilation system.

Figure 8: An existing re-charger battery

Figure 9: An existing Battery Re-charger

4.3 Main Components of the Prototype Design

4.3.1 Filter Cartridge

The filter is used to protect against chemical warfare agents. Chemical Warfare agents are classified into four primary categories. They are:

a) Chemical Warfare Blister Agents are chemicals that burn or blister the skin. These vesicants can also affect other parts of the body including internal air passages and organs. Mustard Gas and Lewsite are two common Blister Agents.

b) Chemical Warfare Choking Agents are chemicals that affect lungs and cause pulmonary edema which results in asphyxiation. Chlorine, Phosgene, and Diphosgene are common examples.

c) Chemical Warfare Blood Agents are chemicals that will interfere with the ability of the blood to carry oxygen, resulting in asphyxiation. Cyanogen Chloride and Hydrogen Cyanide are two common examples.

d) Chemical Warfare Nerve Agents are chemicals that affect the transmission of nerve impulses in the nervous system. These are some of the most toxic chemical agents. Sarin Nerve gas, Soman, Tabun and VX-Nerve gas are some of the common examples.

Figure 10: A filter cartridge

4.3.2 Desiccant Cartridge

4.3.2.1 What is desiccant and its function

Passive microclimate control systems generally use some sort of “moisture mass” medium that will buffer changes in humidity. An effective moisture mass holds a great deal of water relative to its own mass, and absorbs and gives it up freely. Silica gel is commonly used for this purpose and it can be a very powerful tool for maintaining and mitigating moisture changes when given adequate sealed case and enough silica gel.

Desiccant can be described as a polymer based tube (shell) containing straw like structures arranged in parallel to the sides of the desiccant main housing as shown in figures 17 and 18. It uses an activated alumina beads or Silica gel as the drying agents. The both ends of the desiccant main housing were covered by sieve like mesh as shown in figure 16 to keep the desiccants (straws like structure) in place.

Figure 11: Desiccant in straw like structure

Activated Alumina is an aluminum oxide that is highly porous and exhibits tremendous surface area. It is resistant to thermal shock and abrasion and will not shrink, swell, soften nor disintegrate when immersed in water. It is in the shape of a bead. The large surface area of the activated alumina bead maximizes the adsorption of moisture vapor. Based upon dryer design and operating conditions, dew points of -40° F and lower may be achieved with Van Air activated alumina. It is ideal for use in drying compressed air and gas in both large and small dryers.

Figure 12: Activated alumina bead

Silica gel is a granular, porous form of silica made synthetically from sodium silicate. Despite the name, silica gel is in a solid. Silica gel has a very strong affinity for water and will adsorb it in preference to most other substances. The silica gel does not undergo any chemical reaction during adsorption and does not form any by products.

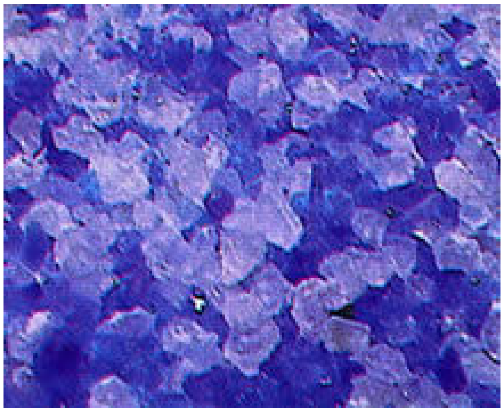


Figure 13: Picture of a Silica gel

4.3.2.2 Design considerations for desiccant housing

- The desiccant should be able trapped in the main body housing and not flow out of the inlet and outlet of the top and bottom cover. It means that when it is turn over from top to bottom, it will not leak out.
- The volume for the desiccant has to be considered so as to determine the amount of desiccant needed.

4.3.2.3 Desiccant housing

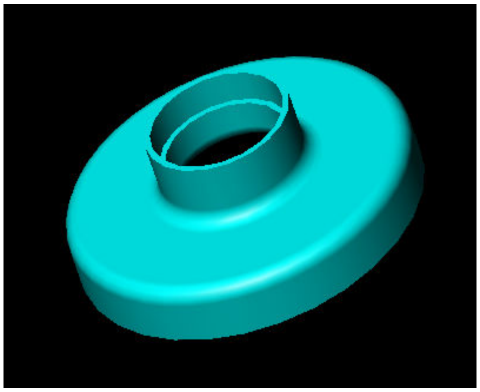
The desiccant housing is fabricated using the thermoplastic materials. The thermoplastic was used due to easy of processing and easily available. It comprises of five parts as shown from figures 14 to 22: (1) top covers, (2) stopper plate # 1, (3) main body housing, (4) stopper plate #2 and (5) bottom cover. The top cover comes with an inlet which has internal threads for the filter to screw onto it. The stopper plate #1 which has many small holes is for the air to flow to the main housing and at the same time keep the desiccants in place.

The main body housing comes with external threads on both sides of it. One of the sides is for the top cover to screw onto it whereas the other side allows the bottom cover to screw onto it. The main function of the main body housing is to contain the desiccant. It can also be described as a polymer based tube containing straw like structures arranged in parallel to the sides of the housing. The straw like activated alumina was used as the drying agents.

When the air is forced to pass through the main housing, the straws serve as diffusers to channel the air into the cross-section of the housing. Although it promotes laminar airflow through the housing, the friction arising from air passing over the surface of the activated alumina resulted in a significant increase in frictional losses.

For the stopper plate #2, this part is identical in design and function to stopper plate #1. It will allow the dry air to flow across it and flow into the blower assembly. The bottom cover comes with an outlet which will be connected to the Y-joint that are been connected to the blowers. The bottom cover at the same time will holds the stopper plate #2 in place.

The frictional losses due to the desiccant and its housing will be taken into account during calculation of the total system head losses of the system.



The Top Cover comes with an inlet. It has an internal thread for the filter to screw onto it.

Figure 14: Top Cover

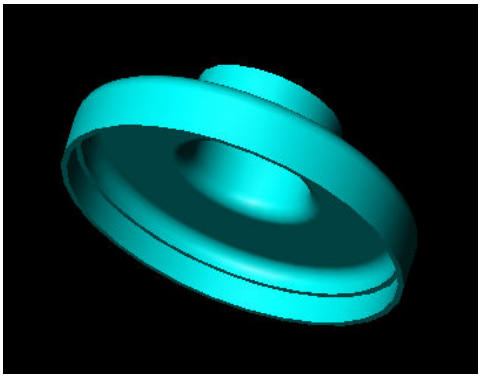
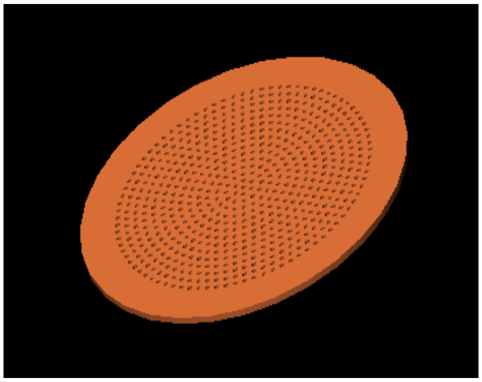
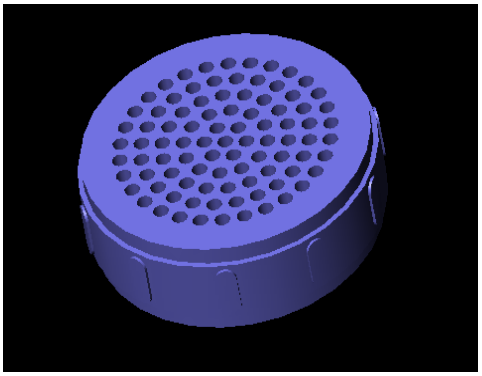


Figure 15: Top Cover



The stopper plate which has many small holes is to allows air to flow into the main housing and at the same time keep the desiccants in place

Figure 16: Stopper Plate



The main housing with many slots is to hold the straw like desiccants

Figure 17: Main Housing

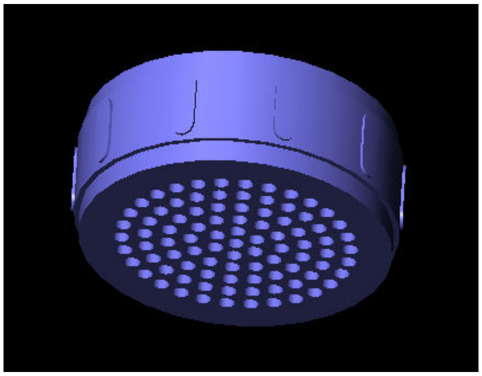
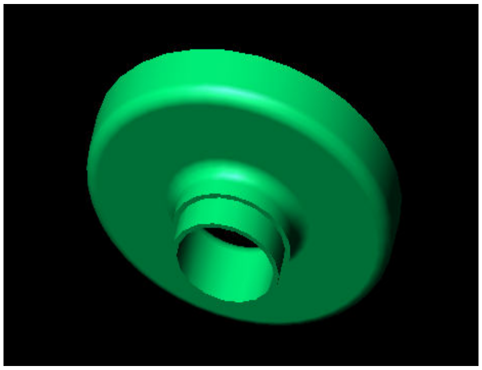


Figure 18: Main Housing



The Bottom Cover comes with an outlet with external threads so that it can connect to the fitting of the blower assembly

Figure 19: Bottom Cover

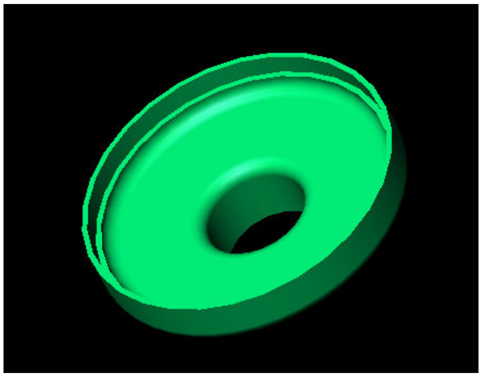


Figure 20: Bottom Cover

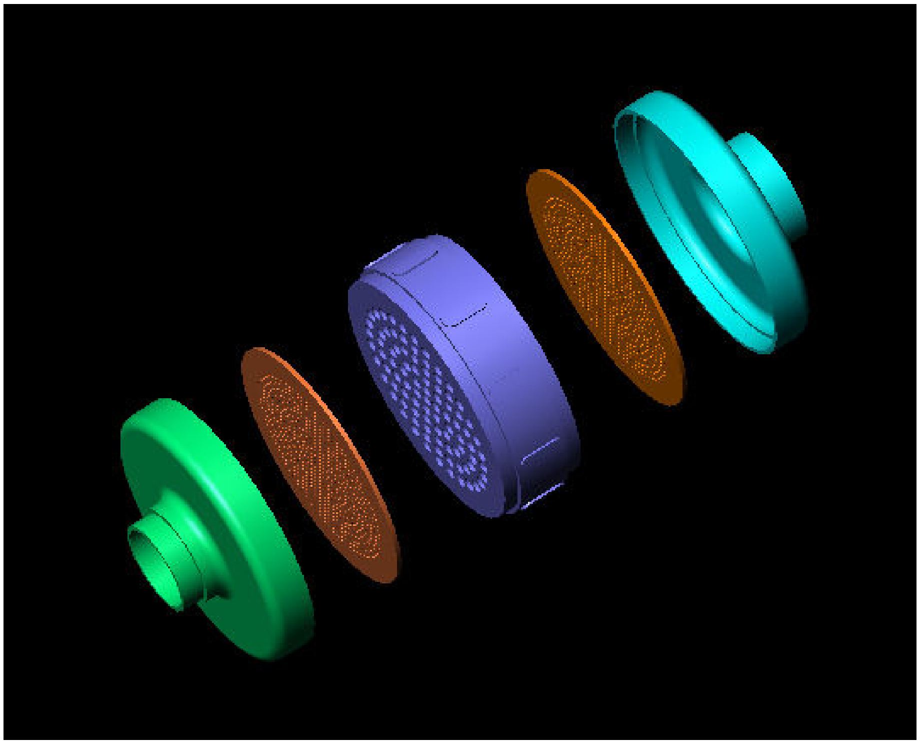


Figure 21: Assembly drawing for desiccant housing

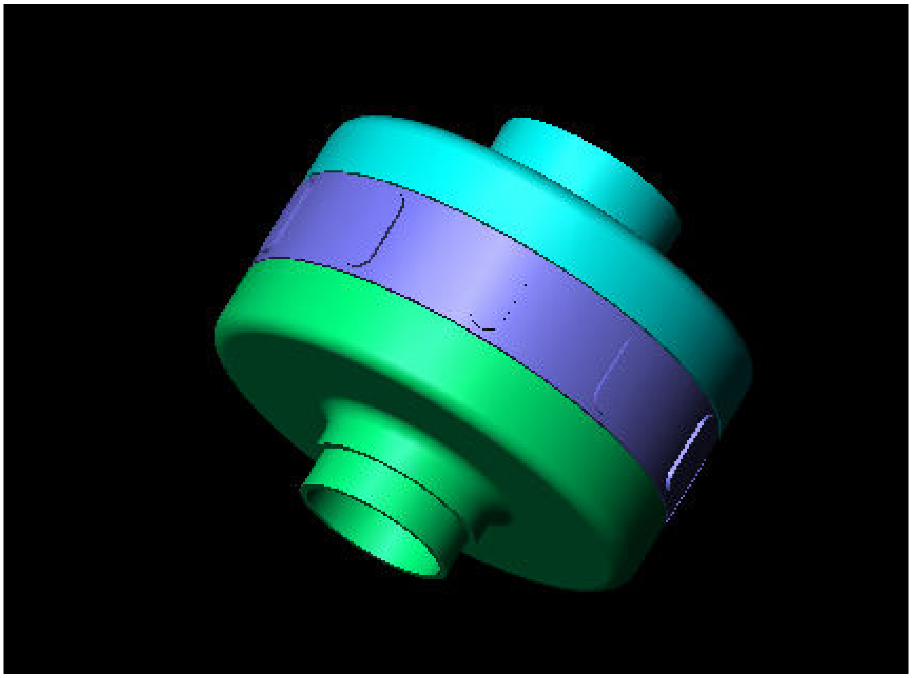


Figure 22: Desiccant Housing

4.3.3 Breathing tube assembly

Breathing tube transport breathable air between air supply devices and face mask or hoods. One end of the breathing tube is connected to the air filter unit and the other end is connected to the face mask or hoods.

Figure 23: Full Face Mask Assembly & (VNP1505-2) Breathing Tube Assembly

Figure 24: A delivery hose

4.3.4 BLOWER HOUSING FOR PROTOTYPE

The blower housing was designed after taken into consideration on the blower and fan selection in Chapter 6.

4.3.4.1 Design considerations for blower housing

- The Top Cover must come with a fitting for the desiccant housing to screw onto it
- The fitting must has a Standard 40mm x 1/7" NATO threaded
- The housing must be able to house two blowers
- The housing must be water resistance

4.3.4.2 Blower Housing

The Blower Housing consists of three parts, namely 1) Housing Cover, 2) Main Housing and 3) Housing Plate. The Housing Cover as shown in figures 25 and 26 comes with an inlet for the Y-joint fitting to screw onto it. This Y-joint fitting is where the two desiccant cartridges are screwed onto it. The main housing is to house the two blowers in place. The holes for the motors of the blower as shown in figure 31 are designed with some spaces clearance for heat dissipation. The Housing Plate as shown in figure 29 was designed with two holes in the center for the blower wiring to pass through it so as to connect to the batteries pack. There will be one gasket laid in between the Housing Cover and the Main Housing. Another gasket will be laid in between the Main Housing and the Housing Plate. The function of this gasket is to ensure the Blower housing are tight fit to prevent water and chemical vapours from entering into the blower compartment.

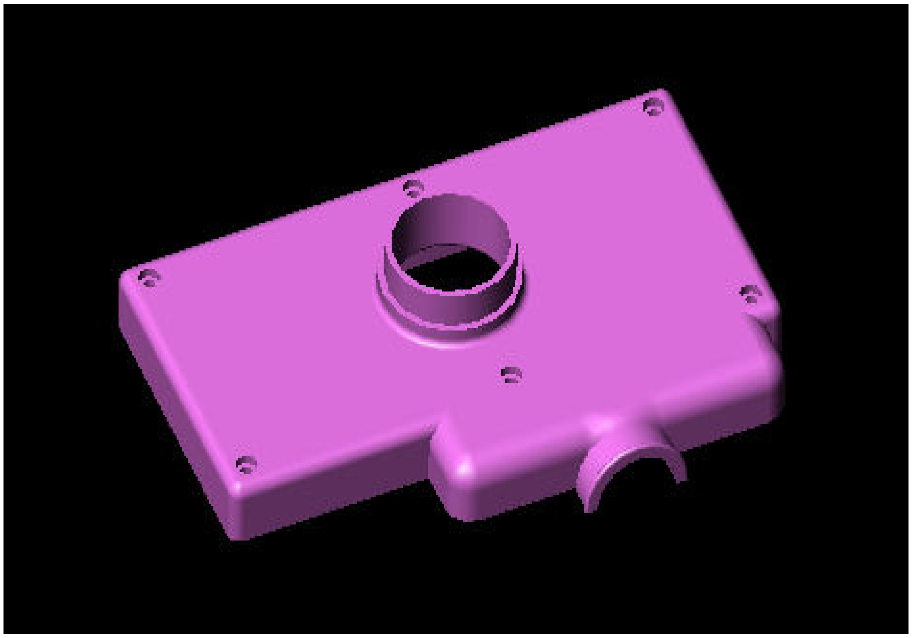


Figure 25: Top view of the Housing Cover

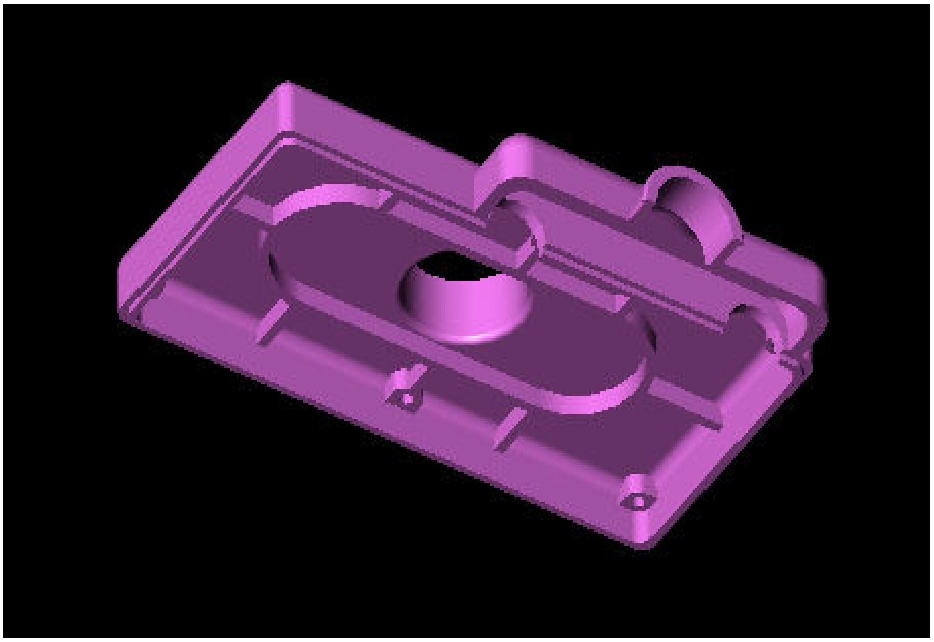


Figure 26: Bottom view of the Housing Cover

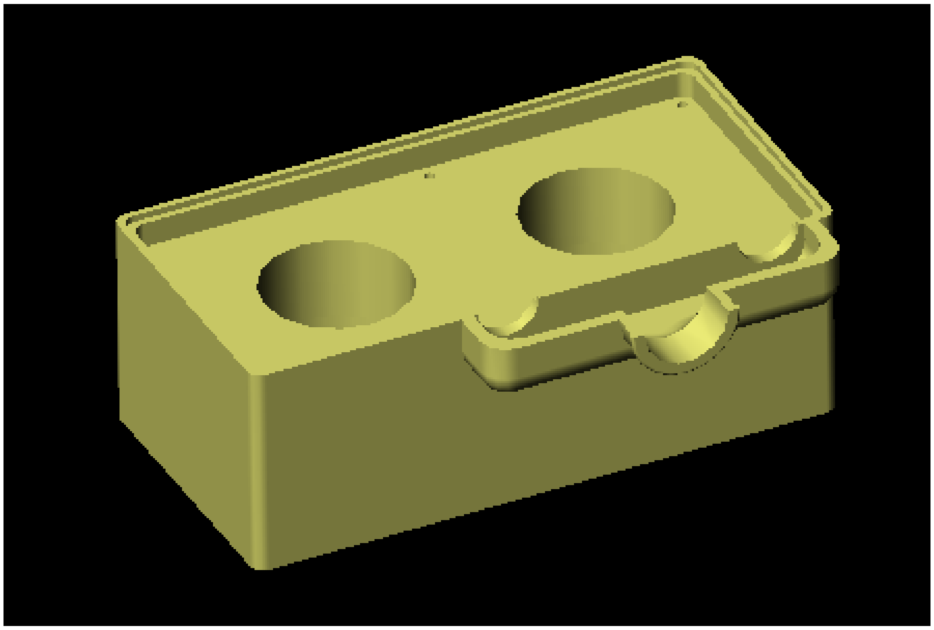


Figure 27: Top view of the Blower Housing

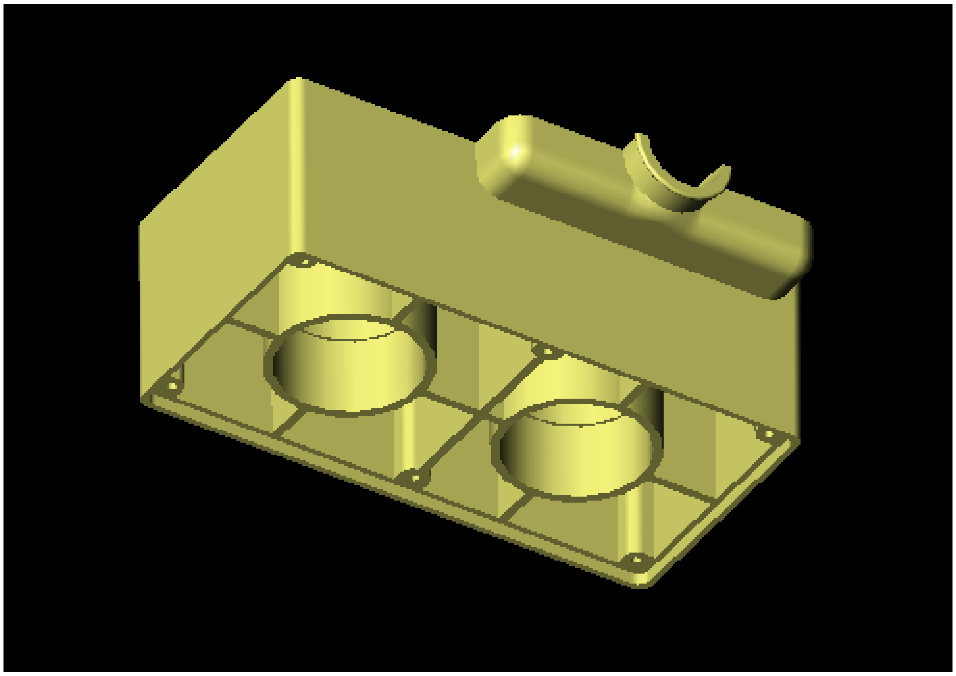


Figure 28: Bottom view of the Blower Housing

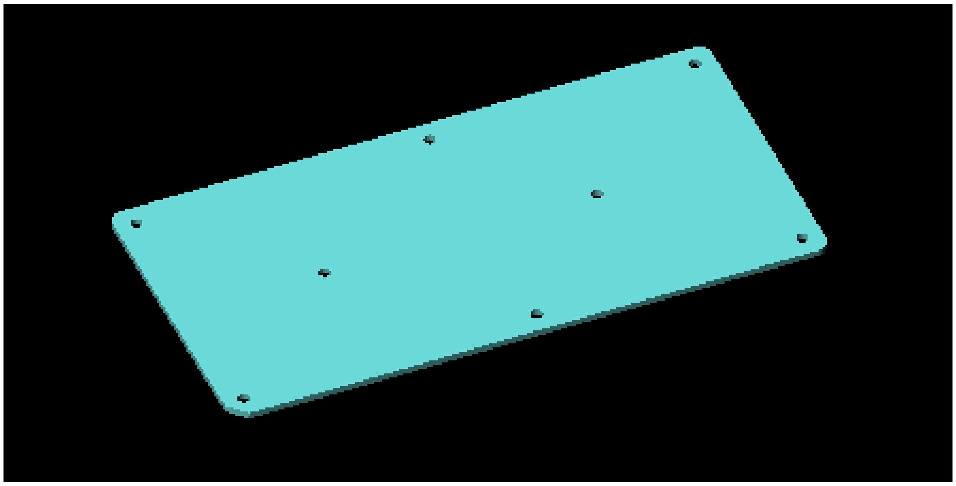


Figure 29: Housing Plate

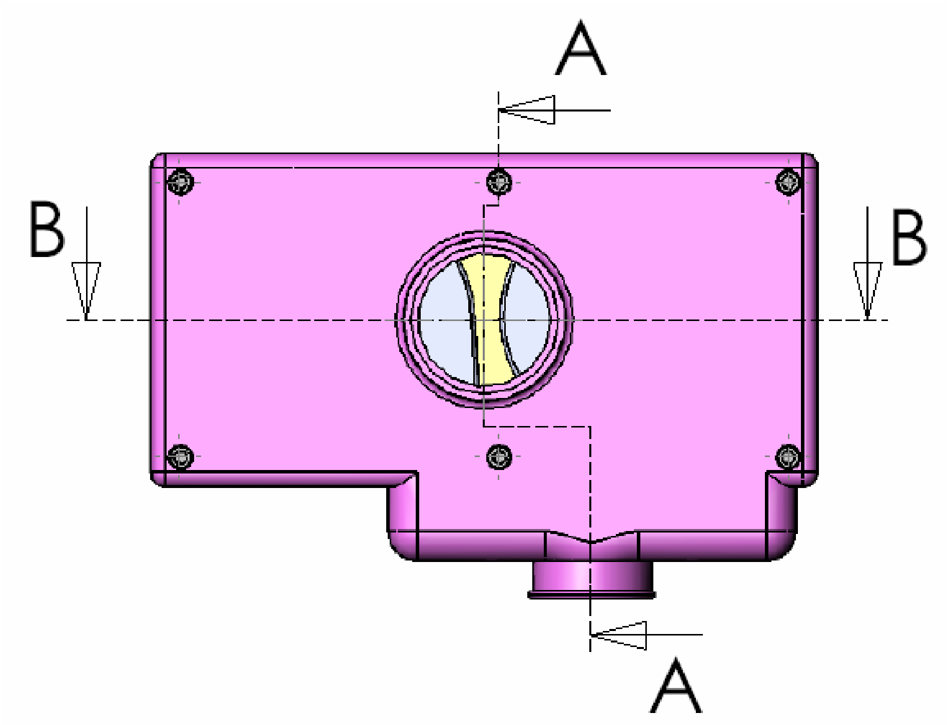


Figure 30: Top View of Housing Cover

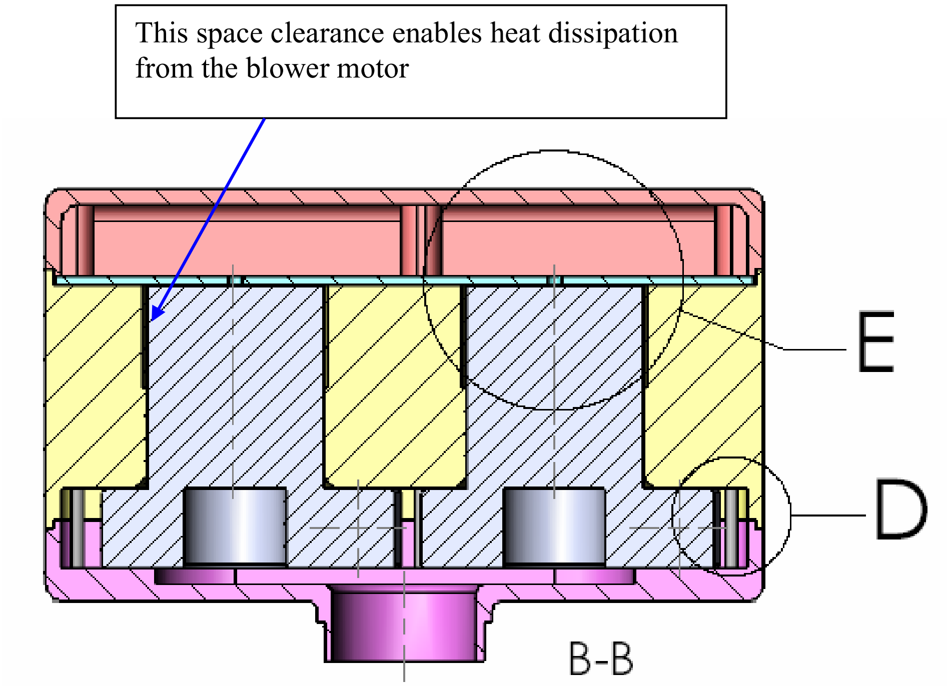

This space clearance enables heat dissipation from the blower motor

Figure 31: Cross-sectional drawing of the blower main housing

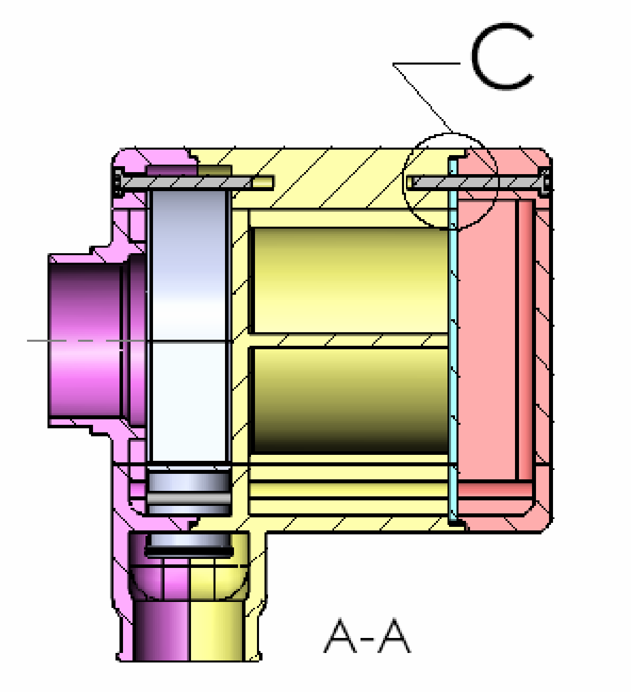
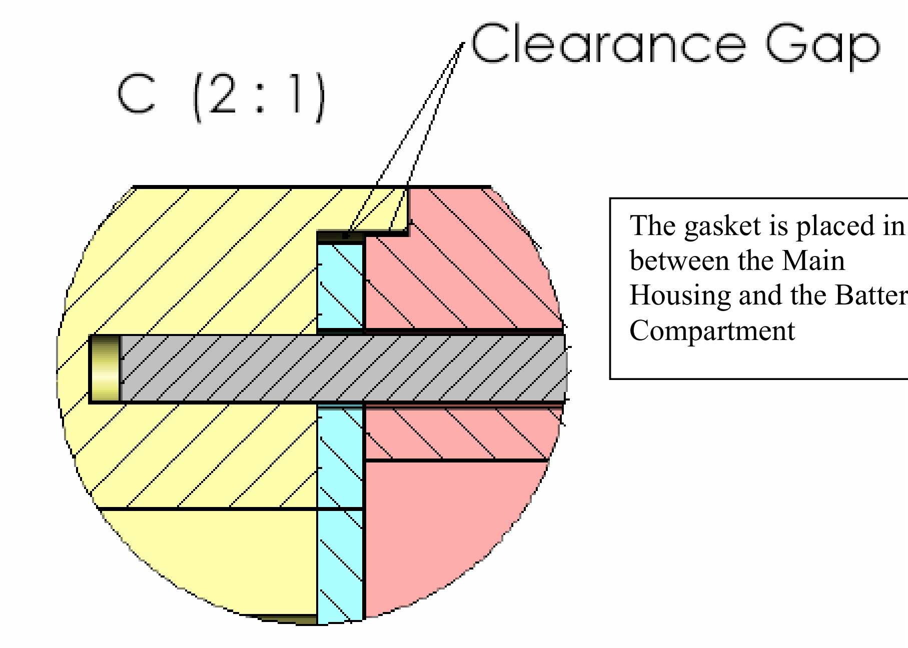


Figure 32: Cross-sectional drawing of the blower main housing and Battery Compartment



The gasket is placed in between the Main Housing and the Battery Compartment

Figure 33: Clearance Gap in between Main Housing and Battery Compartment

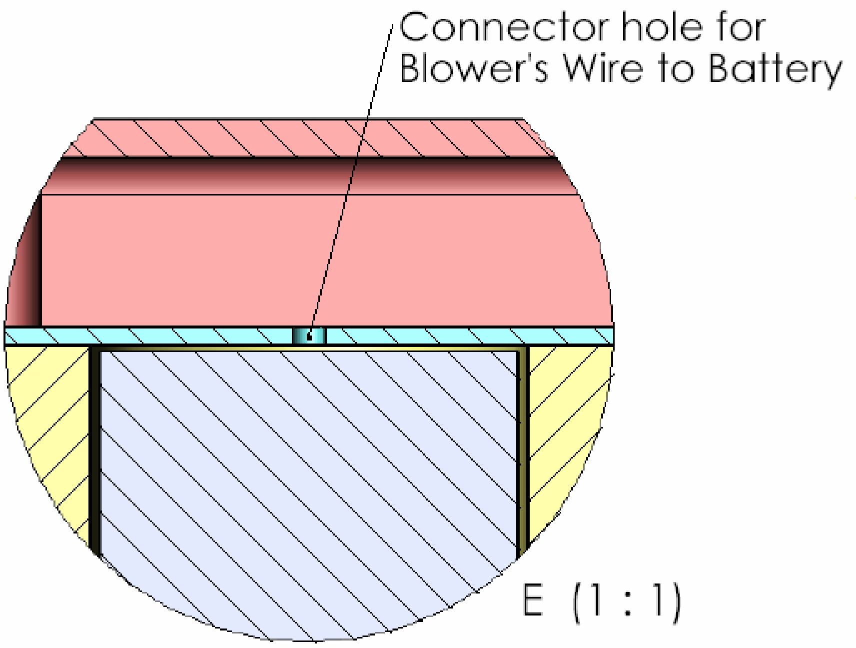


Figure 34: Connector hole for Blower's Wire to Battery

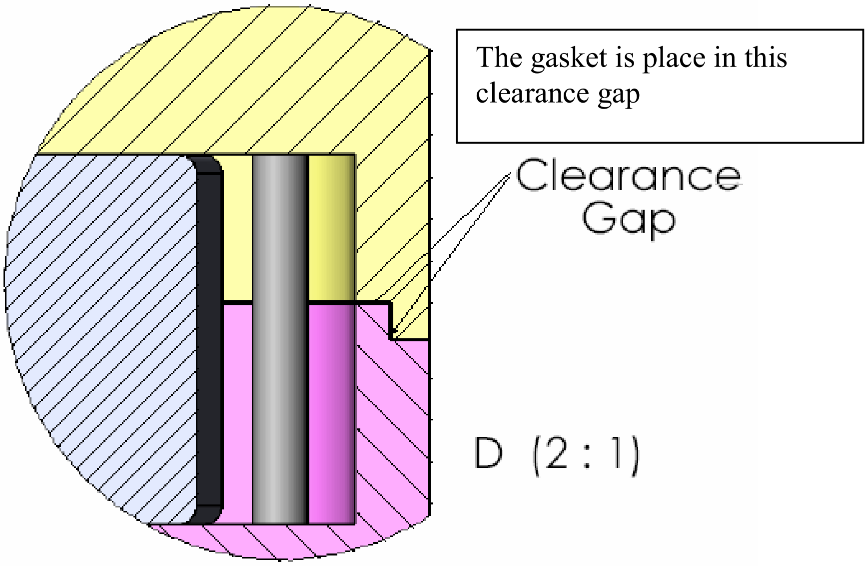


Figure 35: Clearance Gap in between Housing Cover and Main Housing

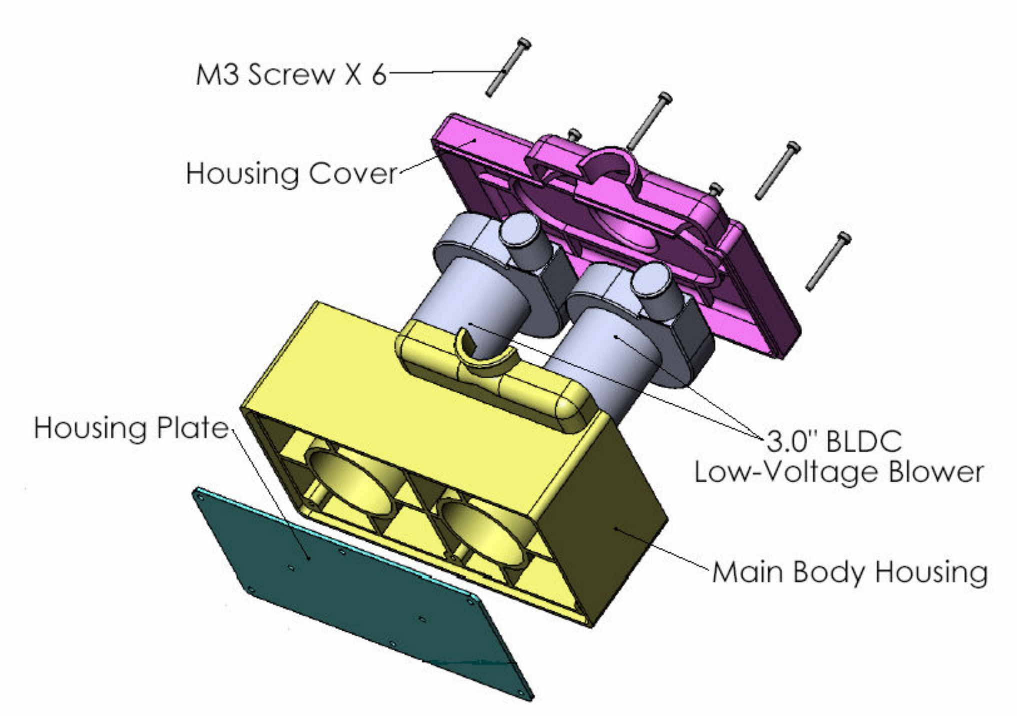


Figure 36: Blower Housing Assembly Drawing

4.4 Power Source for the prototype

The prototype was design to accept a wide range of DC power source. In line with its modular nature, it could even be modified to accept a combination of power sources. At the moment, the prototype is design to be run on two set of four re-chargeable batteries pack weighing a total of approximately 0.8 kg. The sealed battery pack consists of conventional 9V Ni-MH Nickel Metal Hydride cell connected in a series configuration totaling 36V. The 4 pieces pack is arranged in a parallel configuration to extend the working duration of the prototype.

4.4.1 Housing for Battery Packs

The battery compartment has an on/off switch as shown in figures 36 and 37. The battery compartment is designed to house two set of battery packs. The battery compartment is assembled onto the Main Housing using six M3 screws.

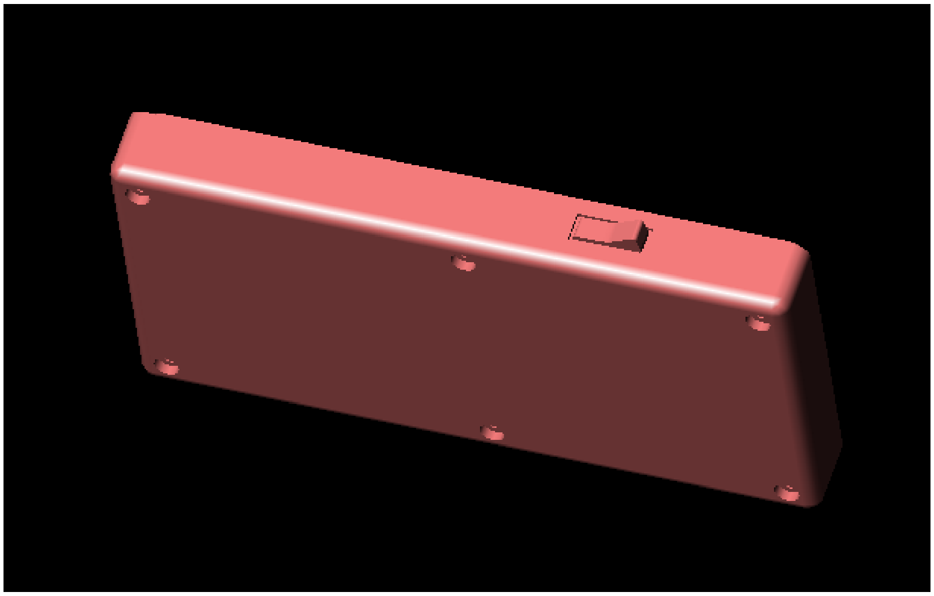


Figure 37: Batteries compartment

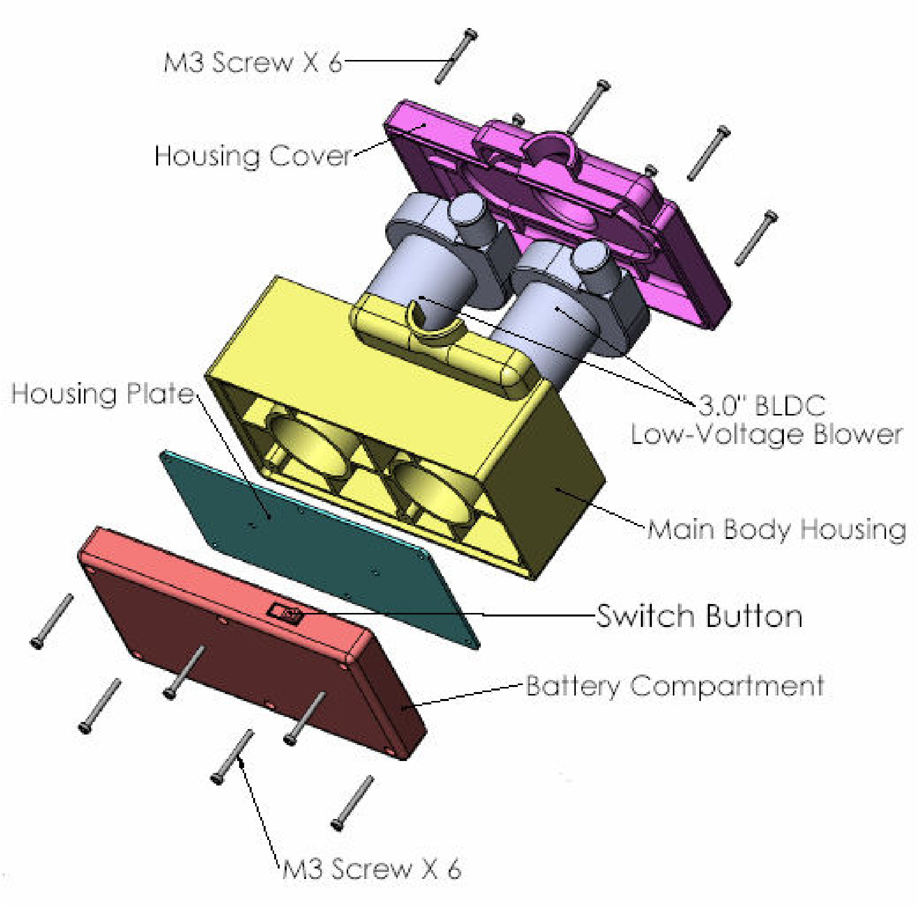


Figure 38: Blower Assembly and Batteries compartment

CHAPTER 5 TOTAL SYSTEM HEAD LOSSES

5.1 Introduction

Friction decreases pressure, causing pressure "loss" compared to the ideal, frictionless flow case. The loss will be divided into "major loss" and "minor loss". The major loss is caused by friction in constant-area portions of the system and the minor loss is resulting from flow through valves, tees, elbows and friction.

Major Losses in Pipes

The head loss due to friction in pipes is given by the Darcy-Weisbach equation:

$$H_l = \frac{fL}{D}\frac{V^2}{2g}$$

whereby,

- Darcy friction factor, f
- the velocity of the flow, V [m s^{-1}]
- the standard constant for acceleration due to gravity g ($g = 9.81$ [m^2 s^{-1}]).

- the ratio of the length to diameter of the pipe, *L/D*

Minor Losses in Pipes

Minor losses are localized losses which arise whenever an adverse pressure exists in the system. Adverse pressure is said to occur whenever the pressure down-stream is larger than the pressure upstream. Once adverse pressure occurs, stream-lines bend and a separation zone is created. This separation zone dissipates energy through turbulence. The mathematical form of all minor losses is as follows:

$$H_{lm} = K\frac{V^2}{2g} + \frac{fL}{D}\frac{V^2}{2g} = (\frac{fL}{D} + K)\frac{V^2}{2g}$$

where,

- the average velocity of the flow, V [m s^{-1}]
- the standard constant for acceleration due to gravity g ($g = 9.81$ [m^2 s^{-1}]).
- the minor loss coefficient which is usually determined from experiments, *k*
- Darcy friction factor, *f*
- the ratio of the length to diameter of the pipe, *L/D*

Examples of locations in pipelines where minor losses occur include pipe bends, elbows and joints, valves, sudden pipe expansion, sudden pipe contraction. Below, qualitative explanation of why and how minor losses occur is provided. In addition, tabulated values for the minor loss coefficients k are given. However, the tabulated values given here are by no means exhaustive.

Calculation for head loss

Total head loss, H_{LT} is regarded as the sum of major losses, H_l, due to frictional effects in fully developed flow in constant-area tubes, and minor losses, H_{lm} resulting from entrances, fittings, area changes.

$$H_{lm} = K\frac{V^2}{2g} + \frac{fL}{D}\frac{V^2}{2g}$$

5.2 Calculations for the delivery hose losses

The delivery head losses due to friction can be determined by Darcy-Weisbach equation:

$$H_l = \frac{fL}{D}\frac{V^2}{2g}$$

whereby,

- Darcy friction factor, f (= 0.025)
- the velocity of the flow, V [m s^{-1}]
- the standard constant for acceleration due to gravity g ($g = 9.81$ [m^2 s^{-2}]).

- the ratio of the length to diameter of the pipe, *L/D*

The flow rate (Q) is converted from CFM (cubic flow per meter) into liter per second (*l*/s) and then to cubic meter per second (m^3/s) using the below conversion factors:

1 CFM = 0.472 *l*/s

1 liter = $0.001\ m^3$

7.08 liters = 0.001 x 7.08

= $0.00708\ m^3s^{-1}$

Formula for Area of pipe = $\pi \times d^2 / 4\ [\ m^2\ ]$

Formula for Velocity = $Q / A\ [m^3 / m^2s = ms^{-1}]$

The value of the velocity was found first and then substituted into the formula for the delivery loses losses in which the answer is in meter of air (m Air). From the m Air, it was then converted into feet of air (ft Air). Finally, it has to be converted into inches of water (in Water) using the below conversion factors:

1 m = 3.2808 ft

1 in Water = 69.4 ft Air

Area of pipe = $\pi \times d^2 / 4\ [\ m^2\ ]$

= $\pi \times 0.03^2 / 4\ [\ m^2\ ]$

= $0.000707\ [\ m^2\ ]$

Velocity = Q / A [ms^{-1}]

= 0.00708 [m^3s^{-1}] / 0.000707 [m^2]

= 10.014 [ms^{-1}]

$$H_l = \frac{fL}{D}\frac{V^2}{2g}$$

H_l = (0.025 x 1.7 x $10.014^{2)}$ / (0.03 x 2 x 9.81)

= 4.261908 / 0.588600

= <u>7.240754 (m Air</u>)

= 7.240754 x 3.2808 (ft Air)

= <u>23.755466 (ft Air)</u>

= 23.755466 / 69.4 (in H_2O)

= <u>0.342298 (in H_2O)</u>

5.3 Calculation for the fitting and exit losses

The fitting and exit losses which are the minor losses can be determined by Darcy-Weisbach equation:

$$H_{lm} = K\frac{V^2}{2g}$$

where,

- the average velocity of the flow, V [$m\ s^{-1}$]

- the standard constant for acceleration due to gravity *g (g = 9.81* $[\mathrm{m}^2\ \mathrm{s}^{-2}]$).
- the minor loss coefficient which is usually determined from experiments, *k (k= 1 for exit, k = 1 for straight fitting)*

The flow rate (Q) is converted from CFM (cubic flow per meter) into liter per second (*l*/s) and then to cubic meter per second (m^3/s) using the below conversion factors:

1 CFM = 0.472 *l*/s

1 liter = 0.001 m^3

7.09 liters = 0.001 x 7.08

= 0.00708 $\mathrm{m}^3\mathrm{s}^{-1}$

Formula for Area of joint = π x d^2 / 4 [m^2]

Formula for Velocity = Q / A $[\mathrm{ms}^{-1}]$

The value of the velocity was found first and then substituted into the formula for the delivery loses losses in which the answer is in meter of air (m Air). From the m Air, it was then converted into feet of air (ft Air). Finally, it has to be converted into inches of water (in Water) using the below conversion factors:

1 m = 3.2808 ft

1 in Water = 69.4 ft Air

Area of joint = π x $(0.03)^2$ / 4 [m^2]

= 0.000707 $[\mathrm{m}^2]$

Velocity = Q / A [ms^{-1}]

= 0.00708 [m^3s^{-1}] / 0.000707 [ms^{-1}]

= 10.014 [ms^{-1}]

<u>Minor Loss for fitting</u>

$$H_{lm} = K\frac{V^2}{2g}$$

= 0.17 x $(10.014)^2$ / 2 x 9.81

= <u>0.868891 [m Air]</u>

= 0.868891 x 3.2808 (ft Air)

= <u>2.850658 [ft Air]</u>

= 2.850658 / 69.4 [in H_2O]

= <u>0.041076 [in H_2O]</u>

There are 2 fittings, therefore H_{lm} = 0.041076 x 2 = 0.082152 [in H_2O]

<u>Minor Loss for exit</u>

$$H_{lm} = K\frac{V^2}{2g}$$

= 1 x $(10.014)^2$ / 2 x 9.81

= <u>5.111121 [m Air]</u>

= 5.111121 x 3.2808 [ft Air]

= <u>16.768566 [ft Air]</u>

= 16.768566 / 69.4 [in H_2O]

= <u>0.241622 [in H_2O]</u>

5.4 Calculation for desiccant losses

The pressure head loss (P_r) for the desiccant was taken to be 510 Pa.

The head loss (H_l) of Desiccant in meter of water (m H_2O) can be determined using the below equation:

$$P = \rho \times g \times h$$

$$H = P / \rho g \ [m]$$

$$= 510 \ [Nm^{-2}] / 1000 \ [kgm^{-3}] \times 9.81 \ [m^2 s^{-2}]$$

$$= 0.051988 \ [m \ H_2O]$$

where,

- the pressure, P [Pa] or [Nm^{-2}]
- the standard constant for acceleration due to gravity *g (g = 9.81* [$m^2 s^{-2}$]*)*
- head loss, h
- density, ρ [kgm^{-3}] (=1000 [kgm^{-3}])

The answer was converted from meter water into inches of water (in H_2O) by using the below conversion factor:

1m = 39.37 inches

$$H = 0.0519 \ [m \ H_2O]$$

$$= 0.051988 \times 39.37 \ [in \ H_2O]$$

$$= 2.046768 \ [in \ H_2O]$$

5.5 Calculation for filter losses

The pressure head loss (P_r) for the filter was taken to be 270 Pa.

The head loss (H_l) of filter in meter of water (m H_20) can be determined using the below equation:

$P \quad = \rho \times g \times h \; [Pa] \text{ or } [Nm^{-2}]$

$H \quad = P / \rho g \; [m]$

$= 270 \; [Nm^{-2}] / 1000 \; [kgm^{-3}] \times 9.81 \; [m^2s^{-2}]$

$= 0.027523 \; [m \; H_2O]$

where,

- the pressure, P [Pa] or [Nm^{-2}]
- the standard constant for acceleration due to gravity *g (g = 9.81* [$m^2 s^{-2}$]*)*
- head loss, h
- density, ρ [kgm^{-3}] = (1000 [kgm^{-3}])

The answer was converted from meter water into inches of water (inches water) by using the below conversion factor:

1m = 39.37 inches

$H \quad = 0.0275 \; [m \; H_2O]$

$= 0.027523 \times 39.37 \; [in \; H_2O]$

$= 1.083581 \; [in \; H_2O]$

5.6 Total system head losses

The total system head losses can be determined by adding up the sum of he looses for the delivery hose, fitting, exit losses, desiccant and filter.

H_L = filter + desiccant + piping + fitting + exit losses

The readings of the air flow rate from 0 CFM to 40 CFM were used to calculate the static pressure (inches H_20) so as to plot the graph for the total head losses.

$$H_L = 1.082675+2.043303+0.342298+(2x0.241622)+0.241622 \text{ [in } H_2O \text{]}$$

$$= 4.193142 \text{ [in } H_2O\text{]}$$

Flow Rate			Delivery Hose Loss			Y-Fitting Losses			Exit Losses			Filter Losses		Desiccant Losses		System Losses
Q			h-pipe			h-fitting			h-exit			h-filter		h-des		h-system
(CFM)	(l/s)	(m^3/s)	(m Air)	(ft Air)	(in H^2O)	(m Air)	(ft Air)	(in H^2O)	(m Air)	(ft Air)	(in H^2O)	(m H^2O)	(in H^2O)	(m H^2O)	(in H^2O)	(in H^2O)
0.00	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0275	1.0836	0.0520	2.0468	3.1303
1.00	0.472	0.0005	0.0322	0.1056	0.0015	0.0039	0.0127	0.0002	0.0227	0.0745	0.0011	0.0275	1.0836	0.0520	2.0468	3.1331
2.00	0.944	0.0009	0.1287	0.4223	0.0061	0.0154	0.0507	0.0007	0.0909	0.2981	0.0043	0.0275	1.0836	0.0520	2.0468	3.1415
3.00	1.416	0.0014	0.2896	0.9502	0.0137	0.0348	0.1140	0.0016	0.2044	0.6708	0.0097	0.0275	1.0836	0.0520	2.0468	3.1553
4.00	1.888	0.0019	0.5149	1.6893	0.0243	0.0618	0.2027	0.0029	0.3635	1.1925	0.0172	0.0275	1.0836	0.0520	2.0468	3.1748
5.00	2.360	0.0024	0.8046	2.6396	0.0380	0.0966	0.3168	0.0046	0.5679	1.8632	0.0268	0.0275	1.0836	0.0520	2.0468	3.1998
6.00	2.832	0.0028	1.1586	3.8010	0.0548	0.1390	0.4561	0.0066	0.8178	2.6830	0.0387	0.0275	1.0836	0.0520	2.0468	3.2304
7.00	3.304	0.0033	1.5769	5.1736	0.0745	0.1892	0.6209	0.0089	1.1131	3.6519	0.0526	0.0275	1.0836	0.0520	2.0468	3.2665
8.00	3.776	0.0038	2.0597	6.7573	0.0974	0.2472	0.8109	0.0117	1.4539	4.7698	0.0687	0.0275	1.0836	0.0520	2.0468	3.3081
9.00	4.248	0.0042	2.6067	8.5522	0.1232	0.3128	1.0263	0.0148	1.8400	6.0368	0.0870	0.0275	1.0836	0.0520	2.0468	3.3554
10.00	4.720	0.0047	3.2182	10.5583	0.1521	0.3862	1.2670	0.0183	2.2717	7.4529	0.1074	0.0275	1.0836	0.0520	2.0468	3.4081
11.00	5.192	0.0052	3.8940	12.7755	0.1841	0.4673	1.5331	0.0221	2.7487	9.0180	0.1299	0.0275	1.0836	0.0520	2.0468	3.4665
12.00	5.664	0.0057	4.6342	15.2039	0.2191	0.5561	1.8246	0.0263	3.2712	10.7321	0.1546	0.0275	1.0836	0.0520	2.0468	3.5304
13.00	6.136	0.0061	5.4388	17.8435	0.2571	0.6527	2.1413	0.0309	3.8391	12.5953	0.1815	0.0275	1.0836	0.0520	2.0468	3.5998
14.00	6.608	0.0066	6.3077	20.6942	0.2982	0.7570	2.4834	0.0358	4.4524	14.6076	0.2105	0.0275	1.0836	0.0520	2.0468	3.6748
15.00	**7.080**	**0.0071**	**7.2410**	**23.7562**	**0.3423**	**0.8690**	**2.8509**	**0.0411**	**5.1112**	**16.7689**	**0.2416**	**0.0275**	**1.0836**	**0.0520**	**2.0468**	**3.7554**
16.00	7.552	0.0076	8.2386	27.0292	0.3895	0.9887	3.2436	0.0467	5.8154	19.0793	0.2749	0.0275	1.0836	0.0520	2.0468	3.8415
17.00	8.024	0.0080	9.3006	30.5135	0.4397	1.1161	3.6618	0.0528	6.5651	21.5387	0.3104	0.0275	1.0836	0.0520	2.0468	3.9331
18.00	8.496	0.0085	10.4270	34.2089	0.4929	1.2513	4.1052	0.0592	7.3602	24.1472	0.3479	0.0275	1.0836	0.0520	2.0468	4.0304
19.00	8.968	0.0090	11.6177	38.1154	0.5492	1.3942	4.5740	0.0659	8.2007	26.9048	0.3877	0.0275	1.0836	0.0520	2.0468	4.1331
20.00	9.440	0.0094	12.8728	42.2332	0.6085	1.5448	5.0682	0.0730	9.0866	29.8114	0.4296	0.0275	1.0836	0.0520	2.0468	4.2415
21.00	9.912	0.0099	14.1923	46.5621	0.6709	1.7031	5.5877	0.0805	10.0180	32.8671	0.4736	0.0275	1.0836	0.0520	2.0468	4.3554

22.00	10.384	0.0104	15.5761	51.1021	0.7363	1.8692	6.1325	0.0884	10.9948	36.0718	0.5198	0.0275	1.0836	0.0520	2.0468	4.4748
23.00	10.856	0.0109	17.0243	55.8534	0.8048	2.0430	6.7027	0.0966	12.0171	39.4256	0.5681	0.0275	1.0836	0.0520	2.0468	4.5998
24.00	11.328	0.0113	18.5369	60.8158	0.8763	2.2245	7.2982	0.1052	13.0847	42.9284	0.6186	0.0275	1.0836	0.0520	2.0468	4.7304
25.00	11.800	0.0118	20.1138	65.9893	0.9509	2.4138	7.9191	0.1141	14.1979	46.5803	0.6712	0.0275	1.0836	0.0520	2.0468	4.8665
26.00	12.272	0.0123	21.7551	71.3740	1.0284	2.6107	8.5653	0.1234	15.3564	50.3813	0.7260	0.0275	1.0836	0.0520	2.0468	5.0082
27.00	12.744	0.0127	23.4607	76.9699	1.1091	2.8154	9.2368	0.1331	16.5604	54.3313	0.7829	0.0275	1.0836	0.0520	2.0468	5.1554
28.00	13.216	0.0132	25.2307	82.7770	1.1928	3.0278	9.9337	0.1431	17.8098	58.4304	0.8419	0.0275	1.0836	0.0520	2.0468	5.3082
29.00	13.688	0.0137	27.0651	88.7952	1.2795	3.2480	10.6559	0.1535	19.1046	62.6785	0.9031	0.0275	1.0836	0.0520	2.0468	5.4665
30.00	14.160	0.0142	28.9639	95.0246	1.3692	3.4758	11.4034	0.1643	20.4449	67.0757	0.9665	0.0275	1.0836	0.0520	2.0468	5.6304
31.00	14.632	0.0146	30.9270	101.4652	1.4620	3.7114	12.1763	0.1755	21.8306	71.6219	1.0320	0.0275	1.0836	0.0520	2.0468	5.7999
32.00	15.104	0.0151	32.9544	108.1169	1.5579	3.9547	12.9746	0.1870	23.2618	76.3172	1.0997	0.0275	1.0836	0.0520	2.0468	5.9749
33.00	15.576	0.0156	35.0463	114.9798	1.6568	4.2057	13.7982	0.1988	24.7383	81.1616	1.1695	0.0275	1.0836	0.0520	2.0468	6.1554
34.00	16.048	0.0160	37.2025	122.0538	1.7587	4.4645	14.6471	0.2111	26.2604	86.1550	1.2414	0.0275	1.0836	0.0520	2.0468	6.3415
35.00	16.520	0.0165	39.4230	129.3391	1.8637	4.7310	15.5214	0.2237	27.8278	91.2974	1.3155	0.0275	1.0836	0.0520	2.0468	6.5332
36.00	16.992	0.0170	41.7080	136.8354	1.9717	5.0052	16.4210	0.2366	29.4407	96.5890	1.3918	0.0275	1.0836	0.0520	2.0468	6.7304
37.00	17.464	0.0175	44.0572	144.5430	2.0828	5.2871	17.3459	0.2499	31.0990	102.0295	1.4702	0.0275	1.0836	0.0520	2.0468	6.9332
38.00	17.936	0.0179	46.4709	152.4617	2.1969	5.5767	18.2962	0.2636	32.8027	107.6192	1.5507	0.0275	1.0836	0.0520	2.0468	7.1415
39.00	18.408	0.0184	48.9489	160.5916	2.3140	5.8741	19.2718	0.2777	34.5519	113.3579	1.6334	0.0275	1.0836	0.0520	2.0468	7.3554
40.00	18.880	0.0189	51.4913	168.9326	2.4342	6.1792	20.2728	0.2921	36.3465	119.2456	1.7182	0.0275	1.0836	0.0520	2.0468	7.5749

Table 1: Total system head losses

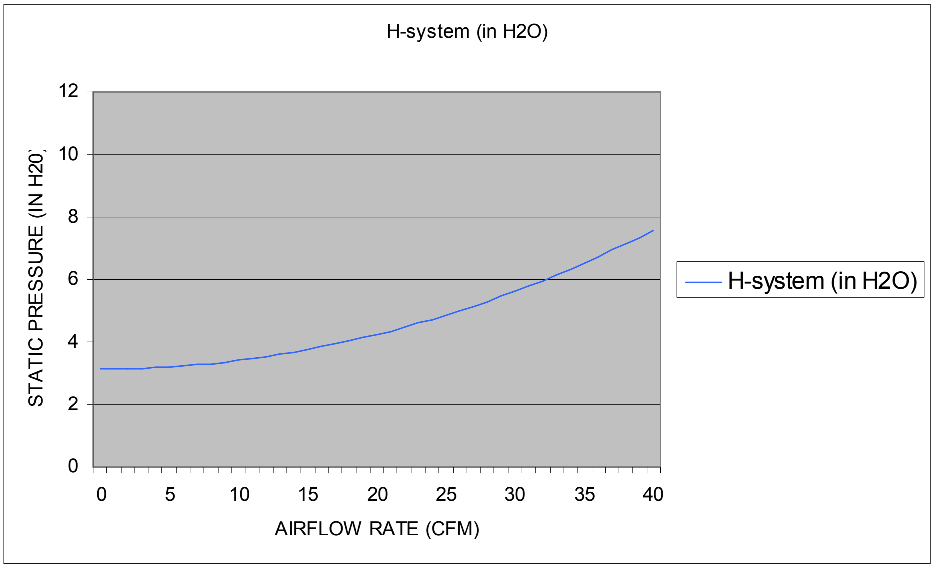


Figure 39: Graph of Total system head losses

5.7 Concluding remarks

For flow rate at 7 liters per second, the system head losses are 3.7554 inches H_2O. 3.7554 inches H_2O when converted to meter H_2O is 0.0954m (95.4 mm H_2O or 935.9 Pa). The blower assembly selected must be able to handle a pressure head up to more than 95.4mm H_2O.

CHAPTER 6   BLOWER ASSEMBLY

6.1 Characteristic of a Centrifugal Blower

Centrifugal blowers move air by means of the centrifugal force generated by rotating a cylindrical runner on which blades have been arranged. Centrifugal blowers have a small outlet, which concentrates air in a single direction, and are therefore suitable for local cooling. They also create static pressure, making them optimal for cooling equipment.

Figure 40: Side view of a centrifugal blower

Figure 41: Inlet view of a centrifugal blower

Figure 42: Motor view of a Centrifugal Blower

6.2 Characteristic of an Axial Flows Fan

Axial flow fans use a propeller to create a flow of air in the direction of the axis of rotation. Because they create a large airflow, axial flow fans are optimal for a wide variety of cooling and other airflow needs.

Figure 43: An axial flow fan

6.3 Blower and fan selection

Case Study #1

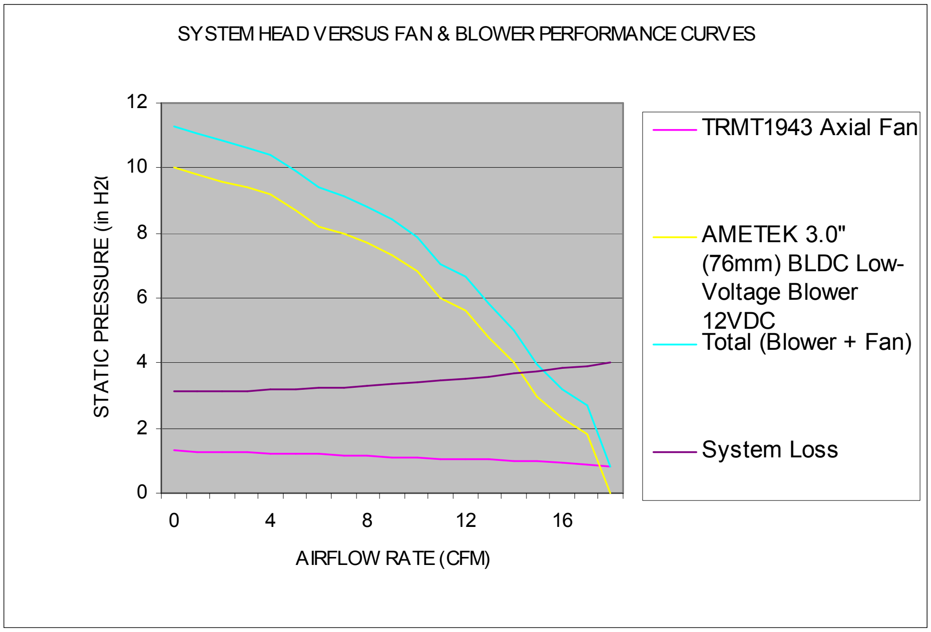


Figure 44: Graph of System head versus fan and blower performance curves for case study #1

The graph for AMETEK 3.0” (76mm) Brushless DC Low Voltage operating in 12VDC, and a TRMT1943 Axial Fan working in 26VDC is shown in Figure 43. The purple line represents the system head losses. From the graph, the X-axis refers to the airflow rate which is in CFM (cubic flow per meter) and the Y-axis refers to the static pressure in inches of water.

The yellow line represents one AMETEK 3.0” (76mm) BLDC Low-Voltage 12VDC blower working alone. The pink line represents one TRMT1943 axial fan working alone. All the data points in the graph are obtained from the catalogue.

The weight of one AMETEK 3.0” (76mm) BLDC Low-Voltage 12VDC blower is about 0.267kg and the weight of the fan is about 0.128kg. The fan working alone does not meet the operating point of curve. The combined weight of the blower and fan is 0.395kg.

They meet the operating point of curve at about16 CFM which is about 7.55 liters per second that is close to the requirement for the prototype. Compared to the required static pressure of 95.4mmH_2O, the blower connect in series with the fan could deliver a static pressure of 100.8 mmH_2O that is slightly higher than the air resistance due to the components of the prototype; therefore, this combination will maybe taken into consideration for the prototype design.

Table 2: Static Pressure for Case study #1

CFM	Static Pressure (in H_2O)			
	TRMT1943 Axial Fan	AMETEK 3.0" (76mm) BLDC Low-Voltage Blower 12VDC	Total (Blower + Fan)	System Loss
0	1.31	10.00	11.31	3.1303
1	1.29	9.80	11.09	3.1331
2	1.27	9.60	10.87	3.1415
3	1.24	9.40	10.64	3.1553
4	1.23	9.20	10.43	3.1748
5	1.21	8.70	9.91	3.1998
6	1.19	8.20	9.39	3.2304
7	1.15	8.00	9.15	3.2665
8	1.13	7.70	8.83	3.3081
9	1.11	7.30	8.41	3.3554
10	1.09	6.80	7.89	3.4081
11	1.07	6.00	7.07	3.4665
12	1.05	5.60	6.65	3.5304
13	1.02	4.80	5.82	3.5998
14	0.99	4.00	4.99	3.6746
15	0.97	3.00	3.97	3.7554
16	0.92	2.30	3.22	3.8415
17	0.87	1.80	2.67	3.9331
18	0.82	0.00	0.82	4.0304

Figure 45: A TRMT1943 Axial Fan

Figure 46: An AMETEK 3.0” (76mm) BLDC Low-Voltage Blower

Case Study #2

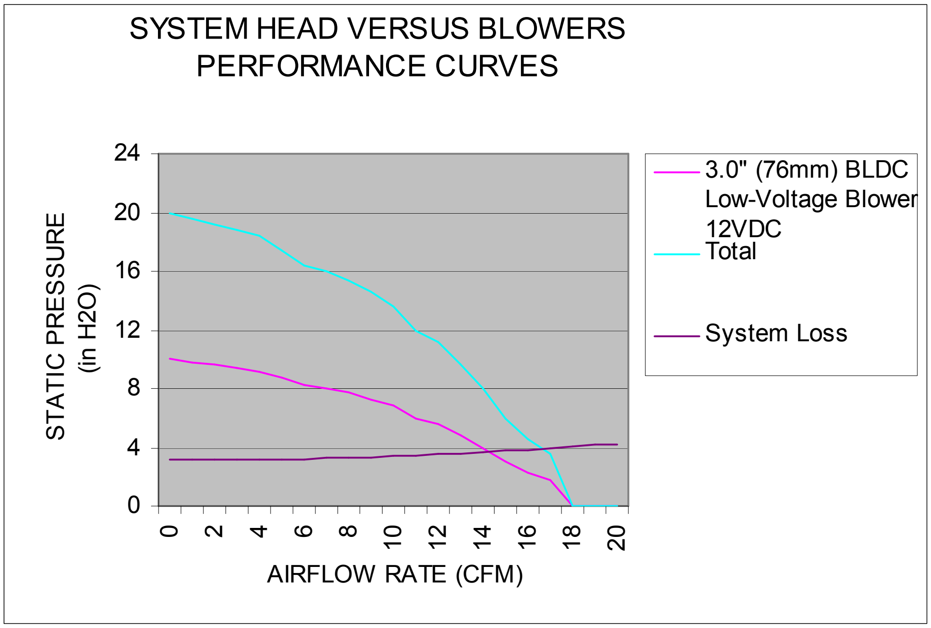


Figure 47: Graph of System head versus blowers performance curves for case study #2

The graph for AMETEK 3.0” (76mm) Brushless DC Low Voltage operating in 12VDC is shown in Figure 46. The purple line represents the system head losses. From the graph, the X-axis refers to the airflow rate which is in CFM (cubic flow per meter) and the Y-axis refers to the static pressure in inches of water.

The blue line represents two AMETEK 3.0” (76mm) BLDC Low-Voltage 12VDC blowers working parallel together. The pink line represents one AMETEK 3.0” (76mm) BLDC Low-Voltage 12VDC that is working alone. All the data points in the graph are obtained from the catalogue.

The weight of one AMETEK 3.0” (76mm) BLDC Low-Voltage 12VDC blower is about 0.267kg and the combination weight of 2 blowers will be 0.534kg.

They meet the operating point of curve is about 15 CFM which is about 7.08 liters per second for one blower working alone. With the combination of another blower working in parallel, the resultant delivery of air was satisfactory. Compared to the required static pressure of 95.4mmH2O at airflow rate about 7 liters per second, the combination of the two blower assembly could deliver a static pressure that is 159.8% more than the air resistance due to the components of the prototype; therefore, this combination will be taken into consideration for the prototype design.

Table 3: Static Pressure for Case study #2

	Static Pressure (in H_2O)			
CFM	3.0" (76mm) BLDC Low-Voltage Blower 12VDC	3.0" (76mm) BLDC Low-Voltage Blower 12VDC	Total	System Loss
0	10	10	20	3.1303
1	9.8	9.8	19.6	3.1331
2	9.6	9.6	19.2	3.1415
3	9.4	9.4	18.8	3.1553
4	9.2	9.2	18.4	3.1748
5	8.7	8.7	17.4	3.1998
6	8.2	8.2	16.4	3.2304
7	8	8	16	3.2665
8	7.7	7.7	15.4	3.3081
9	7.3	7.3	14.6	3.3554
10	6.8	6.8	13.6	3.4081
11	6	6	12	3.4665
12	5.6	5.6	11.2	3.5304
13	4.8	4.8	9.6	3.5998
14	4	4	8	3.6746
15	3	3	6	3.7554
16	2.3	2.3	4.6	3.8415
17	1.8	1.8	3.6	3.9331
18	0	0	0	4.0304
19	0	0	0	4.1331
20	0	0	0	4.2415

Case Study #3

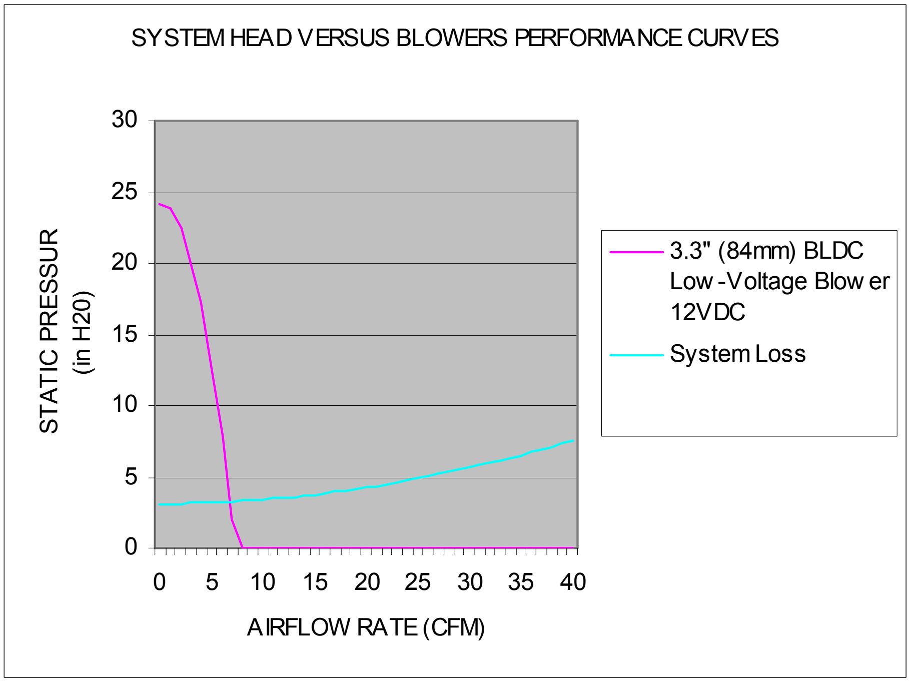


Figure 48: Graph of System head versus blower performance curves for case study #3

The graph for AMETEK 3.3” (84mm) Brushless DC Low Voltage operating in 12VDC is shown in Figure 47. The blue line represents the system head losses. From the graph, the X-axis refers to the airflow rate which is in CFM (cubic flow per meter) and the Y-axis refers to the static pressure in inches of water.

The pink line represents one AMETEK 3.3” (84mm) BLDC Low-Voltage 12VDC blowers working alone. All the data points in the graph are obtained from the catalogue.

The weight of one AMETEK 3.3” (84mm) BLDC Low-Voltage 12VDC blower is about 3.300kg.

It meets the operating point of the curve at 7CFM which is about 3.304 liters per second. This is below the requirement of 7 liters per second. Therefore, this proposal cannot be used for the prototype.

Table 4: Static Pressure for Case study #3

CFM	Static Pressure (in H_2O)		
	3.3" (84mm) BLDC Low-Voltage Blower 12VDC	3.3" (84mm) BLDC Low-Voltage Blower 24VDC	System Loss
0	24.2	25	3.1303
1	23.8	24.2	3.1331
2	22.4	23.8	3.1415
3	20.1	23	3.1553
4	17.2	18.4	3.1748
5	12.4	14.5	3.1998
6	7.8	9.1	3.2304
7	2	2.5	3.2665
8	0	0	3.3081
9	0	0	3.3554
10	0	0	3.4081
11	0	0	3.4665
12	0	0	3.5304
13	0	0	3.5998
14	0	0	3.6746
15	0	0	3.7554
16	0	0	3.8415
17	0	0	3.9331
18	0	0	4.0304
19	0	0	4.1331
20	0	0	4.2415
21	0	0	4.3554
22	0	0	4.4748
23	0	0	4.5998
24	0	0	4.7304
25	0	0	4.8665
26	0	0	5.0082
27	0	0	5.1554
28	0	0	5.3082
29	0	0	5.4665
30	0	0	5.6304
31	0	0	5.7999
32	0	0	5.9749
33	0	0	6.1554
34	0	0	6.3415
35	0	0	6.5332
36	0	0	6.7304
37	0	0	6.9332
38	0	0	7.1415
39	0	0	7.3554
40	0	0	7.5749

Case Study #4

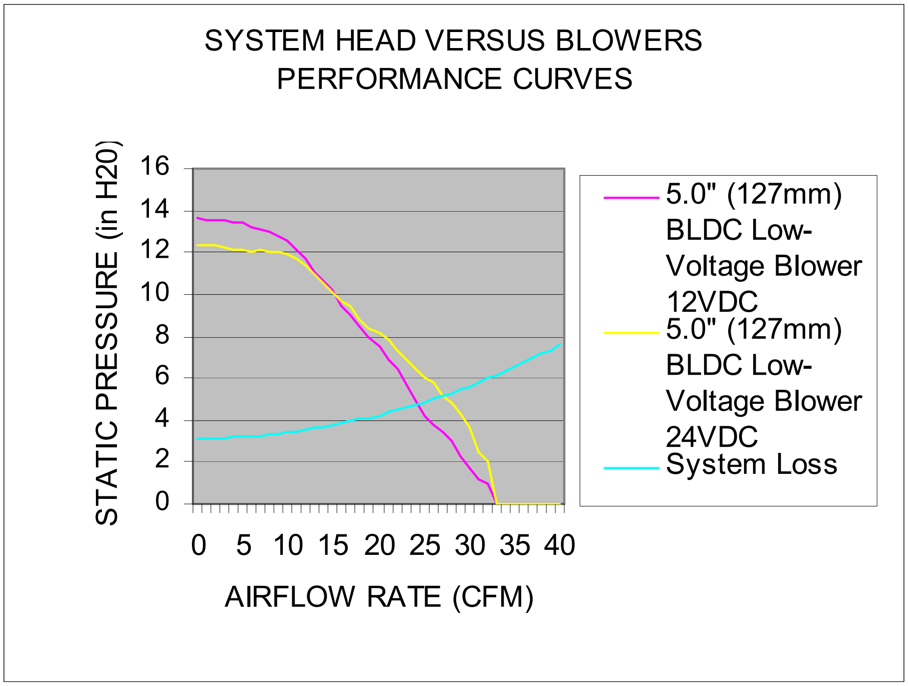


Figure 49: Graph of System head versus blower performance curves for case study #4

The graph for AMETEK 5.0" (127mm) Brushless DC Low Voltage operating in 12VDC and 24VDC is shown in Figure 48. The blue line represents the system head losses. From the graph, the X-axis refers to the airflow rate which is in CFM (cubic flow per meter) and the Y-axis refers to the static pressure in inches of water. The pink line represents one AMETEK 5.0" (127mm) BLDC Low-Voltage 12VDC blowers working alone. All the data points in the graph are obtained from the catalogue.

The yellow line represents one AMETEK 5.0” (127mm) BLDC Low-Voltage 24VDC blowers working alone. All the data points in the graph are obtained from the catalogue

The weight of one AMETEK 5.0” (127mm) BLDC Low-Voltage 12VDC (or 24VDC) blower is about 3.75kg.

The AMETEK 5.0” (127mm) BLDC Low-Voltage 12VDC meets the operating point of the curve at 25 CFM which is about 11.80 liters per second. This is well above the requirement of 7 liters per second. The blower assembly could in turn handle a pressure head up to 13.6 in H_2O (345mm H_2O). Compared to the required static pressure of 95.4 mm H2O at an air flow rate of about 7 liters per second, this blower could deliver accommodate a static pressure 271.3% more than the air resistance due the components of the prototype; therefore, this proposal could be used for the prototype design.

The AMETEK 5.0” (127mm) BLDC Low-Voltage 24VDC meets the operating point of the curve at 28 CFM which is about 13.20 liters per second. This is well above the requirement of 7 liters per second. The blower assembly could in turn handle a pressure head up to 12.3 in H_2O (312mm H_2O). Compared to the required static pressure of 95.4 mm H2O at an air flow rate of about 7 liters per second, this blower could deliver accommodate a static pressure 268.8% more than the air resistance due the components of the prototype; therefore, this proposal could also be used for the prototype design.

Table 5: Static Pressure for Case study #4

CFM	Static Pressure (in H_2O)		
	5.0" (127mm) BLDC Low-Voltage Blower 12VDC	5.0" (127mm) BLDC Low-Voltage Blower 24VDC	System Loss
0	13.6	12.3	3.1303
1	13.5	12.3	3.1331
2	13.5	12.3	3.1415
3	13.5	12.2	3.1553
4	13.4	12.1	3.1748
5	13.4	12.1	3.1998
6	13.2	12	3.2304
7	13.1	12.1	3.2665
8	13	12	3.3081
9	12.8	12	3.3554
10	12.6	11.9	3.4081
11	12.1	11.7	3.4665
12	11.7	11.4	3.5304
13	11.1	11	3.5998
14	10.6	10.5	3.6746
15	10.2	10.1	3.7554
16	9.5	9.7	3.8415
17	9	9.4	3.9331
18	8.5	8.8	4.0304
19	7.9	8.4	4.1331
20	7.5	8.2	4.2415
21	6.9	7.8	4.3554
22	6.4	7.3	4.4748
23	5.7	6.9	4.5998
24	4.9	6.4	4.7304
25	4.2	6	4.8665
26	3.8	5.8	5.0082
27	3.4	5.2	5.1554
28	3	4.8	5.3082
29	2.3	4.3	5.4665
30	1.7	3.7	5.6304
31	1.2	2.5	5.7999
32	1	2	5.9749
33	0	0	6.1554
34	0	0	6.3415
35	0	0	6.5332
36	0	0	6.7304
37	0	0	6.9332
38	0	0	7.1415
39	0	0	7.3554
40	0	0	7.5749

Case Study #5

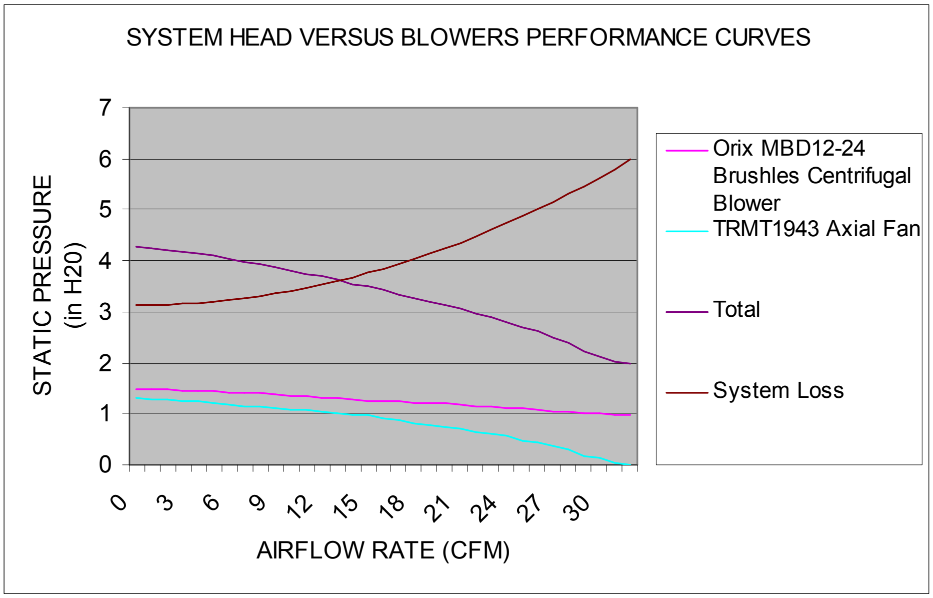


Figure 50: Graph of System head versus fan & blowers performance curves for case study #5

The graph for Orix MBD12-24 Brushless centrifugal blower that operates in 24VDC and a TRMT1943 Axial Fan that works in 26VDC is shown in Figure 49. The brown line shows the curve for the system head losses. From the graph, the X-axis refers to the airflow rate which is in CFM (cubic flow per meter) and the Y-axis refers to the static pressure in inches of water.

The pink line represents one Orix MBD12-24 Brushless centrifugal blower working alone. The blue line represents one TRMT1943 axial fan working alone. The purple line shows the Orix MBD12-24 Brushless centrifugal blower working in series with the TRMT1943 axial fan. All the data points in the graph are obtained from the catalogue.

The weight of one Orix MBD12-24 Brushless centrifugal blower is about 1.5kg and the weight of the fan is about 0.128kg. The fan working alone does not meet the operating. The combined weight of the two blowers and a fan is 3.128kg.

They meet the operating point of curve at about14 CFM which is about 6.608 liters per second that is under the requirement for the prototype. Compared to the required static pressure of 95.4mmH_2O, the two blower connected in series with the fan could deliver a static pressure of 88.6 mmH_2O that is lower than the air resistance due to the components of the prototype; therefore, this combination will not be taken into consideration for the prototype design.

Table 6: Static Pressure for Case study #5

CFM	Static Pressure (inches H_2O)				
	Orix MBD12-24 Brushles Centrifugal Blower	Orix MBD12-24 Brushles Centrifugal Blower	TRMT1943 Axial Fan	Total	System Loss
0	1.49	1.49	1.31	4.29	3.1303
1	1.48	1.48	1.29	4.25	3.1331
2	1.47	1.47	1.27	4.21	3.1415
3	1.46	1.46	1.24	4.16	3.1553
4	1.45	1.45	1.23	4.13	3.1748
5	1.44	1.44	1.21	4.09	3.1998
6	1.42	1.42	1.19	4.03	3.2304
7	1.41	1.41	1.15	3.97	3.2665
8	1.4	1.4	1.13	3.93	3.3081
9	1.38	1.38	1.11	3.87	3.3554
10	1.36	1.36	1.09	3.81	3.4081
11	1.34	1.34	1.07	3.75	3.4665
12	1.32	1.32	1.05	3.69	3.5304
13	1.3	1.3	1.02	3.62	3.5998
14	1.28	1.28	0.99	3.55	3.6746
15	1.26	1.26	0.97	3.49	3.7554
16	1.25	1.25	0.92	3.42	3.8415
17	1.23	1.23	0.87	3.33	3.9331
18	1.22	1.22	0.82	3.26	4.0304
19	1.21	1.21	0.78	3.2	4.1331
20	1.2	1.2	0.73	3.13	4.2415
21	1.18	1.18	0.7	3.06	4.3554
22	1.16	1.16	0.65	2.97	4.4748
23	1.14	1.14	0.61	2.89	4.5998
24	1.12	1.12	0.57	2.81	4.7304
25	1.1	1.1	0.48	2.68	4.8665
26	1.08	1.08	0.45	2.61	5.0082
27	1.06	1.06	0.38	2.5	5.1554
28	1.04	1.04	0.31	2.39	5.3082
29	1.02	1.02	0.18	2.22	5.4665
30	1	1	0.13	2.13	5.6304
31	0.99	0.99	0.04	2.02	5.7999
32	0.99	0.99	0	1.98	5.9749

CHAPTER 7 REULTS AND RECOMMENDATIONS

7.1 Introduction

A microclimate cooling system is used to provide personal cooling and mitigate heat stress in individuals subjected to elevated temperature or wearing thermally restrictive clothing. In operation, two battery powered blowers pull air through two cartridges and delivers a continuous flow of purified air to the wearer. This is different from a normal gas mask, which uses the wearer's lung power to pull air through the filter(s). This microclimate ventilation system is designed to provide air flow in excess of the required minimum flow rate. The airflow is much higher than the wearer needs to breath and the excess flow creates a positive pressure as it passes through the face piece. In the event of a small leak in the face piece or hood, air will flow from inside the face piece or hood to the outside.

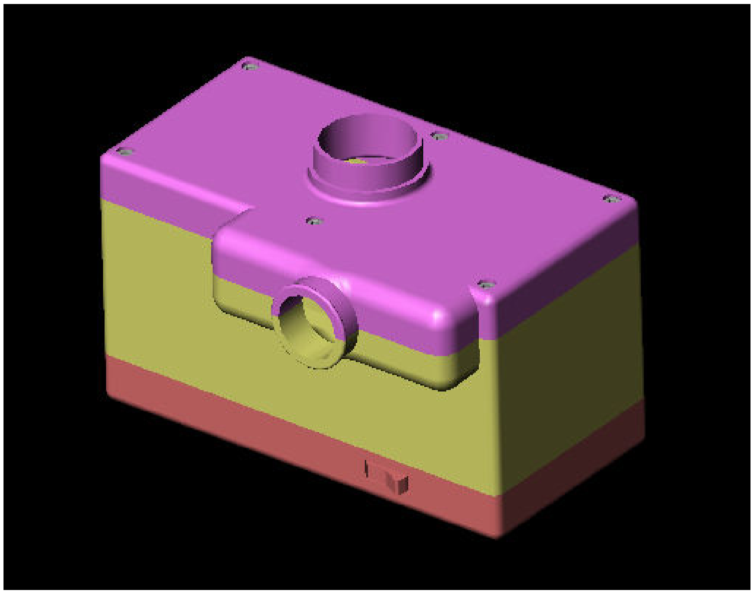


Figure 51: Microclimate Ventilation System

Features:

- it can be used with an entire family of filters and combination cartridges for protection against particulates, toxic gases and vapors
- belt mounted system delivers high air flow
- requires two filters
- re-charger, Ni-MH Nickel Metal Hydride battery pack is sealed and water-resistance for ease of decontamination

Description:

- The microclimate ventilation system provides respiratory protection by filtering contaminants from ambient air and providing air flow to either a face piece or hood.
- Standard 40mm x 1/7" NATO threaded design filter

- Air pressure in the face piece of hood is higher than the surrounding atmosphere, so that in the event of a small leak from the face piece or hood, air will flow from inside the face piece or hood to outside.
- The constant flow of air also provides a cooling effect to the wearer's face.
- A 30 inch corrugated breathing tube connects the blower assembly to the face piece.
- A coupling nut allows for easy detachment and cleaning of the tube, which a threaded connector on the blower assembly further simplifies removal and cleaning.

7.2 Results:

With reference to the objectives set earlier, the prototype succeed in meeting all its goals. The table below compares the objectives against actual results obtained:

Table 7: Results

	OBJECTIVES	ACTUAL RESULTS
AIRFLOW RATE	7-8 liters per second	7 liters per second
STATIC PRESSURE	95.4 mm H_20	152.5 mm H_20
WEIGHT	Low weight 3 to 4 kg	Approx. 3.2 kg
Design	Modular Concept	Modular Concept

All objectives were met or exceeded. The design remained modular in nature and it is believe that the excess airflow and static pressure obtained could be used to overcome air resistance due to additional modules.

Although there is no field trial performed, with the supply of clean, filtered and cool air flow into the breathing zone, it will slow the build up of heat load within the microclimate. The airflow is much higher than the wearer needs to breath and the excess flow creates a positive pressure as it passes through the mask. This pressure pushes out and keeps contaminations from leaking. This is different from a normal gas mask, which uses the wearer’s lung power to pull air through the filter(s).

7.3 Recommendations

As part of the recommendations, it will be good to include the PCM packs as an additional cooling module. It will serve as heat sinks for short term cooling purposes. In order to make improvements to the prototype design, it would be useful to equip the knowledge regarding the nature of airflow within the microclimate in an operational environment. It would be conceivable that various movements made by a person with a low permeability suit would affect the airflow and the quality of the ventilation in the suit. For the microclimate ventilation system, it would also be helpful to study the humidity distribution with the microclimate.

Another aspect requiring attention is the power source. Due to the time constraint, a detail study on the power source was not carry out.

More emphasis should also be paid on the chemical protection of the system once the abovementioned issues have been addressed. This would require the design for a more rigid outer shell of better chemical protective integrity. Care should be exercised during the selection of materials. The materials chosen should be able to withstand the conditions in an operational environment (heat and chemical hazards).

One oversight that appeared was the difficulty of replacing a spent desiccant cartridge in an operationally hostile environment. Modifications need to be introduced to allow the replacement of the cartridges in the field without introducing potential toxins into the system.

7.4 Conclusions

In the coming years, an increasing number of humans will work and recreate in progressively more hazardous environments, placing a continuing emphasis on technological advances to ensure health, performance, and safety. Thus, the use of protective clothing will generally increase the risk oh heat stress and hyperthermia by impairing the capacity for evaporative heat exchange from the body to the environment. Even though the wearer will never feel like he or she is in an air-conditioned room with the use of this microclimate ventilation system, it will allows he or she to perform their job more efficient and safety. In the case for the soldiers, cooling also can be a force multiplier as they can work longer without taking frequency necessary rest because of high ambient temperatures and humidity level. It also can reduce the logistics load by decreasing the water consumption. A microclimate ventilation system (MVS) provides a major operational capability in a hot environment while significantly reducing heat stress related injuries and water consumption.

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Appendix A – Project Specification

A1. Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR: Tan Yok Meng

TOPIC: Design of a Microclimate Ventilation System

SUPERVISOR: Dr. Harry Ku

SPONSORSHIP: N.A.

PROJECT AIM: This project calls for the design and development of a Microclimate Ventilation System that would be able to offer local (Singapore) users of low permeability protective clothing some respite. The protective garments possess an inherent problem of excessive thermal loading and have been used commercially and in the military for protection against Nuclear, Biological and Chemical hazards.

PROGRAMME: **Issue A, 14th March 2007**

1. Problem Statement and Background

Begin : 14th March 2007
Completion : 26th March 2007
Approx. Hours : 30 hours

2. Discuss and Compare the Existing Types of Microclimate Ventilation System

Begin : 27st March 2007
Completion : 7th April 2007
Approx. Hours : 25 hours

3. Reasons for choosing the Evaporative Cooling and PDM Concepts

Begin : 8th April 2007
Completion : 17th April 2007
Approx. Hours : 20 hours

4. Theoretical Estimations of:
    - Ideal Air Flow
    - Required Static Pressure

- Operating Temperature
- Degree of Dehumidification
- Heat Load with the Microclimate

Begin : 18th April 2007
Completion : 12th May 2007
Approx. Hours : 35 hours

5. Selection and Design of Main Component of the Microclimate Ventilation System
    - Power Source and its housing
    - Filter Cartridges
    - Desiccant Cartridges and its housing
    - Blower and its housing
    - Delivery Hose

Begin : 13th May 2007
Completion : 5th June 2007
Approx. Hours : 45 hours

6. Analysis of results

Begin : 6th June 2007

Completion : 15th July 2007

Approx. Hours : 25 hours

7. Draw up conclusions

Begin : 16th July 2007

Completion : 12th August 2007

Approx. Hours : 25 hours

8. Discussion for the thesis outline with supervisor

Begin : 13th July 2007

Completion : 22nd August 2007

Approx. Hours : 10 hours

9. Thesis initial drafting

Begin : 23rd August 2007

Completion : 9th September 2007

Approx. Hours : 40 hours

10. Final draft of thesis to incorporate modifications suggested by supervisor

Begin	: 10th September 2007
Completion	: 20th October 2007
Approx. Hours	: 20 hours

11. Completion of thesis in requested format

Begin	: 21st October 2007
Completion	: November 2007
Approx. Hours	: 20 hours

AGREED: ____________________(student)

(supervisor)

Date: / / 2007 Date: / /

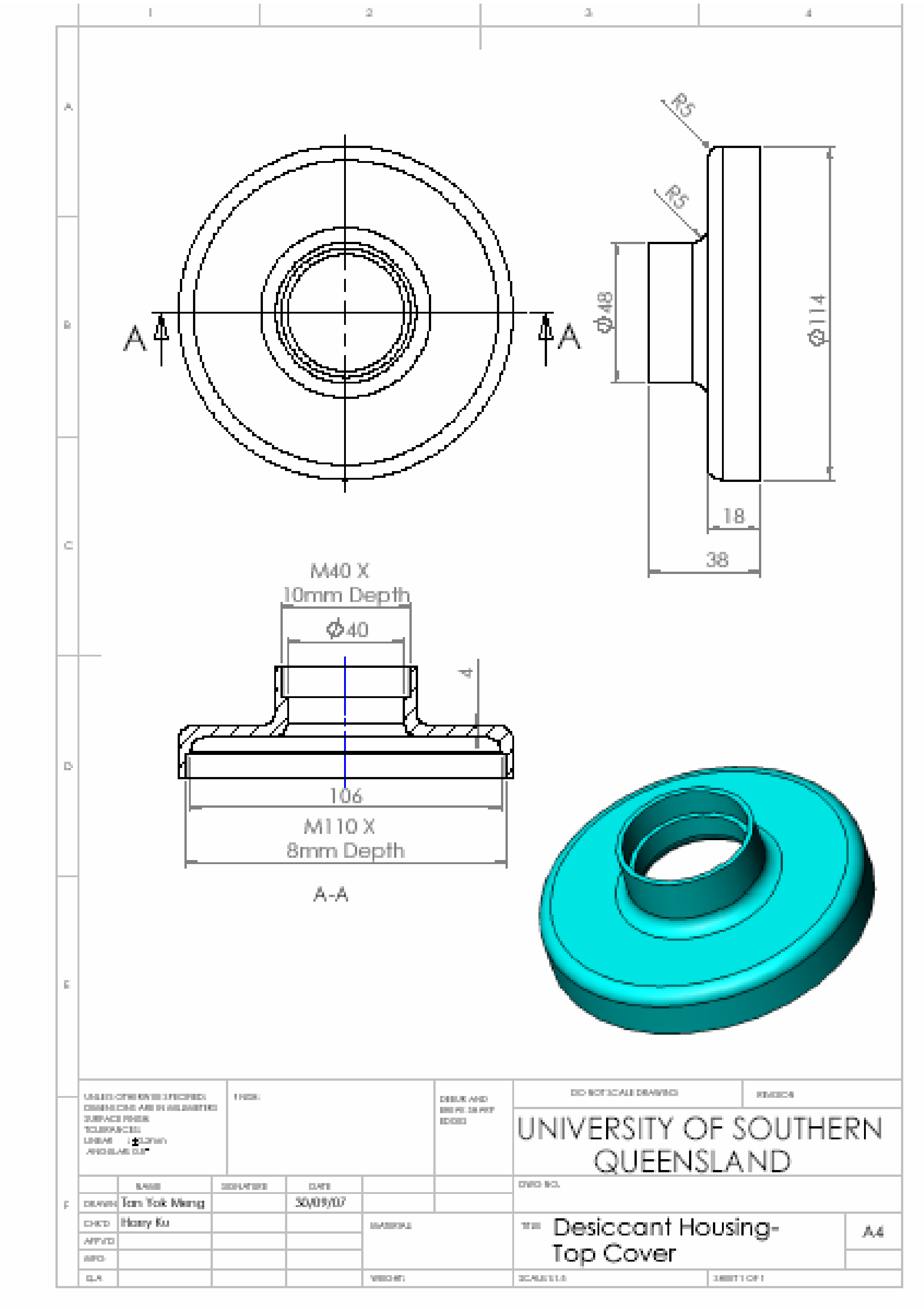
2007

Co-examiner: ________________________

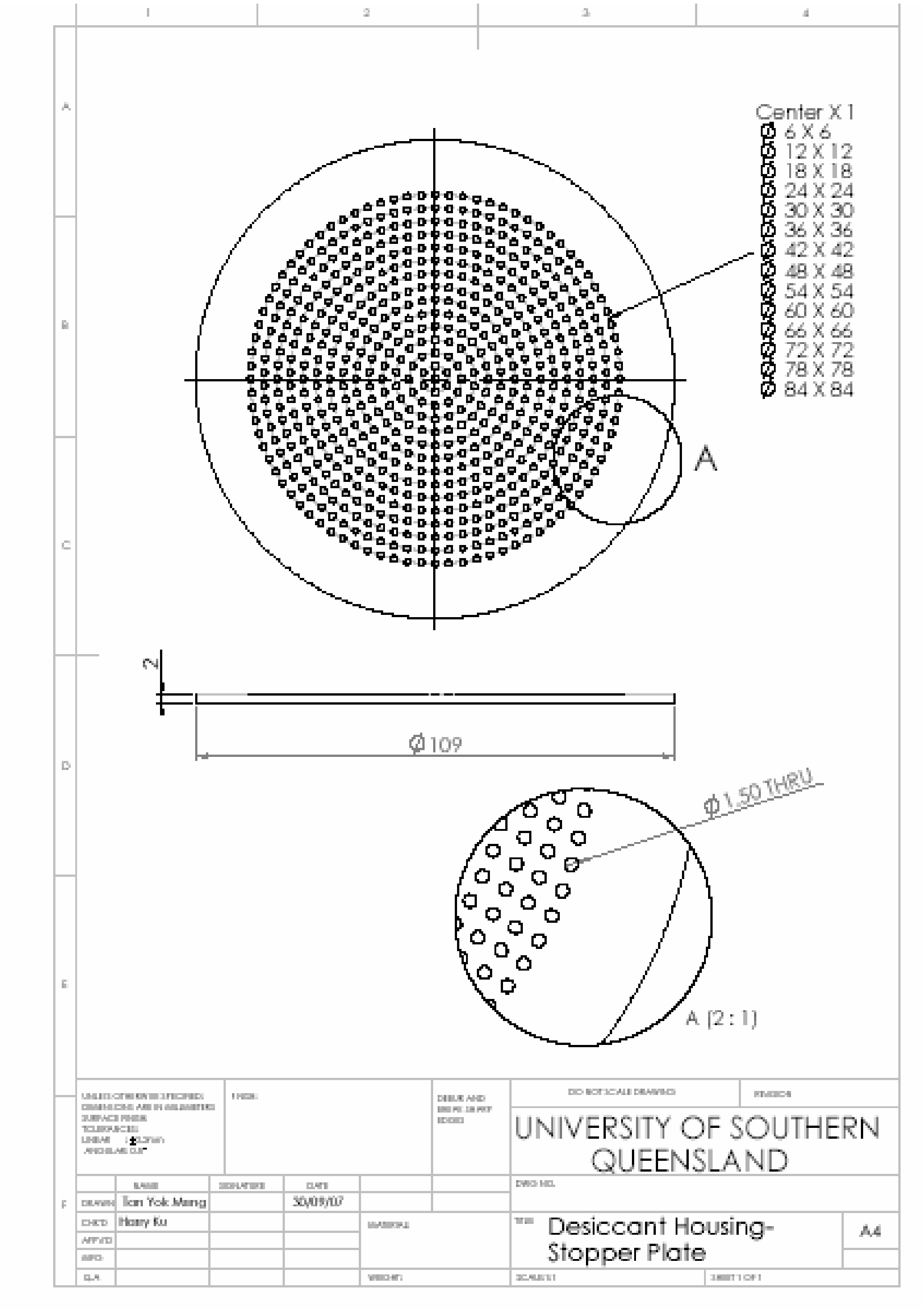
Date: / / 2007

Appendix B – Drawings

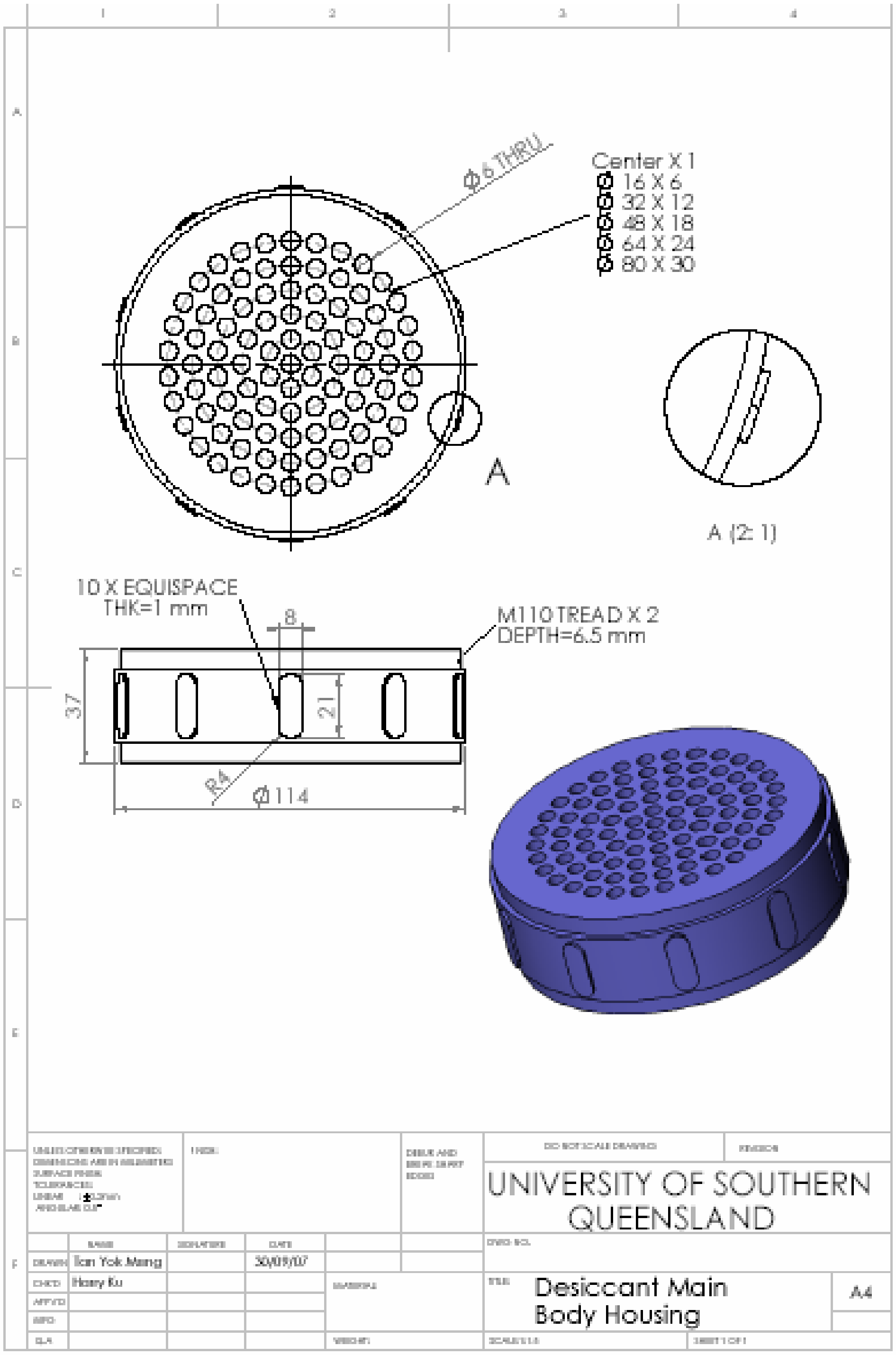
B1. Desiccant Housing - Top Cover



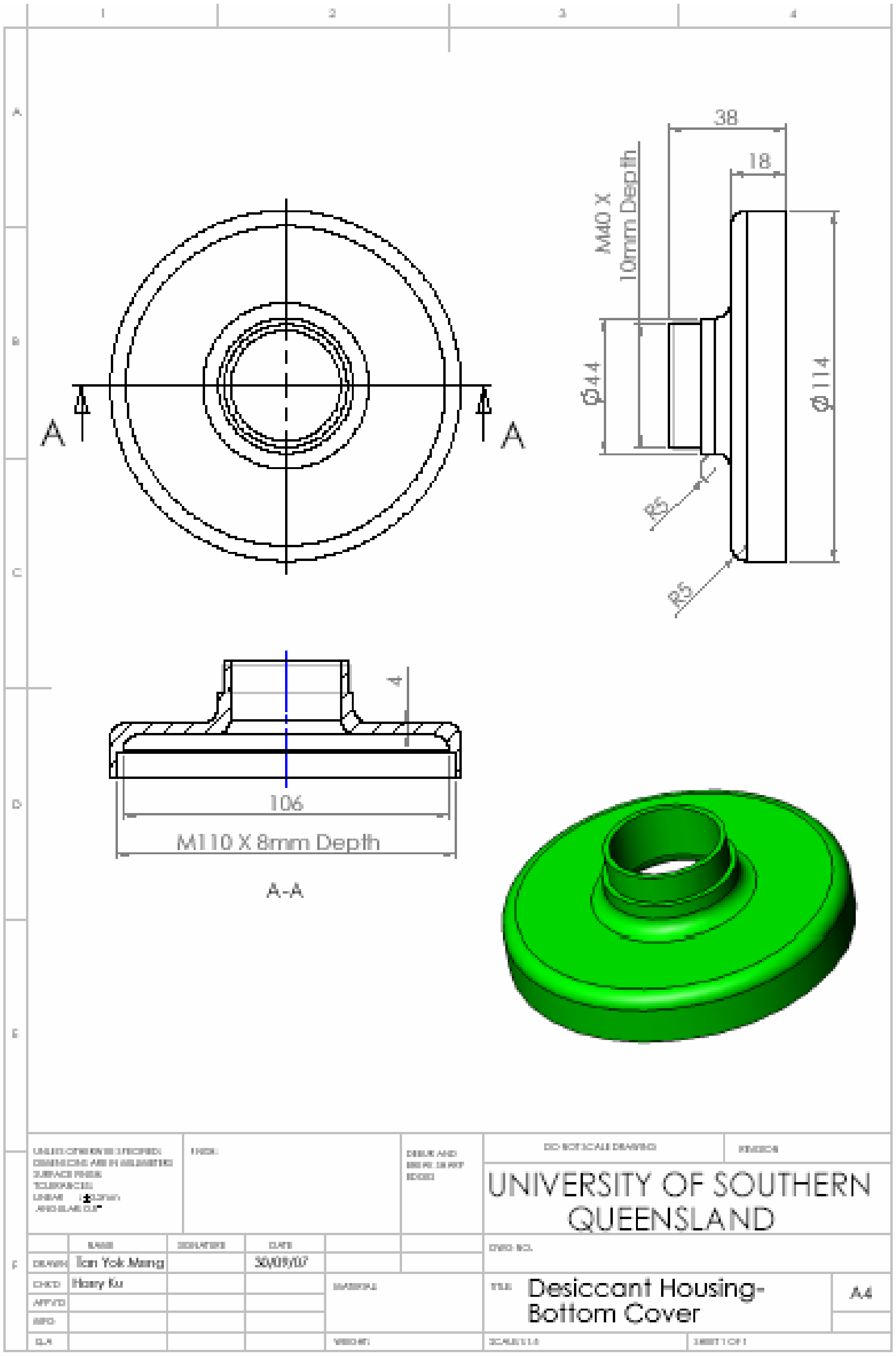
B2. Desiccant Housing – Stopper Plate



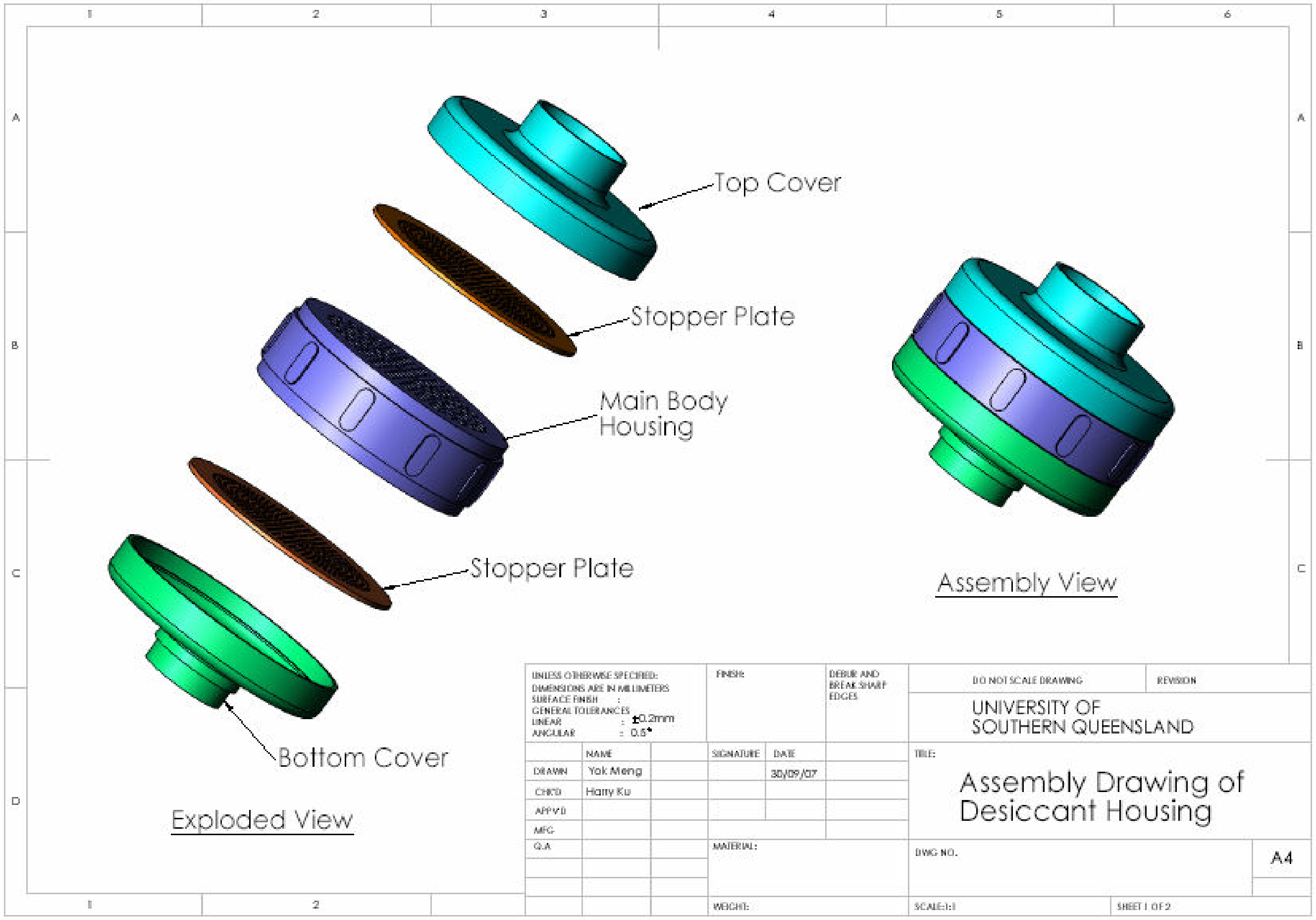
B3. Desiccant Housing – Main Housing



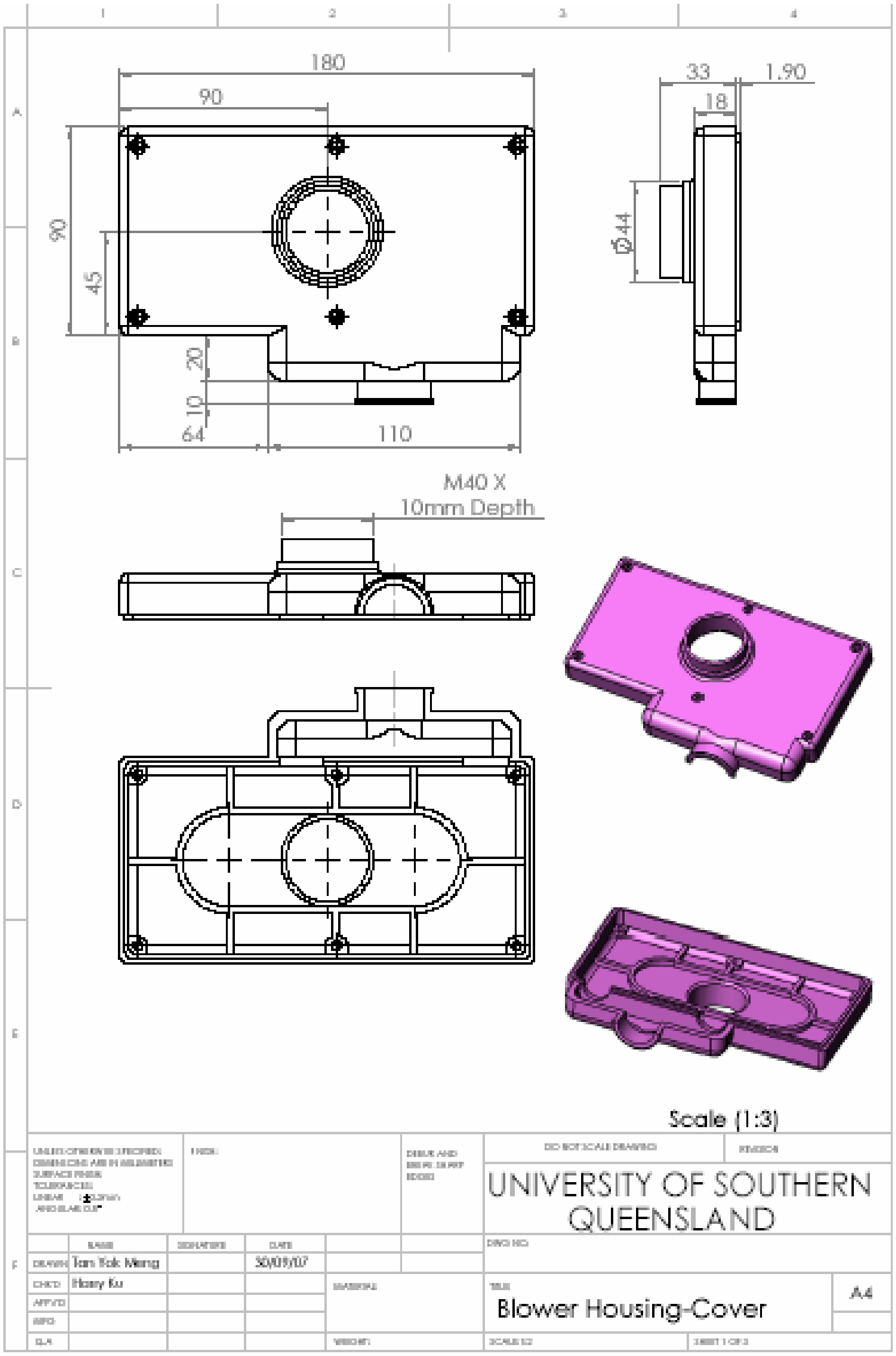
B4. Desiccant Housing – Bottom Cover



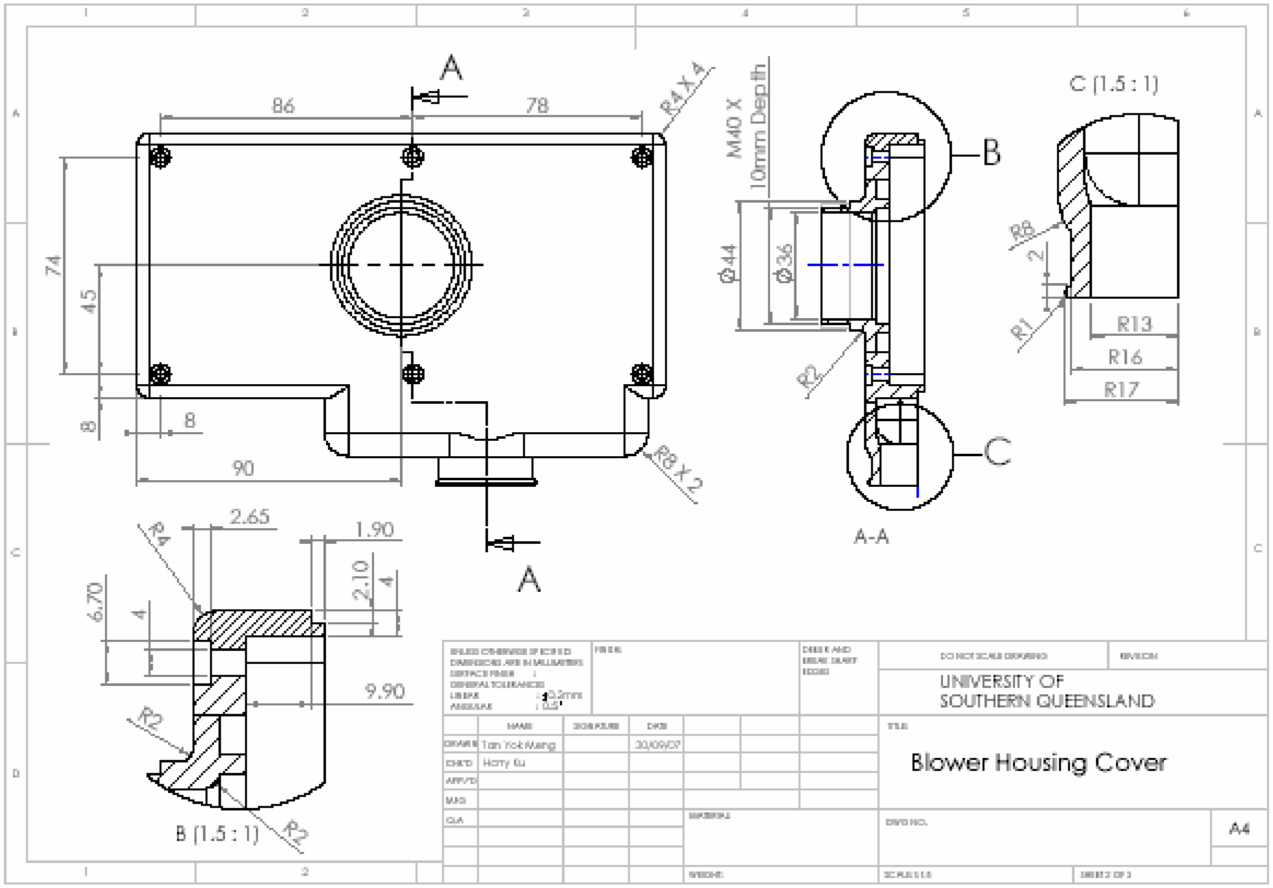
B5. Desiccant Housing – Assembly Drawing



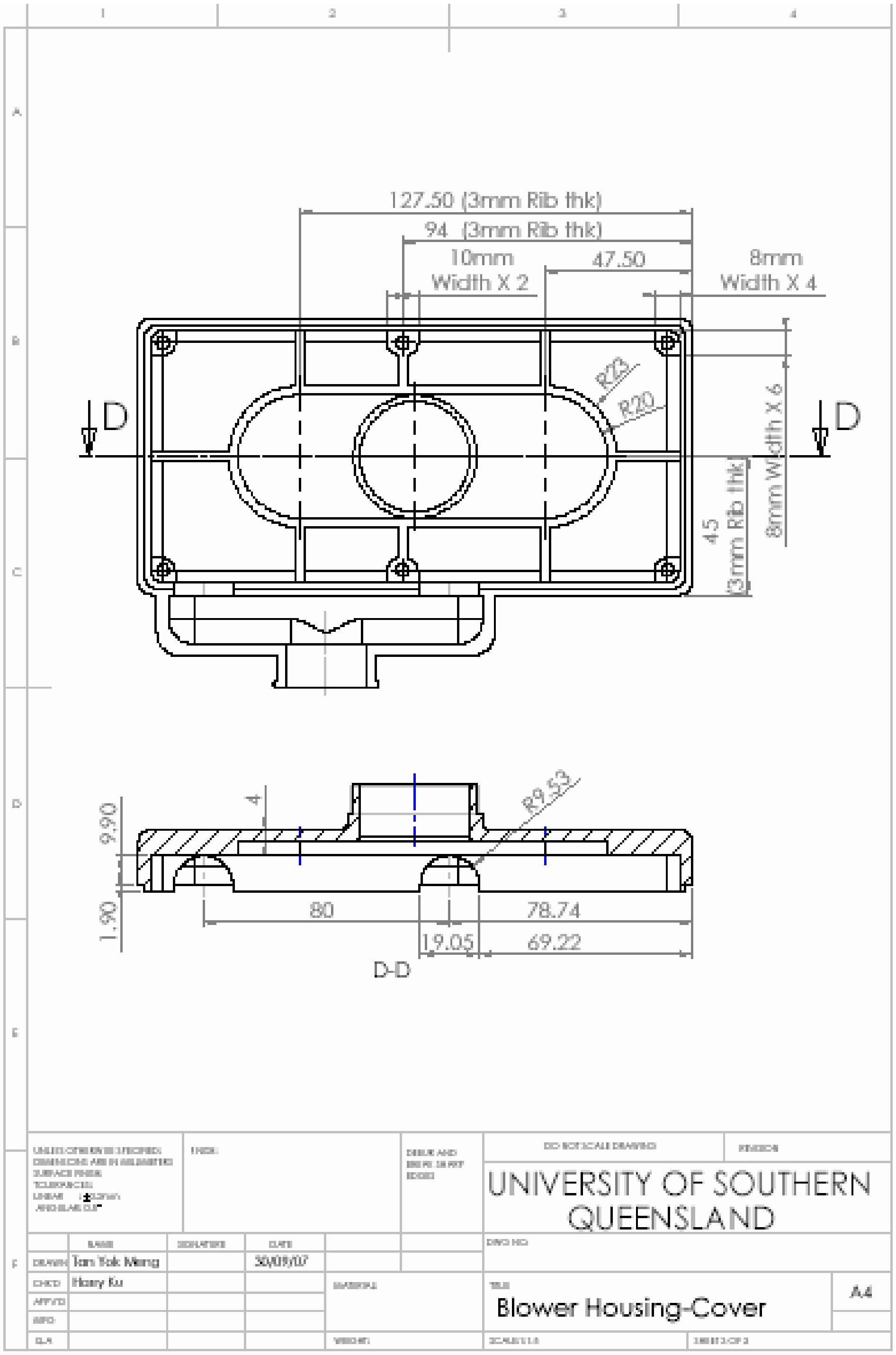
B6. Blower – Top Plate Drawing 1



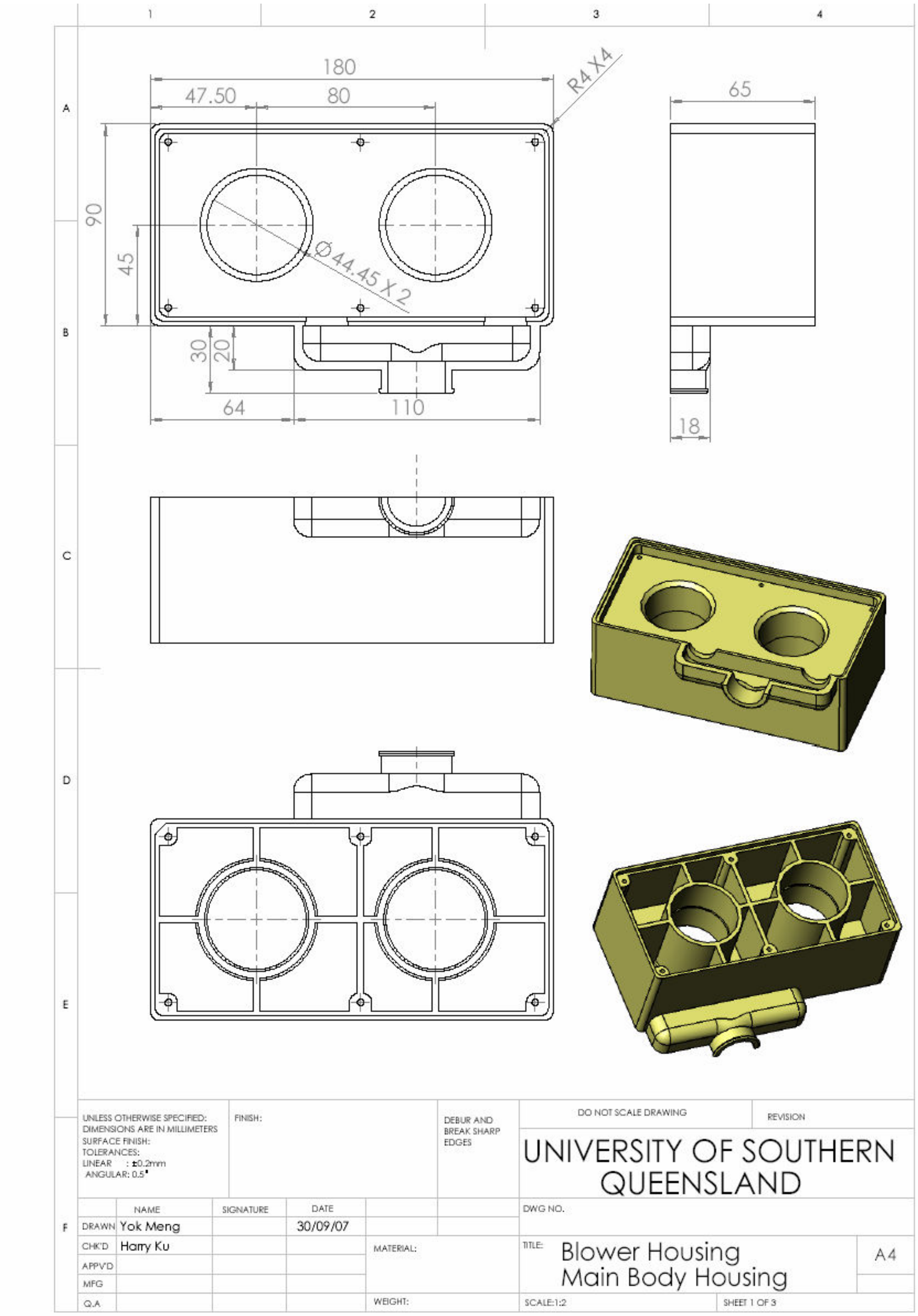
B7. Blower Housing – Top Plate Drawing 2



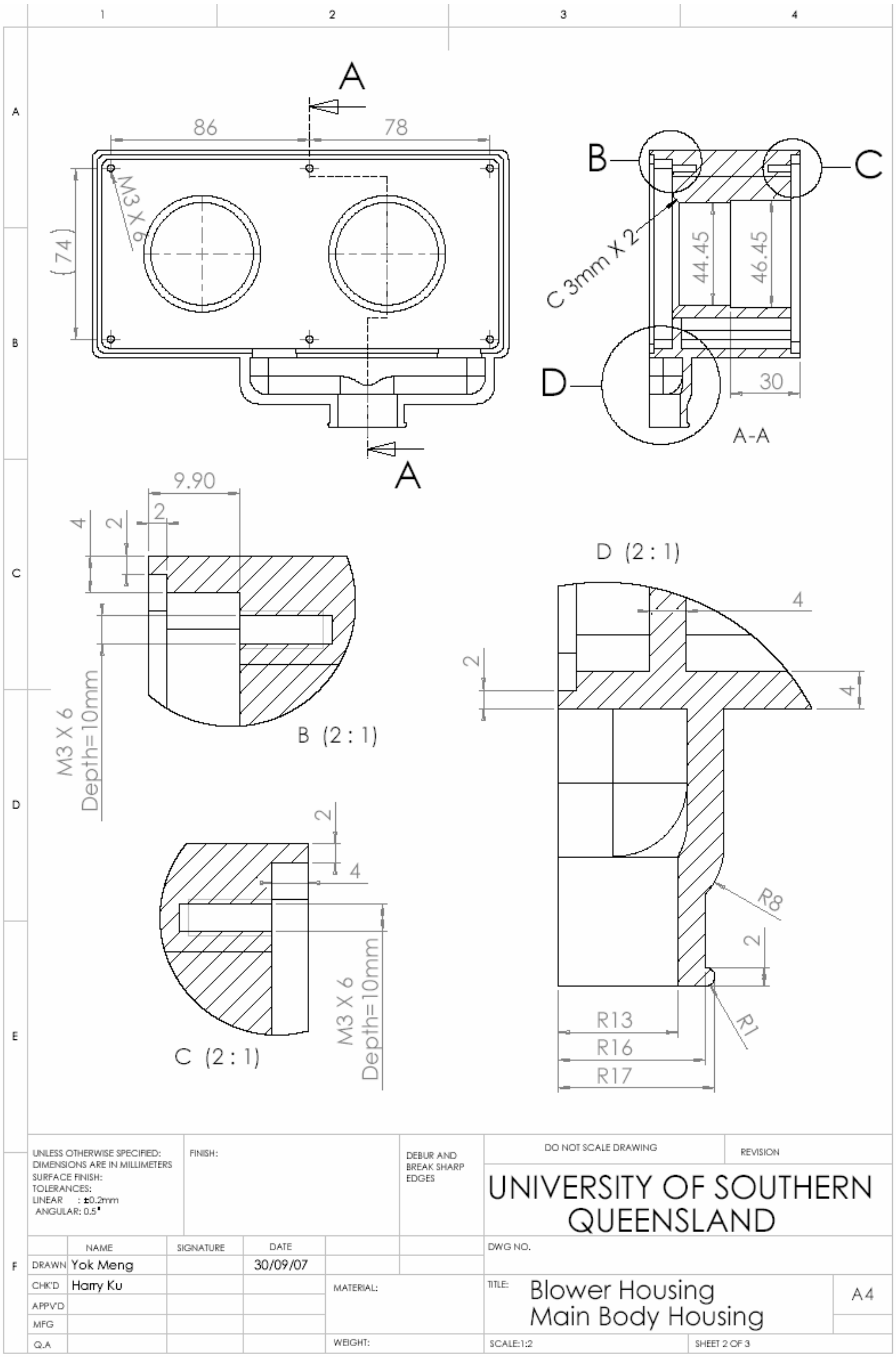
B8. Blower Housing – Top Plate Drawing 3



B9. Blower – Main Body Housing 1



B10 Blower – Main Body Housing 2



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DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR : ±0.2mm
ANGULAR: 0.5°

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

UNIVERSITY OF SOUTHERN QUEENSLAND

	NAME	SIGNATURE	DATE
DRAWN	Yok Meng		30/09/07
CHK'D	Harry Ku		
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

DWG NO.

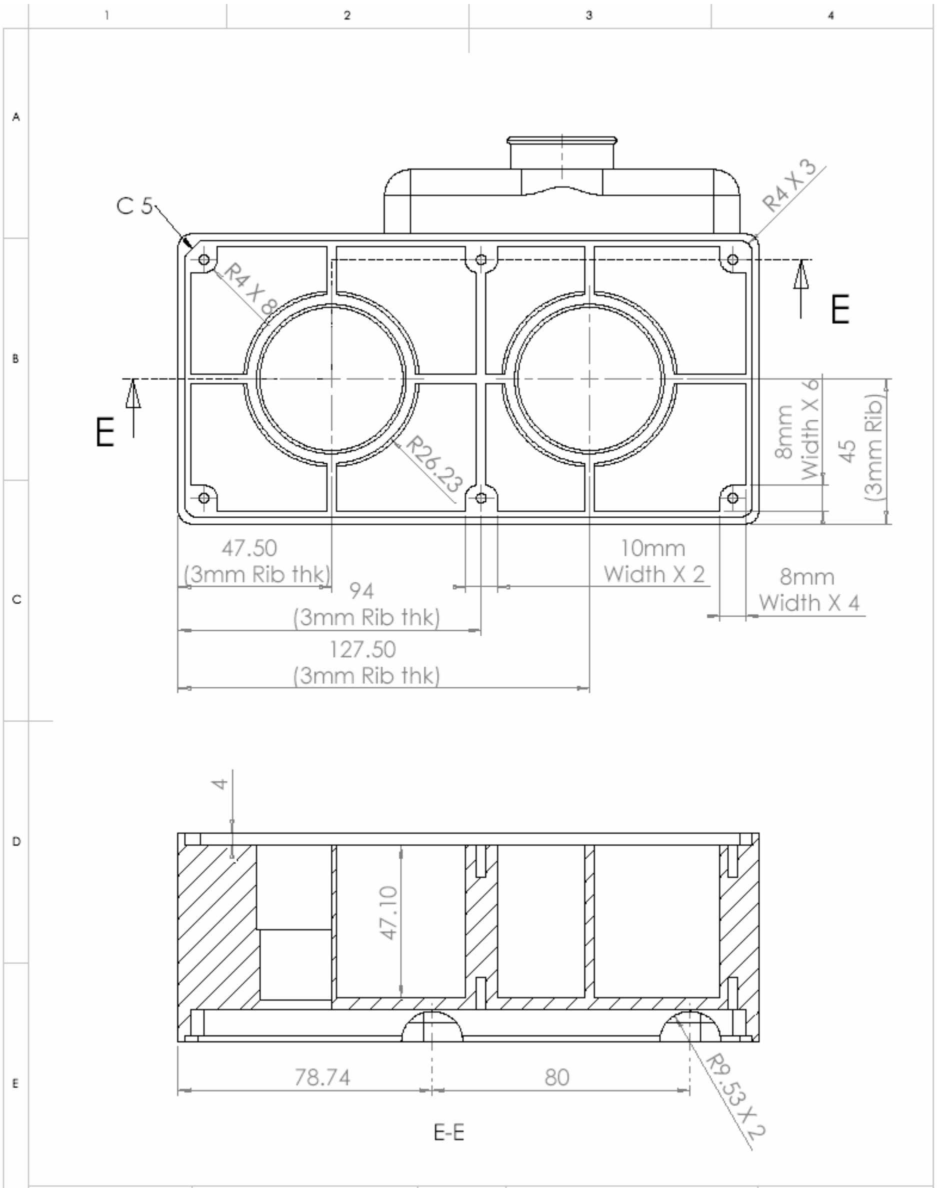
TITLE: Blower Housing
Main Body Housing

A4

SCALE:1:2

SHEET 2 OF 3

B11 Blower Housing – Main Body Housing 3



UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
LINEAR : ±0.2mm
ANGULAR: 0.5°

FINISH:

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DRAWN	Yok Meng		30/09/07
CHK'D	Harry Ku		
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

DWG NO.

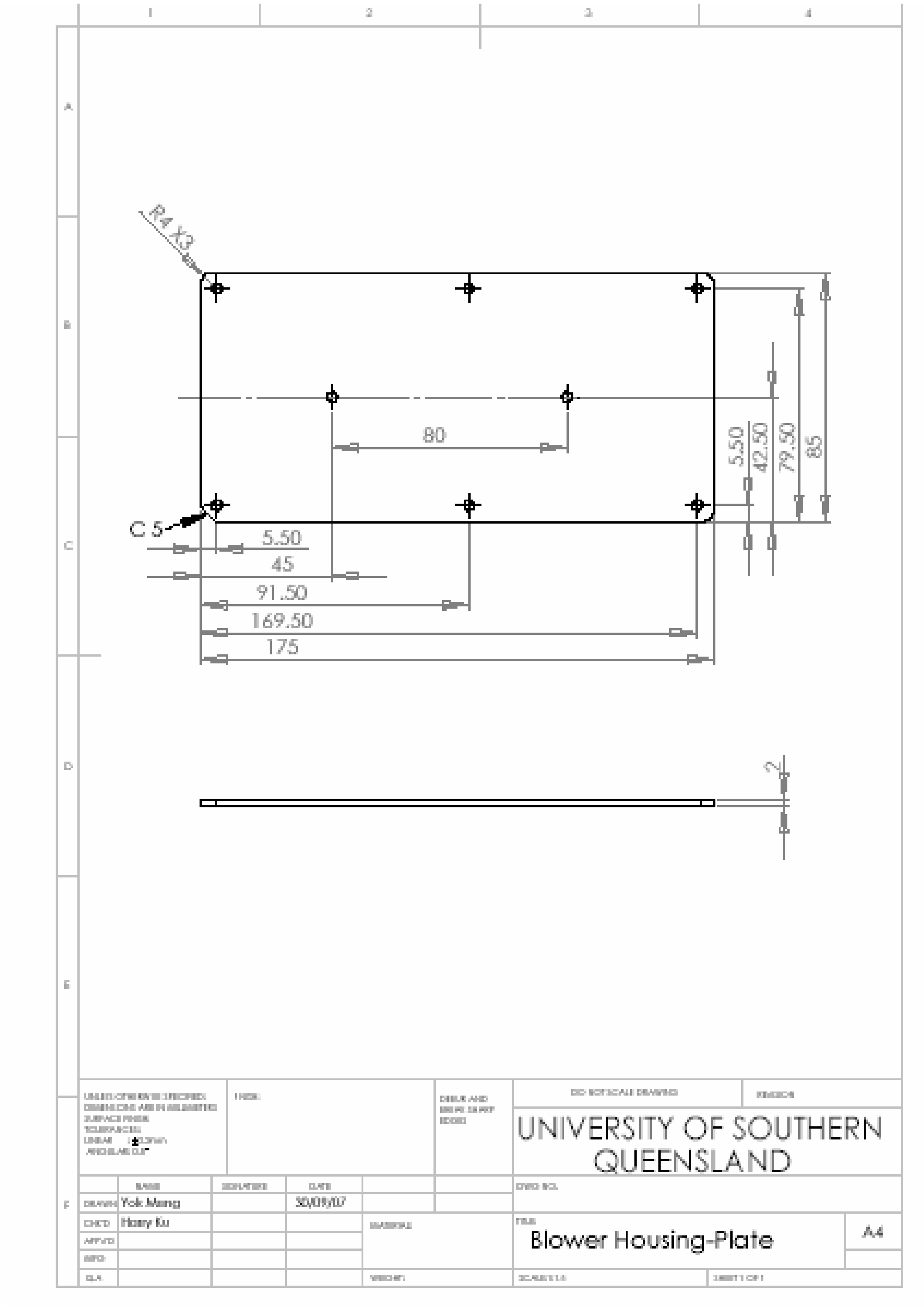
TITLE: Blower Housing
Main Body Housing

A4

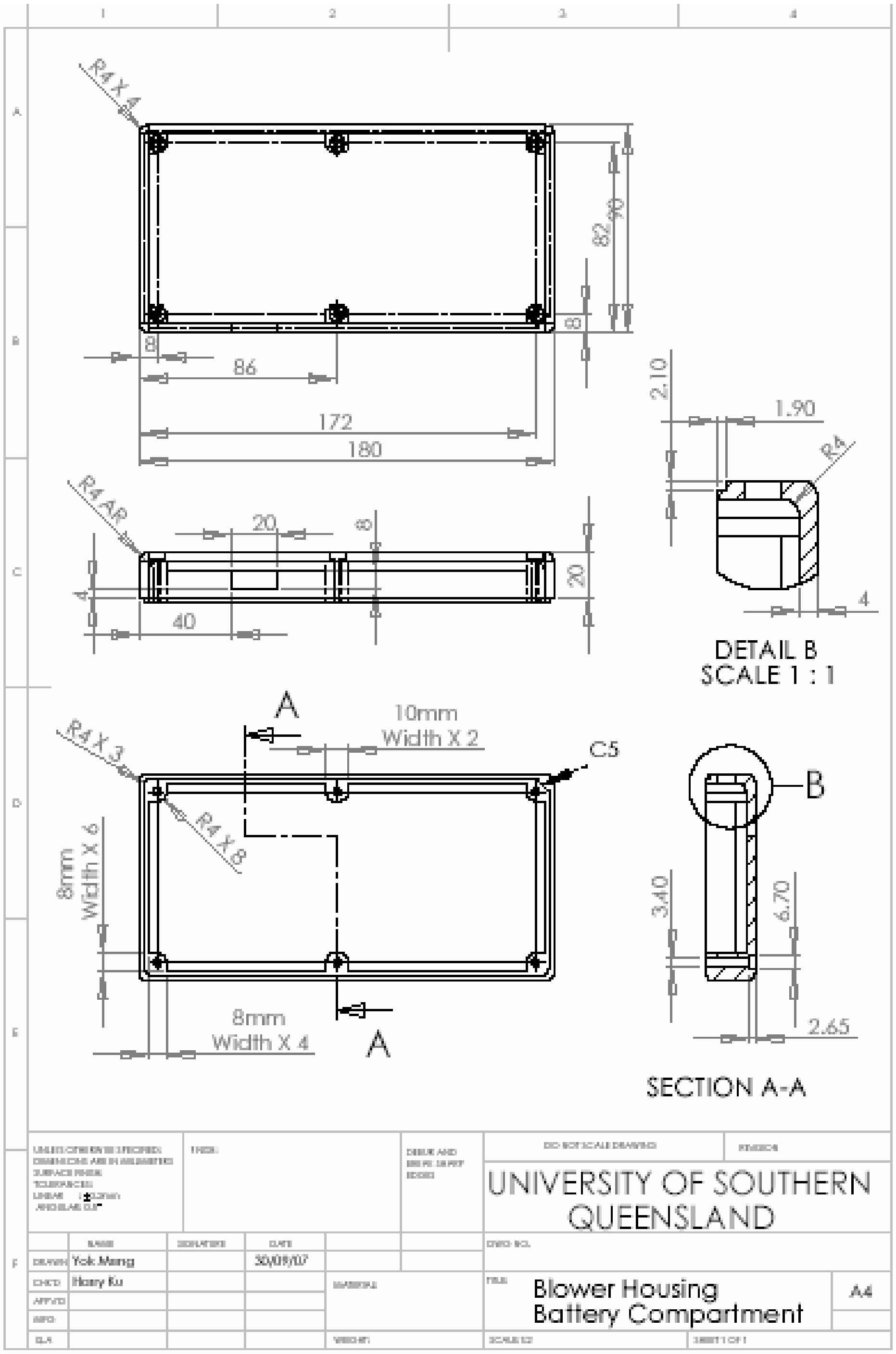
SCALE:1:1.5

SHEET 3 OF 3

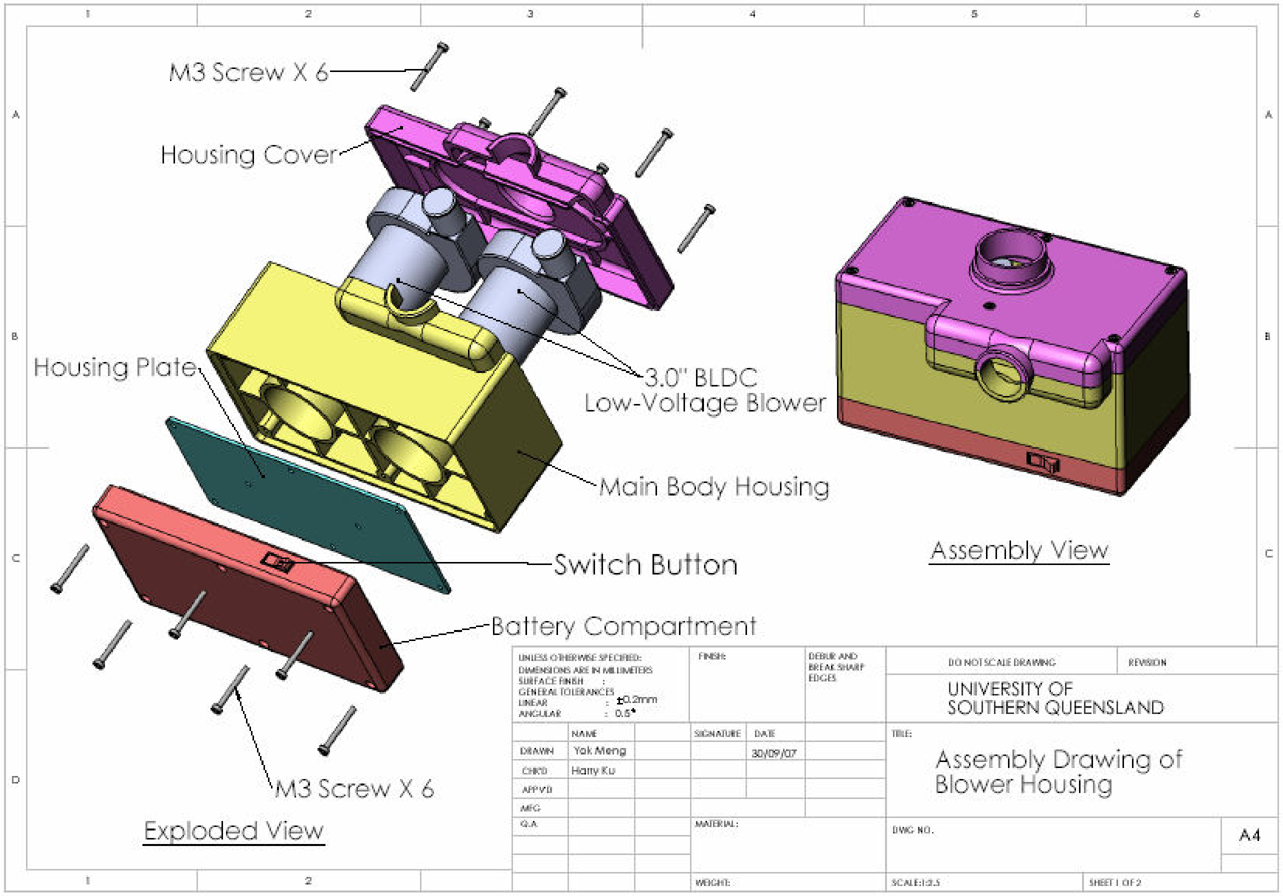
B12 Blower Housing – Housing Plate



B13 Battery Compartment



B14 Blower Housing –Exploded View



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GENERAL TOLERANCES
LINEAR : ±0.2mm
ANGULAR : 0.5°

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

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SOUTHERN QUEENSLAND

	NAME	SIGNATURE	DATE
DRAWN	Yak Meng		30/09/07
CHK'D	Harry Ku		
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

TITLE:
Assembly Drawing of
Blower Housing

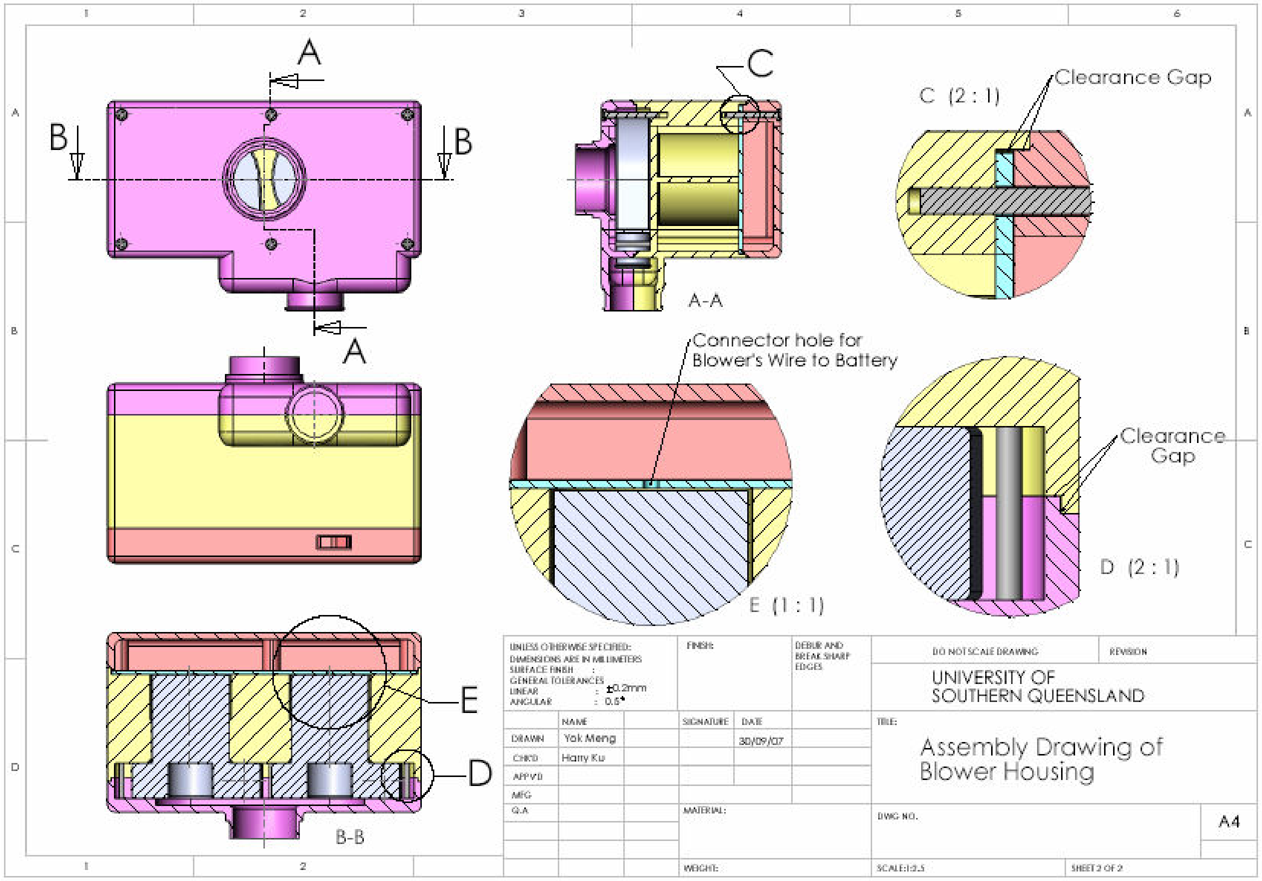
DWG NO.

A4

SCALE:1:2.5

SHEET 1 OF 2

B15 Blower Housing –Assembly Drawing



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
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GENERAL TOLERANCES
LINEAR : ±0.2mm
ANGULAR : 0.5°

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

UNIVERSITY OF
SOUTHERN QUEENSLAND

	NAME	SIGNATURE	DATE
DRAWN	Yak Meng		30/09/07
CHK'D	Harry Ku		
APPV'D			
MFG			
Q.A			

TITLE:
Assembly Drawing of
Blower Housing

MATERIAL:

DWG NO.

A4

WEIGHT:

SCALE:1:2.5

SHEET 2 OF 2

B16 BOM – Microclimate Ventilation System

BOM Table of Microclimate Ventilation System			
ITEM NO.	PART NUMBER	QTY.	DESCRIPTION
1	Blower Housing Main Body	1	Blower Housing Assembly
2	Blower Housing Cover	1	Blower Housing Assembly
3	Blower Housing Plate	1	Blower Housing Assembly
4	Blower Housing Battery Compartment	1	Blower Housing Assembly
5	M3 Screw X 30mm	12	Blower Housing Assembly
6	Desiccant Housing-Main Housing	2	Desiccant Housing Assembly
7	Desiccant Stopper Plate	4	Desiccant Housing Assembly
8	Desiccant Housing-Top Cover	2	Desiccant Housing Assembly
9	Desiccant Housing-Bottom Cover	2	Desiccant Housing Assembly
10	3.0" BLDC Low-Voltage Blower	2	Supplier
11	M40 Y-Join	1	Supplier
12	Switch Button	1	Supplier
13	Battery Set	2	Supplier

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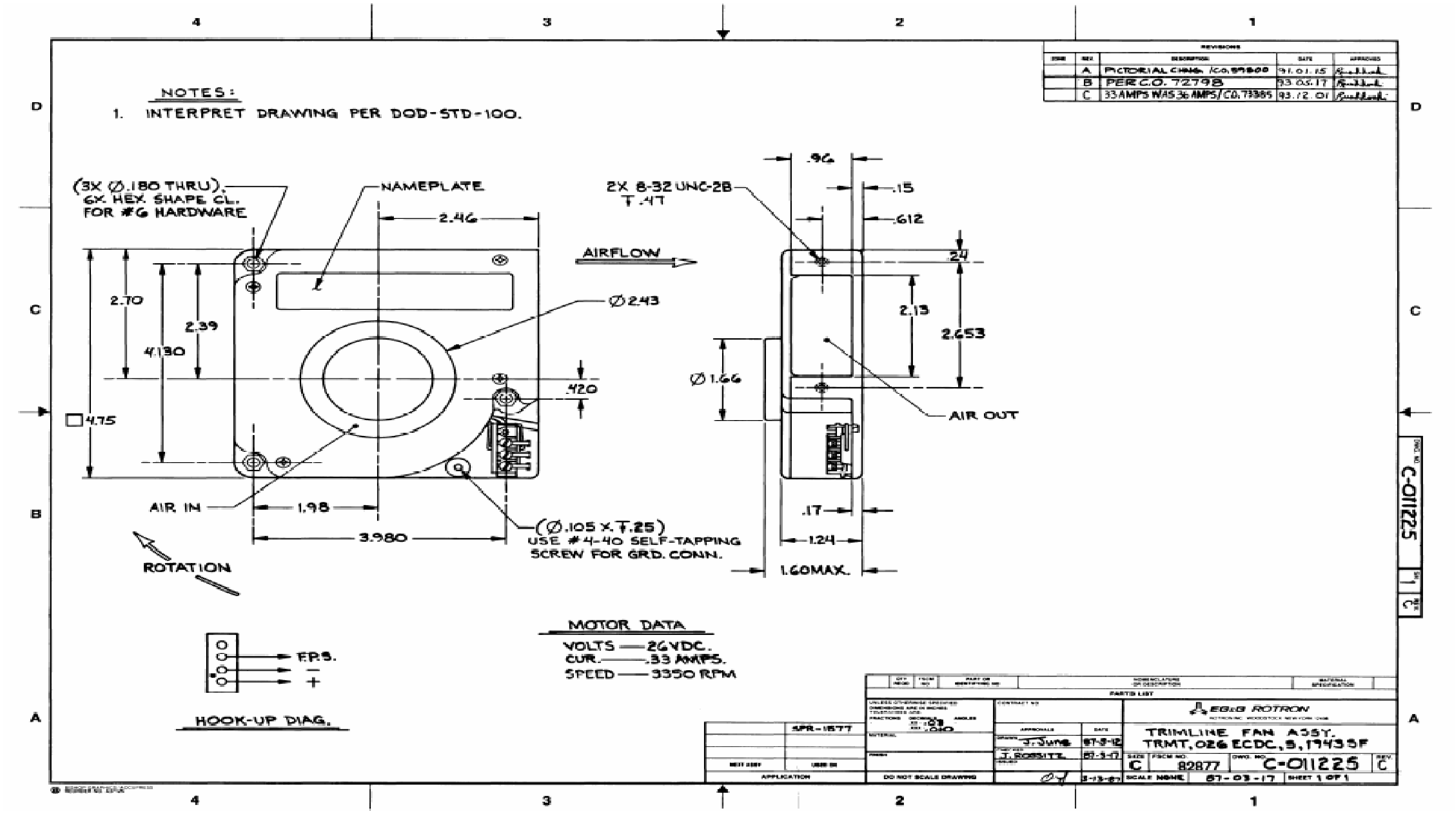
	NAME	SIGNATURE	DATE
DRAWN	Yok Meng		30/09/07
CHK'D	Harry Ku		
APPV'D			
MFG			
Q.A			

TITLE: Bill Of Material-Microclimate Ventilation System

A4

SHEET 1 OF 1

B17 Specification Drawing for TRMT1943 Axial Fan



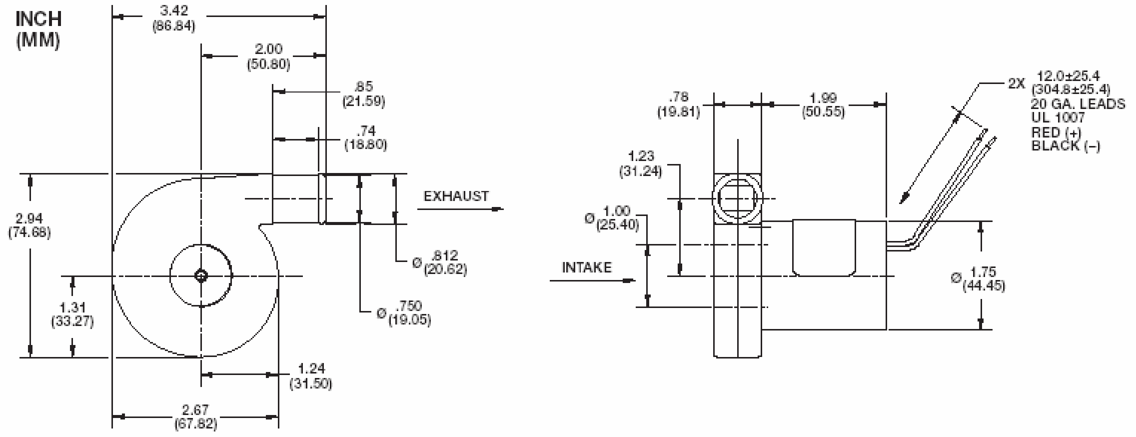
B18 Specification drawing for AMETEK 3.0” (76mm) BLDC Low-Voltage Blower 12/24VDC

AMETEK®

TECHNICAL & INDUSTRIAL PRODUCTS

3.0” (76mm) BLDC Low-Voltage Blower

12/24 VDC



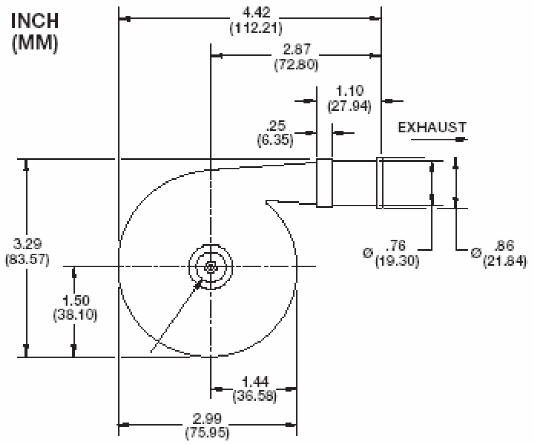
B19 Specification drawing for AMETEK 3.3” (84mm) BLDC Low-Voltage Blower 12/24VDC

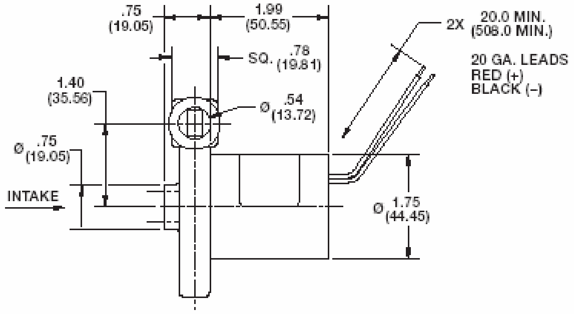
AMETEK®

TECHNICAL & INDUSTRIAL PRODUCTS

3.3” (84mm) BLDC Low-Voltage Blower

12/24 VDC



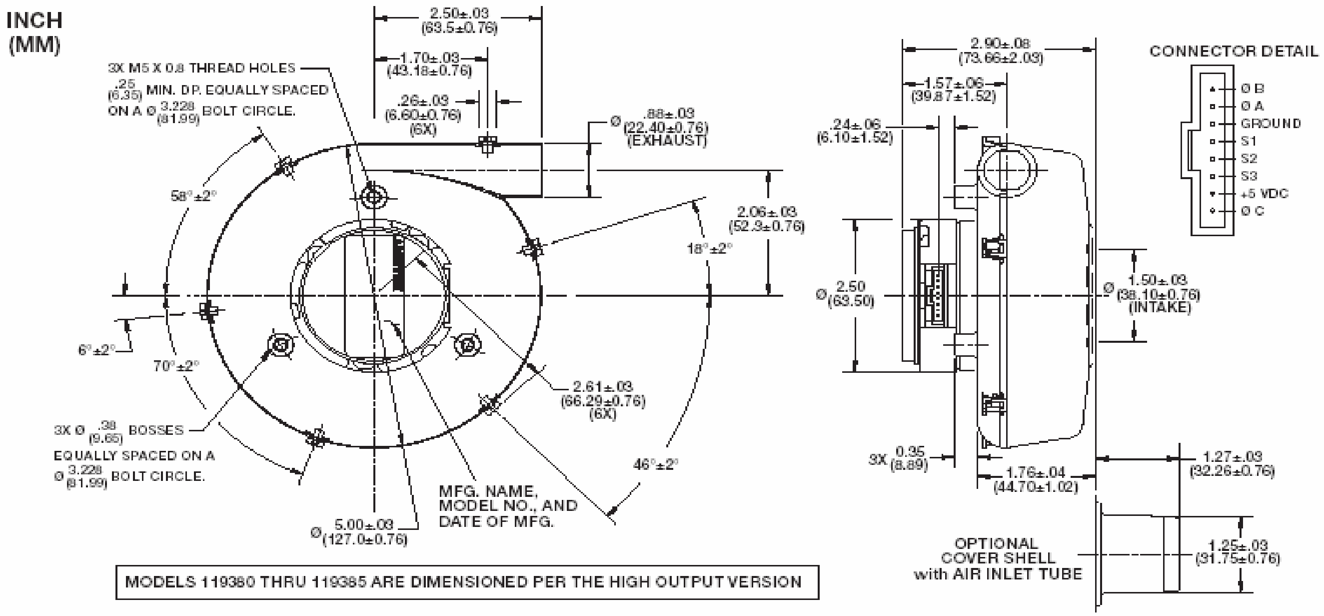


B20 Specification drawing for AMETEK 5.0” (127mm) BLDC Low-Voltage Blower 12/24V

AMETEK®
TECHNICAL & INDUSTRIAL PRODUCTS

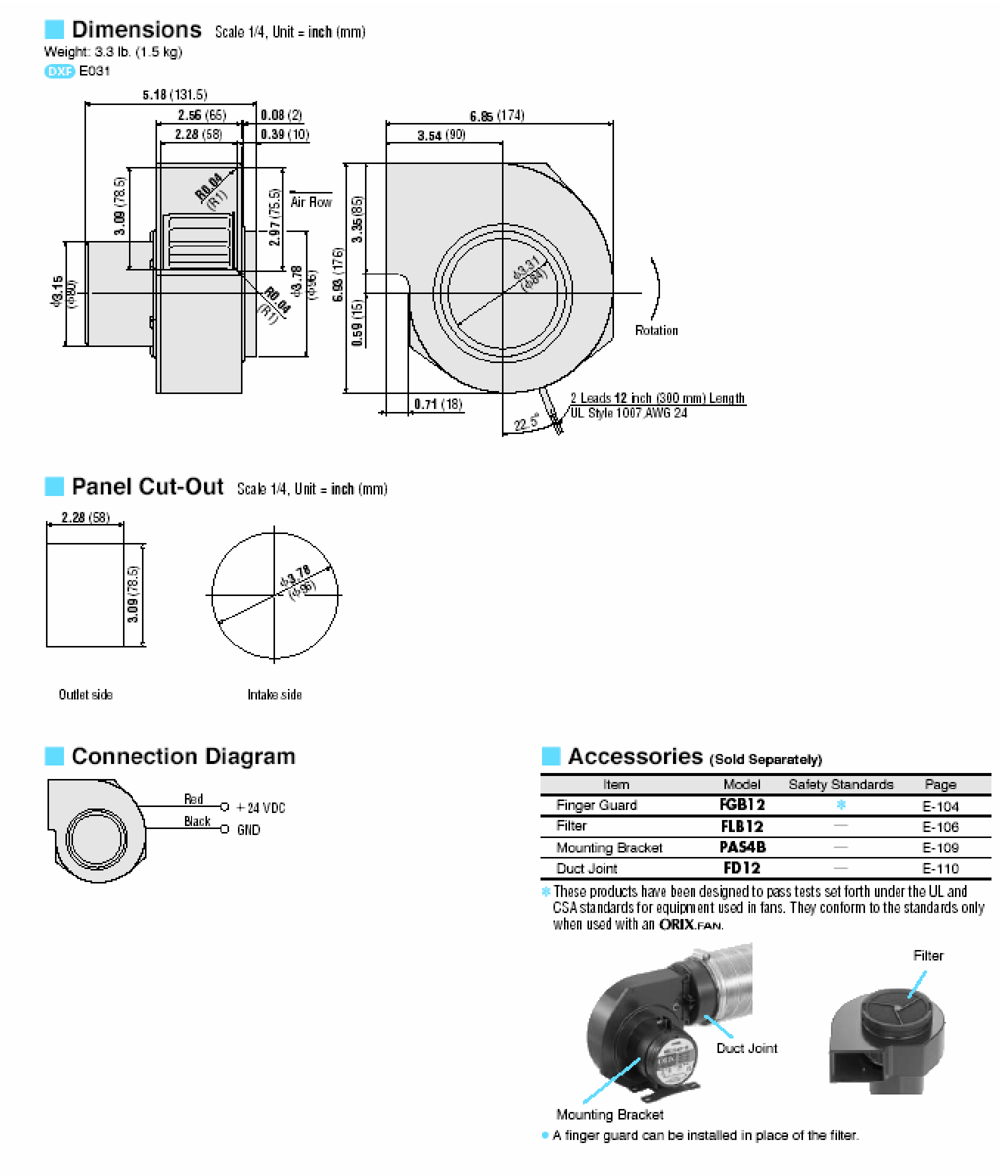
5.0” (127mm) BLDC Low-Voltage Blower

12/24 VDC, Standard Flow System



MODELS 119380 THRU 119385 ARE DIMENSIONED PER THE HIGH OUTPUT VERSION

B21 Specification drawing for Orix MBD12-24 Brushless centrifugal blower 24VDC



Dimensions Scale 1/4, Unit = inch (mm)

Weight: 3.3 lb. (1.5 kg)

DXF E031

Panel Cut-Out Scale 1/4, Unit = inch (mm)

Connection Diagram

Accessories (Sold Separately)

Item	Model	Safety Standards	Page
Finger Guard	**FGB12**	*	E-104
Filter	**FLB12**	—	E-106
Mounting Bracket	**PAS4B**	—	E-109
Duct Joint	**FD12**	—	E-110

* These products have been designed to pass tests set forth under the UL and CSA standards for equipment used in fans. They conform to the standards only when used with an ORIX.FAN.

- A finger guard can be installed in place of the filter.

B22 Moody Diagram (Plot of Colebrook's Correlation)