THE EFFECT OF ENGINEERING CRITERIA IN THE APPLICATION OF COOLING SYSTEM AND AIR-CONDITION SYSTEM USED IN TRADE VEHICLES ON INDUSTRIAL DESIGN CRITERIA

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
Izmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Industrial Design

by

Ferhan KESHAVARZİ

January 2006
İZMİR

We approve the thesis of **Ferhan KESHAVARZİ**

Date of Signature

………………………………… **06 January 2006**

Assist. Prof. Yavuz SEÇKİN
Supervisor
Department of Industrial Design
İzmir Institute of Technology

………………………………… **06 January 2006**

Assist. Prof. Dr. Önder ERKARSLAN
Department of Industrial Design
İzmir Institute of Technology

………………………………… **06 January 2006**

Assist. Prof. Dr. Can ÖZCAN
Department of Industrial Design
İzmir University of Economics

………………………………… **06 January 2006**

Assist. Prof. Yavuz SEÇKİN
Head of Department
İzmir Institute of Technology

…………………………………
Assoc. Prof. Dr. Semahat ÖZDEMİR
Head of the Graduate School

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my advisor Assist. Prof. Dr. Yavuz SEÇKİN for his guidance, suggestions and encouragement throughout the development of this thesis.

And special thanks to my friends Mehmet Yarar, Haldun Karacan and my cousin Ahsen Öztürk for their continuous support and friendship.

Finally, I would like to thank my family and my wife Esra Uzel Keshavarzi for their moral support throughout my graduate study.

ABSTRACT

In this thesis the designing criteria of the cooling system and air conditioners, which are used in trade vehicles, are analyzed in terms of industrial designing. The study describes the stage of the process through which the air conditioner is created and designed in accordance both with the criteria of engineering and industrial design. The thesis also dwells on the functioning principles of the air conditioner and the impacts of its use on the human life and working conditions. The other issues dealt with are the reasons why the industrial designer should use the engineering criteria to complete the design of the air conditioner and why he should use the industrial design criteria to make the design preferable. In order to show the effects of the engineering and designing criteria on the design of the air conditioner, all the phases are shown in this thesis.

ÖZET

Bu tezde, ticari araçlarda kullanılan soğutucuların ve klimaların tasarım kriterleri bir endüstri ürünleri tasarımcısının bakış açısına göre incelenmiştir. Çalışma, klimanın mühendislik kriterlerine göre nasıl oluştuğu, endüstri ürünleri tasarım kriterlerine göre nasıl şekillendiği sürecini adım adım anlatmaktadır. Klimanın çalışma prensibi, insana ve çalışma hayatına olan etkileri de tezdeki diğer konular arasındadır. Endüstri ürünleri tasarımcısının klima tasarımını tamamlamak için mühendislik kriterlerinden faydalanması gerektiği ve tasarımın tercih edilebilir hale gelebilmesi için endüstri ürünleri tasarım kriterlerinin ne kadar önemli olduğu da tezde değinilen konulardır.Mühendislik ve tasarım kriterlerinin klima tasarımı üzerindeki etkileri gösterebilmek için bir klimanın tüm tasarım evreleri tezde açıklanmıştır.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. Definition

The effects of global warming are getting worse each day and are estimated to be much worse in the future. As everyone can see, it has very bad effects on every form of human life. Today action is occurring at every level to reduce, to avoid, and to better understand the risks associated with the global warming. Especially to avoid the decrease in the productive power, air conditioners are becoming much more important.

With the developing technology, the decrease in the cost of the productions, and the change in the comfort conditions, new functions are added to the conditioning systems. Air conditioners, which used to have only the function of cooling, now also regulates the humidity and the warmth of the environment that are used in. In addition to this, new types of filters are developed to clean and to sterilize the air, even to increase the amount of the oxygen in the system. The developing technology also serves the nature by producing smaller, quieter, and cheaper devices.

Instead of using the cooling liquids R12 and R22, which are the main factors to damage the ozone layer, which protects life on earth by filtering out harmful ultraviolet radiation from the sun, new environmentally friendly cooling gases are developed. The new technology not only enables a progress in the components of the air conditioner but also in the polyester material which is used in the cover of the air conditioner and in many other fields intensively due to its importance in engineering and designing criteria.

1.2. Aim of Thesis

All the big air conditioner producers in the world especially in Europe and the United States make it possible to use air conditioners in every single place where people look for comfort. Besides houses, office buildings, and schools, with the new regulations it is now obligatory to use air conditioners in all public transportation vehicles such as buses, minibuses, streetcars, and subways.

In Turkey, Safkar, which has the knowledge and experience to compete with the other companies in the world, has been the leader for many years to use the new technology and adapt it to Turkey's conditions. PRO X cabin air conditioner, which is used in this thesis, is designed by Safkar for Street Car Project.

1.3. Methodology

In this study the relationship and the priority of engineering and designing criteria is analyzed. Although they appear to be unrelated concepts basically, their relationship and adaptation with each other during the production stage, has a direct effect on the designing period and the functioning of the device. Case study and observation methodologies are used to collect detailed data about all design phases of equipment and reflect the process correctly.

1.4. Scope of the Work

Information about definition, aim and methodology of the thesis is covered in chapter 1, chapter 2 gives brief information about heat and heat transfer. Chepter3 covers information, in which, air-conditioner, filters of air-conditioner, comfort conditions, history of air-conditioner and components used in air-conditioner are explained. Detailed information about polyester which is material of air-conditioner cover is given in chapter 4. In chapter 5, production phase and design criteria's of PRO X equipment are explained by case study and observation methods. Finally, effects of engineering criteria's on design criteria's are outlined in last chapter, conclusion.

CHAPTER 2

GENERAL KNOWLEDGE ABOUT HEAT

2.1. The Nature of Heat

Heat can be thought of as the internal kinetic energy of the atoms and molecules that make up a substance. Being a form of energy, it is measured in the standard unit of Joule, the other units of heats are:

- Calorie: This is the heat energy needed to raise 1 gr of water 1 ^{o}C. 1 calorie is equal to 4.186 Joules.
- BTU: This is a British thermal unit, still used as a rating on some furnaces, and is the heat energy needed to raise 1 pound of water 1 ^{o}F. 1 BTU = 252 calories = 1,054 Joules. (WEB_1, 2003)

Two forms of heat are relevant in air conditioning:

- Sensible heat
- Latent heat

2.1.1. Sensible Heat

When an object is heated, its temperature rises as heat is added. The increase in heat is called sensible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat. Heat that causes a change in temperature in an object is called sensible heat.

2.1.2. Latent Heat

All pure substances in nature are able to change their state. Solids can become liquids (ice to water) and liquids can become gases (water to vapor) but changes such as these require the addition or removal of heat. The heat that causes these changes is called latent heat. Latent heat however, does not affect the temperature of a substance - for example, water remains at 100°C while boiling. The heat added to keep the water boiling is latent heat. Heat that causes a change of state with no change in temperature is called latent heat. Appreciating this difference is fundamental to understanding why refrigerant is used in cooling systems. It also explains why the terms 'total capacity' (sensible & latent heat) and 'sensible capacity' are used to define a unit's cooling capacity. During the cooling cycling, condensation forms within the unit due to the removal of latent heat from the air. Sensible capacity is the capacity required lowering the temperature and latent capacity is the capacity to remove the moisture from the air. (WEB_2, 2004)

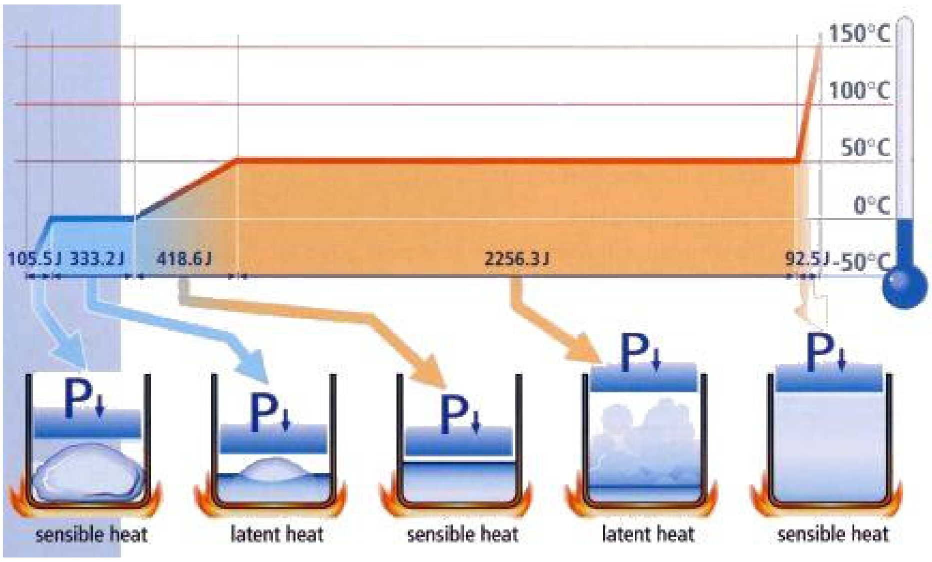


Figure 2.1. Difference of Latent Heat and Sensible Heat

(Source: WEB_2, 2004)

2.2. Heat Capacity

The heat capacity of a substance is a measure of how well the substance stores heat. Whenever a material is heated, it will necessarily cause an increase in the material's temperature. The heat capacity is defined, as the amount of heat required per unit increase in temperature, so that “Heat added = heat capacity x (change in temperature)”

Thus, materials with large heat capacities, like water, hold heat well - their temperature won't raise much for a given amount of heat - whereas materials with small heat capacities, like copper, don't hold heat well - their temperature will rise significantly when heat is added. (WEB_3, 2005)

2.3. Temperature

Heat refers to the total amount of heat energy in a substance - two liters of boiling water have more heat energy than one liter. Temperature, on the other hand, is a relative term, and refers to the average kinetic energy of the atoms and molecules in a substance. One fundamental property of temperature is that Heat will not flow between two substances at the same temperature.

There are three main temperature scales used in the world - Celsius, Fahrenheit, and Kelvin. These are compared in the following table.

Table 2.1. Temperature Scale Comparisons

	^oC	K	^oF
Water Boils	100	373	212
Water Freezes	0	273	32
Absolute Zero	-273	0	-459

The difference between the Celsius scale and the Kelvin scale is simply a shift by 273 ^{o} The Kelvin scale is more convenient to measure substances with very low temperatures. Moreover 0 Kelvin has a very deep physical significance: absolute zero, as the name suggests is the lowest temperature that can, even in principle, be achieved in Nature. It is the temperature associated with empty space that is completely devoid of all motion and/or energy. In practice it is impossible to obtain, although one can get arbitrarily close. (WEB_4, 2005)

2.4. Heat Transfer

There are three ways that heat may be transferred between substances at different temperatures - conduction, convection, and radiation. We consider each of these in turn.

- Conduction
- Convection
- Radiation

2.4.1. Conduction

The flow of heat by conduction occurs via collisions between atoms and molecules in the substance and the subsequent transfer of kinetic energy. In figure 2.2 two substances at different temperatures separated by a barrier which is subsequently removed, as in figure. 2.2

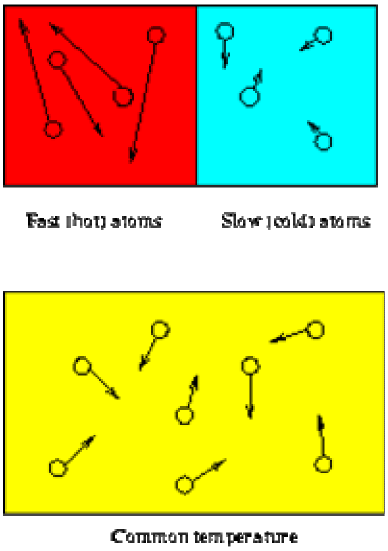


Figure 2.2. Heat Transfer by Conduction
(Source:WEB_5, 2005)

When the barrier is removed, the fast (“hot") atoms collide with the slow (“cold") ones. In such collisions the faster atoms lose some speed and the slower ones gain speed; thus, the fast ones transfer some of their kinetic energy to the slow ones. This transfer of kinetic energy from the hot to the cold side is called a flow of heat through conduction. Different materials transfer heat by conduction at different rates this is measured by the material's thermal conductivity. For example a material in between two reservoirs at different temperatures, as in the following figure.

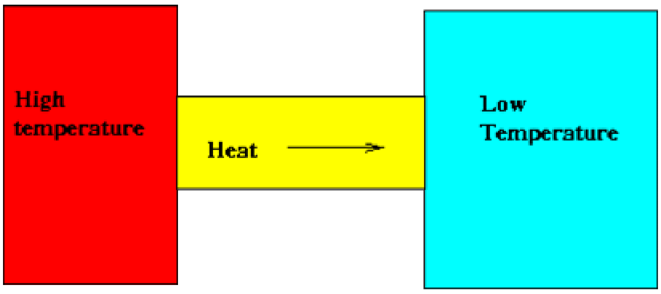


Figure 2.3. Measurement of Thermal Conductivity
(Source:WEB_5, 2005)

Then the flow of heat through the material is measured over time. Knowing the material's cross-sectional area and length, the thermal conductivity of the material is then defined as" Heat flow over time = thermal conductivity x (area / length) x (temperature difference between reservoirs)" Thus, for a given temperature difference between the reservoirs, materials with a large thermal conductivity will transfer large amounts of heat over time - such materials, like copper, are good thermal conductors. Conversely, materials with low thermal conductivities will transfer small amounts of heat over time - these materials, like concrete, are poor thermal conductors.Home insulation is thus a poor thermal conductor, which keeps as much heat in as possible. Instead of being rated in terms of thermal conductivity, insulation is therefore usually rated in terms of its thermal resistance, which is defined as "Thermal resistance = length / thermal conductivity" Materials, which have a high thermal conductivity, have, by definition, a low thermal resistance - they are poor heat insulators. On the other hand, materials with a low thermal conductivity have a high thermal resistance - they are good heat insulators. Good insulating materials therefore should have a high thermal resistance. In fact, the ``R'' value quoted for insulation is the thermal resistance (in British units). (WEB_5, 2005)

2.4.2. Convection

Convection is the flow of heat through a bulk, macroscopic movement of matter from a hot region to a cool region, as opposed to the microscopic transfer of heat between atoms involved with conduction. When a local region of air, the molecules spread out, causing this region to become less dense than the surrounding, unheated air. Being less dense than the surrounding cooler air, the hot air will subsequently rise due to buoyant forces - this movement of hot air into a cooler region is then said to transfer heat by convection. These convection currents are illustrated in the following figure.

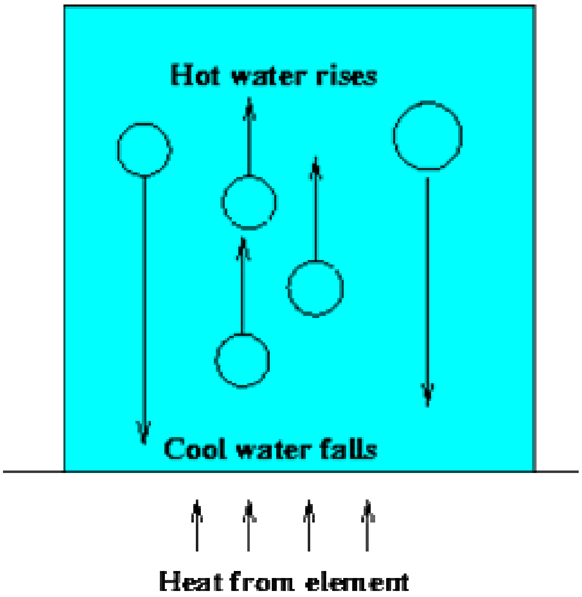


Figure 2.4. Convection Currents in Boiling Water
(Source:WEB_6, 2005)

If two regions are separated by a barrier, one at a higher pressure relative to the other, and subsequently remove the barrier, as in the following figure. These convection currents are illustrated in the following figure.

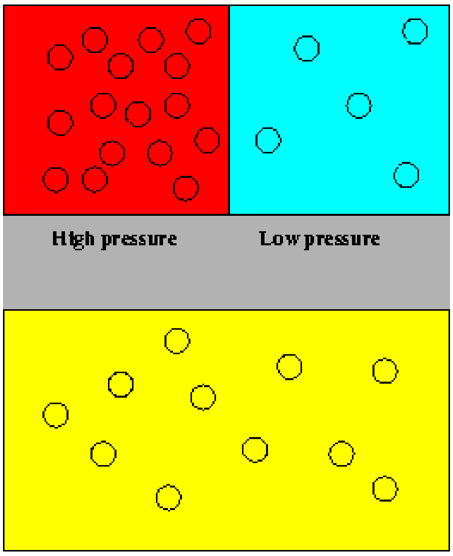


Figure 2.5. Flow of Material Through a Pressure Difference

(Source:WEB_6, 2005)

When the barrier is removed, material in the high pressure (high density) area will flow to the low pressure (low density) area. If heating of the material originally created the low-pressure region, one sees that movement of material in this way is an example of heat flow by convection. (WEB_6, 2005)

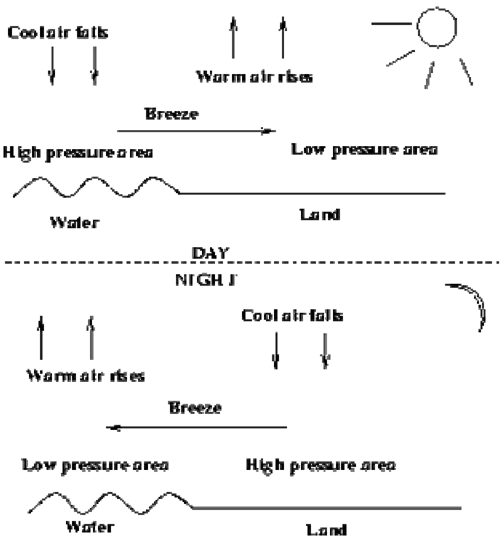


Figure 2.6. Formation of Breezes near Large Bodies of Water

(Source:WEB_6, 2005)

2.4.3. Radiation

The third and last form of heat transfer is radiation, which in this context means light (visible or not). This is the means by which heat is transferred, for example, from the sun to the earth through mostly empty space - such a transfer cannot occur via convection nor conduction, which require the movement of material from one place to another or the collisions of molecules within the material.

Some of the light can be in the form of visible light that we can be seen, but a great deal of the light emitted is infrared light, whose longer wavelength is detectable only with special infrared detectors. The hotter the object is, the less infrared light is emitted, and the more visible light. (WEB_7, 2005)

CHAPTER 3

CLIMATIZATION

3.1. Climatization

Climatization is a very important aspect considering people's health. ”Climatization” is getting desired climate conditions. Indoor air condition should be good to get sustainable comfort and health and also to get a more effective performance from working people. The required conditions are the combination of fresh-air, clean-air, humidity, temperature and velocity of air. Also “climatization” can be defined as conditioning of air in a close environment to optimized temperature, humidity, cleanliness, and movement of air for health and comfort of human or industrial work. Application zone of climatization can be grouped into 3 such as application for comfort (building, air-planes, bus, car, shops etc.), application for places including sensitive equipments (laboratories etc) and application for industry (press industry, agricultural processes etc. (WEB_8, 2005)Air conditioning is the process of treating the temperature, humidity, cleanness and distribution of the air. With air conditioning you can create the comfort in which you feel best, with the right temperature and a comfortable humidity. Air-cooling system service one or more environments. These systems contain electric motor, refrigent, fan and the other details placed in protection cover. For same application, resistance is used for heating in winter.) (WEB_9, 2005)

3.1.1. Cooling

Air conditioners offer precise temperature control. They give opportunity to create the climate, with the right temperature. Not only does it create comfort, it makes you feel fresh and active even in the most extreme outside conditions.

3.1.2. Heating

Air conditioners can also offer heating. The perfect constant temperature all year through can be achieved not taking care of out side conditions. It is an environmentally friendly alternative to traditional heating because it takes energy from the outside air and brings it inside.

3.1.3. Cleaning

Air conditioners produce clean, healthy air. In air, there can be dust, smoke containing mass and liquid materials, vapour, mist and gasses as pollutant. These can be in the form of organic or inorganic, flammable or in flammable, poisonous or non-poisonous. Air pollution cause many diseases such as headache, nausea etc. Every air conditioning unit has a filter. The type of filter depends on the type of air. A system conditioning system with integrated ventilation requires a less effective filter. The efficiency of a filter is measured in the percentage of arrestance of particles. Another factor in the efficiency of a filter is the airflow.

3.1.3.1. Dust Filter

Removes airborne dust and particles to ensure a steady supply of clean air. The dust comes from the skin, hair, and clothes or just comes off shoes when we walk in and out. The mildew, fungus and molds can come in along with the dust. The dust filter can easily be washed or vacuumed.

3.1.3.2. Air Purification Filter

The air purification filter traps small dust**,** particles and pollen as small as 0,01 microns and prevents the propagation of bacteria and viruses. The filter is double-sided with an air-cleaning electrostatic filter on the front side and a deodorising activated charcoal filter on the rear side. The air-purifying filter is always combined with a regular filter.

3.1.3.3. Photo Catalytic Deodorising Filter

This filter is an anti-bacterial and deodorising filter, which powerfully decomposes cigarette and pet odors and also restrains the reproduction of bacteria**,** viruses and microbes caught in the filter. The photo catalytic deodorising filter is always combined with an air-purifying filter.

3.1.4. Dehumidifying

In cooling mode, an air conditioner dehumidifies the air, creating a better feeling of well-being. Bear also in mind that a correct humidity level limits the growth of dust mites and molds, which again has a positive effect on people with allergies. Human beings feel that 40 to 60 % is a comfort level of humidity. Also a correct humidity level ensures a longer lifetime of your appliances and house. And, humidity of at least 50 % greatly reduces the survival rate of the influenza virus.

3.1.5. Ventilating

Ventilation can be integrated in the air conditioning system. It takes out the inside air and pushes in fresh, conditioned air from outside. In mid season, when the air conditioning is turned off, the ventilation can work independently. Ventilation systems can also be installed without the air conditioning installation. One of the important points of ventilation is air velocity in canals. Air velocity in canals is dependent on usage of canal, type of building and noise degree. Air velocity should be selected taking care of the aim of usage of air. If more velocity is selected than appropriate one, non-desired noise occurs. Also; because of dependence of air velocity to power of system fan, increasing velocity requires increasing flow-rate and load of fan. And also selecting lower velocity prevents to reach sufficient air- flow-rate. In this condition, desired air-conditioning or climatization cannot be achieved. There is a close correlation between an operative's personal performance and the temperature of his immediate surroundings. An environment that is too hot, too cold or too damp will certainly not contribute to higher working efficiency. Indoor air quality is an important point for people .Air conditioning is able to prevent or reduce some of the health problems. (Aktaş, D., Özdemir, M .2004)

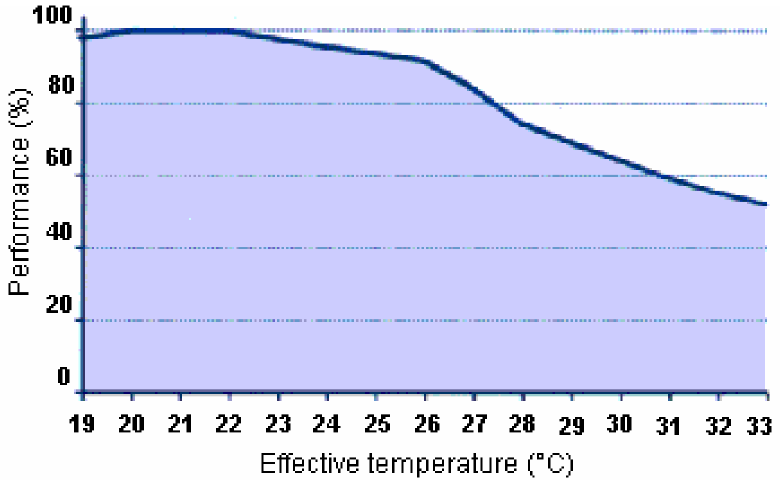


Figure 3.1. Performance in Function of Temperature.

(Source:WEB_9, 2005)

The graph illustrates this correlation. Performance begins to drop at about 22°C whilst above 26°C, it falls dramatically. It is important therefore, to keep temperature under control. It is scientifically proven that:

1. Accidents tend to occur more frequently during extreme temperatures - the optimum temperature appears to be about 20°C.
2. Mental performance and work rhythm drop off sharply when it is too hot.
3. Obviously, the provision of a constant environment is subject to many influences. (WEB_9, 2005)

3.2. Thermal Comfort

People can fix their life conditions regarding to changing outdoor air conditions, but this does not change to require some comfort conditions to feel comfortable. Thermal conditions of human body have to be adapted to different environmental and physical conditions. Beside this, supplying comfort conditions are not totally due to outdoor air conditions. Cloths, health, foods, age, seasonal conditions and works are the sub elements that effects comfort directly .The most factors that effects human comfort are; temperature of air, wall temperature of building, air movement, humidity of air, smell, gasses environmental noise and lighting. (Doğan, H. 2002)

A bad air conditioning and climatization causes health problems and lack of motivation at work Problem of clean air is one of the factors that has to be taken care of.

Temperature and movement of air is not more important than clean air but also not less important than, either (Köktürk, U., 2001)

There is no doubt that same illnesses spreads around with microbe air. In the past people were not aware of this danger. But today this is a very important matter. By experience, decrease of rate of bacteria in air can be achieved with appropriate climatization.

“Thermal Comfort” is satisfaction of a person because of thermal conditions of the environment. The values effecting heat transfer between human and environment forms environment thermal conditions. Heat radiation temperature of an environment is dependent on temperatures of all surfaces in and surrounding environment. Heat transfer from human to environment is dependent on type and degree of work and type of clothes. (Kaynaklı, Ö., Yiğit, A. 2003)

The addition of thermal resistance due to clothing affects heat transfer mechanisms between the human body and the environment. "Clo" value is a numerical representation of a clothing ensemble's thermal resistance, 1 Clo = 0.155 m2K/w. [14]

Table 3.1. 'Clo' Values for Clothing

Clothing Combination	Clo	m^2K/W
Naked	0	0
Shorts	0.1	0.018
Typical tropic clothing outfit	0.3	0.047
Light summer clothing	0.5	0.078
Working cloths	0.8	0.124
Typical indoor winter clothing combination	1.5	0.233

A human body continuously produces heat. Same of this energy is used for muscles and protecting body internal temperature, rest of it goes into environment as latent and sensible heat by skin surface and respiration. In limited time, body resists to lose more or less heat than produced. If heat transfer to the environment in required velocity does not occur, physiological control mechanisms work to protect body normal internal temperature (approximately 36°C). But, these mechanisms have limited effects on protection. In comfort climatization, in a room full of resting or working in low degree people, relative humidity is %50. While air temperature equal to or close to environmental heat radiation temperature, and velocity for people wearing appropriately for the season, in winter 21°C –22 °C and 0.15 m/s, in summer 24°C-26°C and 0.25 m/s. in summer, if relative humidity decrease to %35, air temperature should be risen to 26°C. (Bu J. U., Kim T.Y. 1995)

If air temperature is over 27°C, an air moving between 0.25 m/s and 1.25 m/s has a cooling effect on people. More air velocity values should be preferred for over %60 relative humidity. Except too hot and too humid environment, air velocities more than 1.25 m/s disturb people. In environment having relative humidity between %30-%70, heat comfort condition can be achieved by fixing other heat conditions in summer and winter. It is known that in an environment having more than %75 relative humidity bacteria and virus generate more than in an environment having less than %23 relative humidity. Respiration diseases are seen more, if temperature decreases less than 21°C. Air temperature is 19°C in winter in condition of 24°C heat radiation temperature, or it is 31°C in summer in conditions of 25 °C heat radiation temperature; heat comfort conditions are achieved. Temperature of surfaces is mostly related to heat isolation and heat loading specification. (Aktaş D., Özdemir, M. 2004)

3.3. History of Air Conditioning

In 1902, the first air-conditioning was in operation. Willis Haviland Carrier found a way to control the climate in printing plant. Fluctuations in heat and humidity had caused the dimensions of the printing paper to keep altering slightly, enough to ensure a misalignment of the colored inks. The new air conditioning machine created a stable environment and aligned four-color printing become possible. Air conditioning becomes a financial blessing for industrial plant that depended upon stable climate conditions. Before air conditioning, cotton threads snapped, cigarette machines jammed, film attracted dust and chocolate went gray with fluctuating heat and humidity. Cool and dry air could also make factory workers more comfortable, more productive and less prone to call in sick.

The 'Apparatus for Treating Air granted in 1906, was the first of several patents awarded to Willis Haviland Carrier. The recognized 'father of air conditioning' is Carrier, but the term 'air conditioning' actually originated with textile engineer, Stuart H. Cramer. Cramer used the phrase 'air conditioning' in a 1906 patent claim filed for a device that added water vapor to the air in textile plants - to condition the yarn. In 1911, Willis Haviland Carrier disclosed his basic Rational Psychometric Formulae to the American Society of Mechanical Engineers. The formula still stands today as the basis in all fundamental calculations for the air conditioning industry.

Industries flourished with the new ability to control the temperature and humidity levels during and after production. Film, tobacco, processed meats; medical capsules, textiles and other products acquired significant improvements in quality with air conditioning. Willis and six other engineers formed the Carrier Engineering Corporation in 1915 with a starting capital of $35,000 (1995 sales topped $5 billion). The company was dedicated to improving air conditioning technology.

Until 1921, refrigeration machines used reciprocating compressors (piston-driven) to pump refrigerant (often toxic and flammable ammonia) throughout the system. Carrier designed a centrifugal-compressor similar to the centrifugal turning-blades of a water pump. The result was a safer and more efficient chiller. Also it was the first practical method of air conditioning large spaces. (WEB_11, 2004)

Cooling for human comfort rather than industrial need began in 1924. Mechanical cooling let architects break the rules of urban design. They got rid of the window awnings (no need for shade), added more offices (no need for windows) and erected glass towers immune to the outside world as long as the air conditioner kept the inside world a pleasant 22°C. In 1928, Willis Haviland Carrier developed the first residential 'Weather maker', an air conditioner for private home use.

By 1929, refrigerator maker Frigidaire created a small, expensive "room cooler" that could be installed in homes or small stores. This led to the window box unit, air conditioners in cars and, later, the rise of new house designs. Widespread adoption of so-called "comfort cooling," however, slowed until after the Great Depression and

Second World War. After the war, consumer sales started to grow again. (WEB_12, 2002)

3.3.1. History of Automotive Air Conditioning System

Early automobiles were not exactly comfortable. They were open vehicles and their skinny tires and rugged construction provided for a very rough ride. In winters, passengers bundled up and in the summer, air conditioning was a breeze that resulted from a top speed of 15 mph. And when the car companies started closing up the hoods, things got worse. The interiors got very hot and something serious needed to be done. They put up vents in the floor of the car, but this brought in more dirt and dust than it did cool air. More ingenious ideas followed. In 1884, William Whitely made experimentation by placing blocks of ice in a holder under horse carriages and blowing air inside by means of a fan attached to the axle. A bucket near a floor vent was the automotive equivalent. An evaporative cooling system followed next.

The temperature-reducing effect of air passing over water was adopted by a company called Nash and was called a Weather Eye. But the first car with an actual refrigeration system was the 1939 Packard. It consisted of a large evaporator, called the 'cooling coil,' which took up the entire trunk space. The only control was a blower switch. Packard, in fact, ran its advertising as, "Forget the heat this summer in the only air-conditioned car in the world. (WEB_13, 2004)

Cadillac followed suit in 1941 with 300 air-conditioned cars. All of these early air-conditioning systems had one big drawback: there was no compressor clutch, so the pump was on when the engine was running. To shut the system off, one had to stop, get out, open the hood, and remove the belt. It wasn't until after WWII that Cadillac advertised a new, high-tech feature: the air-conditioning controls. The controls were located on the rear package shelf, which meant that the driver had to climb into the back seat to shut the system off. Yet it was still better than reaching under the hood. The Harrison Radiator Division of General Motors may be credited with developing the first efficient, affordable unit that could be made in mass production. It was available as an option on all 1954 Pontiacs with V8s. It featured a two-cylinder reciprocating compressor, and an all-brazed condenser. It also used a magnetic clutch, so when it was not in use, no power was needed to drive the compressor, which improved performance and fuel economy. (WEB_13, 2004)

However, air conditioning continued to be a rare option for many years. It wasn't until the late 70s and 80s that air-conditioned cars became a craze. Systems were getting better and people realized that they didn't really have to sweat it out because their air-conditioning units did not run well. It's estimated that now over 80% of the cars and light trucks in operation in the United States have air conditioning.

Today, heating and air-conditioning systems are very efficient. Modern Automatic Temperature Control set-ups are more dependable than the older vacuum and thermostatic creations. Computers also insure that both the passenger and driver are comfortable, maintaining the optimum temperature. The future of automotive air conditioning is changing, and for the better. Now there are new electronic and compressor designs. The concern over the chlorofluorocarbon emissions and the damage they cause to ozone layer has induced innovations in order to reduce the emissions. Most cars today use a new refrigerant called R-134A, which contains no chlorine. Auto repair businesses are also taking steps to reduce the amount of R-12 or chlorofluorocarbons that escapes during service work. (WEB_13, 2004)

3.4. Refrigeration Cycle Parts

In this section, introduction of the apparatus and equipment used in vapor compression will be handled. A vapor compression cycle is formed of the parts bellowed.

1. Compressor
2. Evaporator
3. Condenser
4. Expansion Valve
5. Drier
6. Receiver Tank

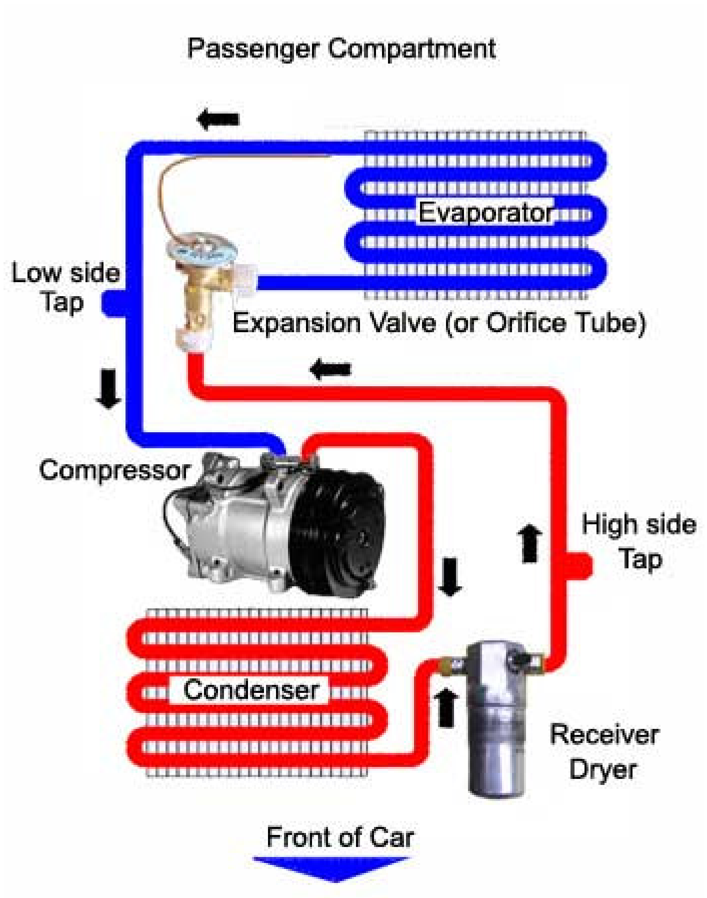


Figure 3.2. Refrigeration Cycle
(Source:WEB_14, 2004)

Refrigeration cycle is basically formed of two main parts, which are high-pressure line and low-pressure line the compressor, which are the main element of the system intakes the low-pressured refrigerant and sends the high-pressured gas to the condenser by compressing thus increasing the heat. So the compressor provides the fluid with circulation in the system. (WEB_14, 2004)

3.4.1. Cooling Compressors

Function of cooling compressor in system:

1. To remove the refrigerant from evaporator where the refrigerant is loaded heat and to provide continuity of flow by making a place for next fluid.
2. To increase pressure of refrigerant in vapour phase to a level which is opposite of condensation temperature in condenser.

An ideal compressor should consist of these general and control characteristics;

1. Continuous control of capacity and adaptable to work load transferring within wide range.
2. Long working life and no breakdown
3. Compressor's efficiency must not be got less with partial load.
4. Supplying per cooling valve consuming less energy.
5. Operating cost must be as lower as possible.

However, there is no compressor that has whole these characteristics. In practice the compressor providing maximum amount of these characteristics will be preferred. Cooling compressors can be grouped as in below considering general structure of compressor.

3.4.1.1. Positive Compressed Compressors.

1. Piston compressors
2. Palette compressors
3. Screwed type rotational compressors

Piston compressors are used in mobile cooling system and air conditioner for vehicle. Piston compressors are proper for refrigerant whose pressure is too much between suction and pressure line. Application conditions of piston compressors suit refrigerants requiring less cylinder volume, which is equal to cooling capacity of per refrigent, and also having more difference between suction and press pressure. In these compressors, which compress by a piston moving linear in a cylinder; rotational movement of motor is turned into linear movement by flywheel system.

To day piston compressors generally having single effect, low round and big numbers of cylinders are designed and produced as open type or hermetic type. (Tian, C., 2002)

Figure 3.3. Cutaway of Piston compressors
(Source:WEB_14, 2004)

3.4.1.2. Performance of Compressor

Performance of machine can be defined as evaluation of capability that fulfils defined work. Compressor performance is conclusion of design, which is formed by certain physical boundaries of cooling system, compressor and motor.

1. Long life without breakdown
2. Minimum inlet power must provide maximum cooling effect.
3. Minimum cost
4. Wide working range
5. Lower vibration and noise level

There are two criterions about compressor performance. One is capacity, which is related with compressor movement the other is performance factor. System capacity is cooling effect that provided by compressor. It is equal to difference of total enthalpies between inlet and outlet it is called as [kJ/kg].

3.4.2. Evaporator

Evaporator is a device where the refrigerant takes heat from place in order to evaporate. Other words it is a cooler. Refrigerant is expanded by an expansion valve and comes in evaporator in mixture of liquid and vapour. Most of it is in liquid phase. There are lots of useful points of heating refrigent which is vapoured as heat in evaporator, before suction and superheating between 3-8°C to transfer superheated vapour phase. Main point can be defined as preventing the movement harmful refrigent to compressors. In all evaporators the refrigerant pressure is lower if it is compared with pressure in condenser. Because of this reason evaporator side is called as lower pressure side of system (Lee,G.H , 2000)

Structure of evaporator should be designed considering good and fast vaporization of refrigerant, taking heat from cooled material with high efficiency and minimum level of pressure difference between inlet and outlet. But the last one is generally opposite of first two points. Because of this reason, evaporator design requires experience, care and also study with experiments. Coil producers, which have references in domestic market and international markets, use computer aided simulation programs such as “Coils UNILAB” etc. to get heat capacity, heat transfer surface area. etc. for prototype and sample processes .(WEB_15, 2004)

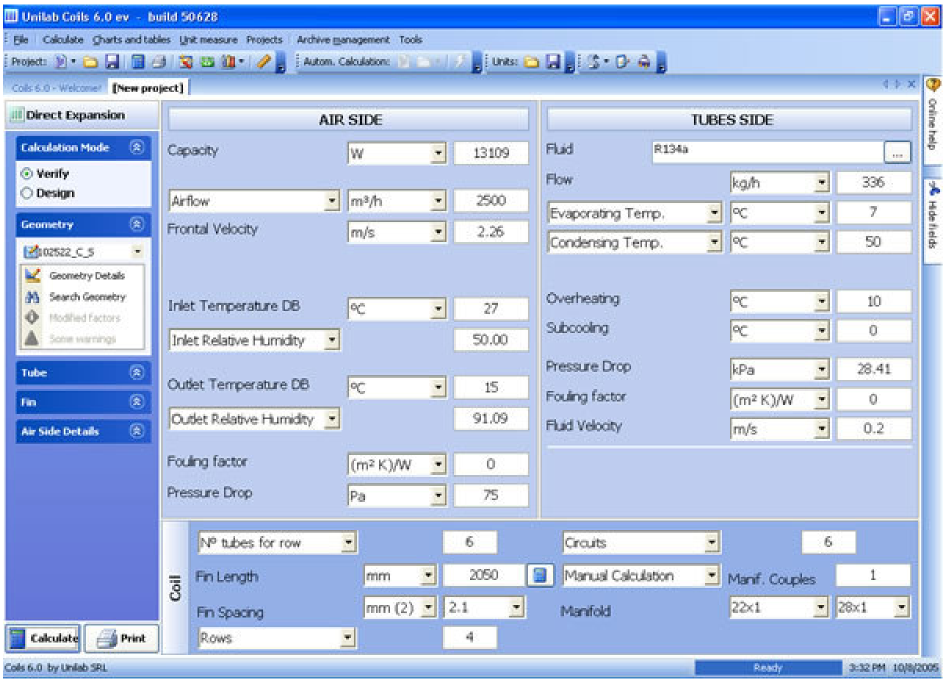


Figure 3.4. An Interface from "Coils UNILAB" Program

(Source:WEB_15, 2004)

Type of evaporators can be listed in 3 main groups according to some application properties.

1. The evaporators used for cooling some material which are gas phase (usually air)
2. The evaporators used for cooling some material which are liquid phase (glycol, water, antifreeze…etc)
3. The evaporators used for cooling some material which are solid phase (ice, ice skate field, metals…etc)

3.4.2.1. Air-Cooling Evaporators

This type compressor is used in mobile cooling system and air conditioner for vehicle. In this type, in order to increase heat transfer surface, some additional serpentines are used, because of the fact that heat conductivity coefficient of air is too low. And also in order to increase conductivity coefficient, velocity can be increase by using ventilator. Conductivity coefficient is between 2 and 10 kcal/hCm^2 for copper pipe and aluminum serpentine and the more serpentine or more pipes causes lower conductivity coefficient.

Figure 3.5. Evaporator Coils Having Different Dimensions and Heat Capacities (Source:WEB_15, 2004)

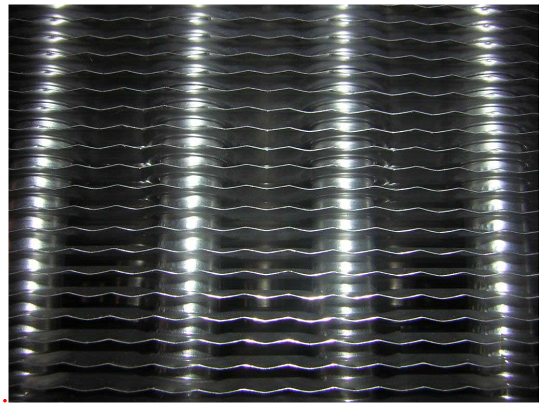


Figure 3.6. Evaporator Unit with Copper Pipe and Aluminum Serpentine (Source:WEB_15, 2004)

These type devices are consisting of cooler serpentine, air ventilator, condensing plate and protection unit. Air ventilation can be placed both to blow and to suck.

Figure 3.7. Air Ventilators for Evaporator Units
(Source:WEB_13, 2004)

These type evaporators can be listed in two main groups as follows,

1- Low velocity (1-1,5m/s): Low velocity cooling system is used for applications that high air velocity may harm the materials (flower, frozen food, etc.)

2- High velocity (4-10m/s): High velocity cooling system is commonly used for general air conditioning applications (WEB_15, 2004)

3.4.3. Condenser

The heat that refrigerant has taken from evaporator in cooling system and the heat that has been added in the pressing period in compressor has been taken from the system by condenser. By this way refrigerant liquefies and becomes pressed and after this has been expanded for taking the heat from evaporator.

The condenser of steams and gas on a layer depends on the properties of the layer (smoothness, brightness, geometric position, etc.)

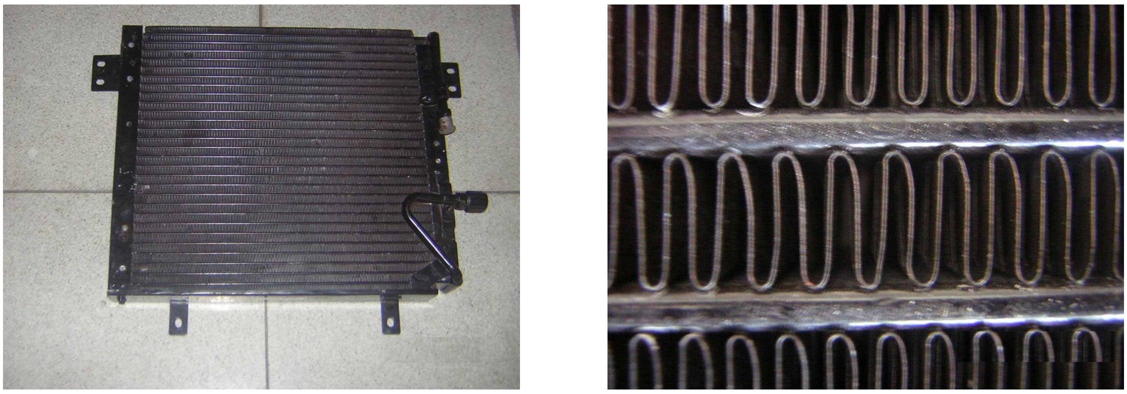


Figure 3.8. Condenser Unit with Copper Pipe- Al. Wings Serpentine

It can be considered that the process of heat transfer in condenser has 3 levels. These are;

1. Decreasing the high temperature
2. The condense of refrigerant
3. Extreme cooling

Extreme cooling will use %0-10 of the condenser area related to its design. Decreasing the temperature will use %5 of the area. According to this heat transfer ways, the heat transfer factor and the temperature differences will be different from each other. There are 3 different condensers in general (WEB_15, 2004)

1. Water cooling condensers
2. Water- Air cooling condensers
3. Air cooling condensers

3.4.3.1. Air-Cooling Condensers

Air cooling condensers are used in automotive air conditioning systems and in industry mobilized cooling systems. Especially the reasons, being used in the cooling systems, which have the working power under 1HP, are being simple, low cost of set-up and operation and low cost of maintenance. Also it is modular for every cooling system. Usually, air circulation fan has been fixed integrally to the rotor of the open type condenser so there is no need for another motor.

The heat transfer in air-cooling condensers occurs in 3 steps;

1. Decrease the temperature of refrigerant
2. Condensing
3. Extreme cooling

A receiver is used to take the condensed refrigerant from the condenser and store. This is because of using the useful area condenser for the liquid storage Usually air-cooling condensers are manufactured from copper pipe- AL wings, copper pipe-copper wings or copper/steel pipe- steel wings. It is also possible to see AL composed pipe-wing styles. The diameter of the pipes is between ¼" and ¾". The numbers of wings are between 9 and 14 in 1" types. The numbers of wings are calculated according to the heat transfer amount and the transfer area. In these types the transfer amount is

2,5m/sec. The rotation of the fans must be between 900-1400 rpm. The fans used in condensers are usually axial type but radial types are used for the silence. The design properties like the position of the pipes, wing spaces, number of the pipe rows and area effects the flow rate of the air, flow resistance and due to this the size of the fan, fan engine power, the working group sound level and the total cost. In today's condenser design, the hot refrigerant is sent to the system from the collectors. While its journey it condenses and goes down the system. After it's extreme a collector takes cooling it from the system.

Air cooling condensers differ according to their grouping types;

1. Grouped with the compressor (Monoblock)
2. Set up away from the compressor. (Split condenser)

It is possible to set the condenser according to the flow direction, axial or radial. Also the fan can be set for the incoming or outgoing air.

Figure 3.9. Condenser Fan Unit
(WEB_15, 2004)

For the efficiency of the cooling system the condensing pressure and the temperature must be in a standard level. This is related with the working stability of the condenser. To ban the extreme heat and the pressure is related with the condenser's cooling area and also related with the flow rate in the cooling system.

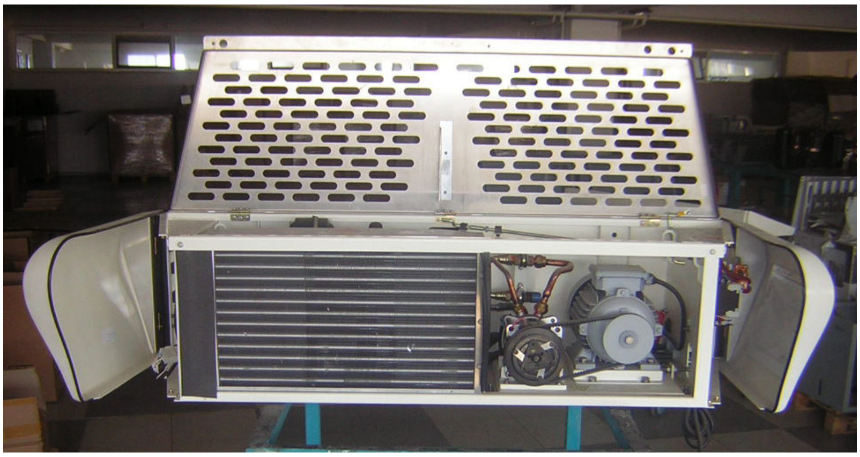


Figure 3.10. Condenser Unit of Cooling System

3.4.4. Thermostatic Expansion Valve (TEV)

The thermostatic expansion valve (TEV) controls the flow of liquid refrigerant entering the direct expansion (DX) evaporator by maintaining a constant superheat of the refrigerant vapor at the outlet of the evaporator. Superheat is the difference between the refrigerant vapor temperature and its saturation temperature. To measure the superheat the TEV controls, the difference between the actual temperature at the sensing bulb and the saturation temperature corresponding to the suction pressure at the sensing bulb location is determined. By controlling superheat, the TEV keeps nearly the entire evaporator surface active while not permitting liquid refrigerant to return to the compressor. The ability of the TEV to match refrigerant flow to the rate at which refrigerant can be vaporized in the evaporator makes the TEV the ideal expansion device for most air conditioning and refrigeration applications (Hannifin, P.2005)

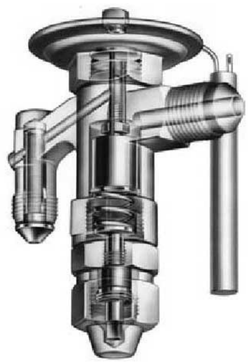


Figure 3.11. Thermostatic Expansion Valve

(Source:Hannifin,P. 2005)

Evaporator pressure is transmitted to the underside of the valve diaphragm by one of two methods. If the valve is internally equalized, the evaporator pressure at the valve outlet is transmitted to the diaphragm via a passageway within the valve body or through a clearance around the pushrods. If the valve is externally equalized, the underside of the valve diaphragm is isolated from the valve outlet pressure by the use of packing material around the pushrods or with pushrods, which are closely fitted. Evaporator pressure is transmitted to the diaphragm by a tube connecting the suction line near the evaporator outlet to an external fitting on the valve. The external fitting is connected to a passageway, which leads to the underside of the valve diaphragm (Hannifin, P. 2005)

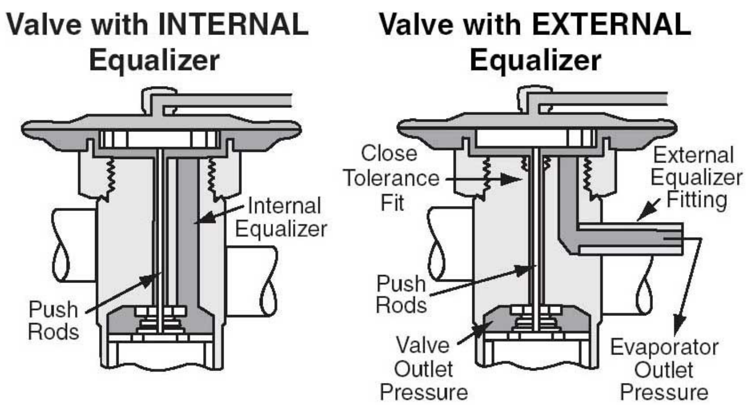


Figure 3.12. Internally and Externally Equalized Valves
(Source:Hannifin, P. 2005)

3.4.4. Drier and Filter

It is for the cleaning of the system. There must be only clean and dry cooling liquid and oil in the system. There will be probably water that mixed in the system while the filling time and also can be mixed from the other system equipments. This water sticks the end of the capillary pipe by being frozen and hinders the cooling operation. Also the little particles and dust can sticks in the capillary pipe. It is usually impossible to prevent the system from dust and water. In the cooling liquid there may be acids also. The duty of the dryer and the filter are to prevent the cooling system from the dust and the acid particles and filtering the liquid (WEB_16, 2005)

The parts of the drier and the filter are;

1. The main body constructed from the copper pipe is designed according to the pressure in the main body. It has got holes to fix the copper pipes.

2. The thin filter fixed to hold the little particles.

3. The filter that hold the humid and the acid is has got the property holding the materials in 4-5 mm thickness (WEB_16, 2005)

Figure 3.13. Driers with Different Dimensions
(Source:WEB_16, 2005)

3.4.5. Receiver Tank

The receiver tank is of welded steel construction and is installed on the discharge side of the compressor. It acts as a surge tank as well as a condensation chamber for the removal of oil and water vapors. It stores enough air during operation to actuate the pressure control system and is fitted with at least one service valve, a drain or blow-by valve, and a safety valve.

Figure 3.14. Assembled Receiver Tank and Drier

3.5. Analysis of Vehicle Air Conditions with R12 and R134a and their Effect on Environment

In the first cooling systems developed in the 2nd half of 19th century, natural materials such as carbon dioxide, water, and ammonia were used as cooling fluid. In the following century, chlrofluorocarbons and hydrochlorocarbons were used instead of these materials that were artificially produced. However, as these materials mixed into atmosphere in a time, some ecological problems occurred such as the increase in the greenhouse effect and destroy on the ozone layer which protects especially livings from dangerous solar radiations, is destroyed as the chlorine, that exists in the structure of the cooling materials, sets free and ozone molecules are spited. (James M., David A., 1997)

The ecology is polluted for years because; lot artificial and natural materials that are used in several industries cannot be used again and thrown to nature. Intensive researches begun about the components that destroy ecology in the last years as the ecological problems increased means of pollution. At the end of these researches, cooling materials, which are used in both air conditioner and cooling industries and also as the CFF (Chlorofluorocarbon), which is used in various industries, all these subjects became daily problems. (Esen,D.,Hoşöz,M.)

Destroy on the ozone layer became important around the world and countries started for action together to avoid the distortion. By the Montreal Protocol, drew the principles of this action, which was signed in 1987 by 43 countries, production and usage of CFC type of cooling fluids that R12 is included, were restricted stage by stage. Nowadays, R134a, one of the alternatives for R12, is spread used in the cars. R134a, which includes hydrogen, fluorocarbon atoms and is included in HFC group, doesn't include chlorine, so it doesn't destroy ozone layer. As a result, ozone consumption potential is zero. Beside these, transformation of R12 into R134a became an obligation in vehicles air conditions, because R12 is expensive and it's had to find it. (Esen, D., Hoşöz, M.)

In a cooling circle, cooling fluids that are used as a semi-component takes heat from an environment to another. It can do it by evaporating from liquid to steam phase and condensing from steam phase to liquid. General properties of coolers are; boiling temperature must be low in atmospheric pressure. Latent heat of vaporization must be high; saturation pressure must be below expansion valve pressure. It mustn't be explosive. It mustn't be poisonous. It must be cheap and must be supplied easily. It must be suitable to use in compressors with low capacity. Leakage in close circuits must be caught easily. There is not any universal cooling fluid that can supply every property in all conditions. But as pointed above, some of these may be neglected in the practice.

R12: (CCl2F2) is mostly used in home type air conditioners and vehicles air conditioners. When the compounds including chlorine spreads to atmosphere, as they deco posited by the effect of solar radiation and chlorine (Cl) atoms are set free. Ozone molecules, which have weak bond reacts with, free chlorine and are transformed into chlorine monoxide (ClO). At he end of this reaction, O3 molecules are transformed into O2. This reaction is continuous. Chlorine atoms effects ozone thousands of molecule till it leaves stratosphere. (Jung.D,Park.B.,1999)

R134a: Thermodynamic and physical properties of R134a are similar to R12. Ozone consumption coefficient is zero. It is the most suitable alternative for vehicle and home type air conditioners. It can be supplied easily. In the high and medium evaporating temperatures, the absorbing capacity coefficient is almost the same with R12. (Jung.D,Park.B.,1999)

R12 destroys ozone layer and has a negative effect on ecology as it was suspected bye the Montreal Protocol. So, R134a took place for R12 cooling fluid of air conditioner systems. When the values of absorbing capacity coefficient checked, it was determined that, system with R12 was about 2-3% higher than the system with R134a. And as a result, it was seen that there was a decrease in the cooling capacity. When the condensing pressure examined which depends on the condensing temperature, it's clear that condensing pressure of R134a is higher than R12 and this will cause a high pumping line pressure on the system. Another important point is, R134a can work 18-20% less mass flow than R12 with the same cooling load. For this reason, for the systems that was transformed to R134a, it will be enough to change R134a with the amount of 75-90% R12< Beside this, in spite of the cooling load that was determined for the both system, when the compressor powers needed was compared, R134a will need more compressor power (kW) than R12.Cooling fluids must have certain chemical a physical property to be used economically and safely described above. It wouldn't be possible to apply these properties every time, as they will change up to applying and working conditions. (WEB_17, 2004)

Table 3.2. Some Refrigerant Types

Refrigerant	Chemical Definition	Chemical Formulation
R11 (CFC11)	Triclorfluormethane	CFCL3
R12 (CFC12)	Diclorfluormethane	CF2CL2
R13 (CFC13)	Clortrifluormethane	CCLF3
R22 (HCFC22)	Clordifluormethane	CHF2CL
R23 (HCF23)	Trifluormethane	CHF3
R32 (HCF32)	Difluormethane	CH2F2
R113 (CFC113)	Triclortrifluorethane	C2F3CL3
R114 (CFC114)	Diclortetrafluorethane	C2F4CL2
R115 (CFC115)	Clortentafluorethane	C2F5CL
R123 (HCFC123)	Diclortrifluorethane	C2HF3CL2
R125 (HFC125)	Pentafluorethane	CF3CHF2
R134a (HCF134a)	Tetrafluorethane	C2H2F4
R141b (HCFC141b)	Fluordiclorethane	C2CL2FH3
R143a (HFC143a)	Trifluorethane	CF3CH3
R152a (HCF152a)	Difluorethane	C2H4F2
R290 (HC290)	Propane	C3H8
R600 (HC600)	Butane	CH3CH2CH2CH3

CHAPTER 4

COMPOSITE MATERIALS WITH POLYMER AND THEIR USAGE IN PRODUCT DESIGN

Composite material is basically defined as a new kind of material composed of two or more materials that have different properties than the components that make it. Generally, plastic materials strengthened with filament are understood as composites.

After improving the first modern synthetic plastics in the early 1900's, plastic materials' properties were developed to compete with the other types of materials by the end of 1930's. Easy shaping, having a lower density than the other metals, high quality on surface, enduring against corrosion are the most important qualifications of plastics. Among these qualifications, not having enough hardness and endurance caused to make more improvements on plastics to strengthen them. And to remove this insufficiency, composites with polymer were developed in the 1950's. Composites present advantages on high resistance, hardness, dimensional and temperature stability, endurance on depreciation. Beside composites' ability to compete with metals about endurance and hardness, they have significantly less weight. Composites are consisting of matrix and reinforcement mixture. Composites are basically composed of filaments or clipped filaments sunk deeply into the matrix that is used as a model. These components dissolve in each other or mix. In composites, filaments maintain the physical properties like hardness and strength; plastic matrix materials make filaments not only to be tied with each other to maintain the structural entire, but also to distribute the weight among and to protect filaments against the chemical effects and atmospheric conditions. (WEB_19, 2005)

Table 4.1. Structure of Matrix, Reinforcement, and Composites Materials

Matrix Materials	**Reinforcement Materials**	**Structure of Composites Materials**
Polymer	Fiber	Shells
Metals	Granite	Covering
Ceramic	Whiskers	Film-Foil

4.1. The Materials that are Used in Composites as Matrix

The matrix used in composite materials change from polymers (termostet and thermoplastics) to metals and ceramics. Polymer has less density and less endurance. Basic polymer matrix materials are polyester, epoxy, and phenol and vinyl ester.

4.2. Fiber Used as Reinforcement in Composites

1. Natural fibers (now they are replaced with synthetic filaments)
2. Synthetic, organic fibers; nylon, Aramid (they are strong filaments with lower density)
3. Synthetic, inorganic fibers; glass, Carbon boron etc.

The mostly used components combinations are; fiberglass + polyester, graphite fiber+ epoxy and Aramid fiber+ epoxy components. Composite materials can be applied on corrugated layers or thin layers. Fiberglass Reinforced polyester/GRP, which was developed in the end of 1940's, is the first modern composites with polymer and now it is the most common type of composites. Today all the composite materials that are produced are consisting of GRP by the rate of 85% and they are used in sports equipments, craft bodies, panels and in car bodies. (WEB_19, 2005)

Today GRP's and other composite combinations being preferred reasons are their weight and solidity. It is possible to produce materials that give high utility by strengthening various plastic materials with ceramic, metal or sometimes hard polymers' fibers. Because of the plastics used in these material combinations, they can be easily shaped and because of fiber reinforcement, they are significantly light and hard. These properties make these material combinations to find new usage areas every day. Beside, they have advantages on depreciation, endurance on corrosion and tolerating damages on materials in accordance to metals. Despite all these utilities, composites cannot completely take place of metals. This has 4 reasons.

1. Composites cannot reply the need of some metals like titanium and steel about critical temperature and mechanical properties.

2. Fibers' all properties cannot be known as metals in the newly produced matrix materials.

3. Some complicated types cannot be produced with less cost.

4. The cost of the composites per kilogram is higher than metals especially aluminum.

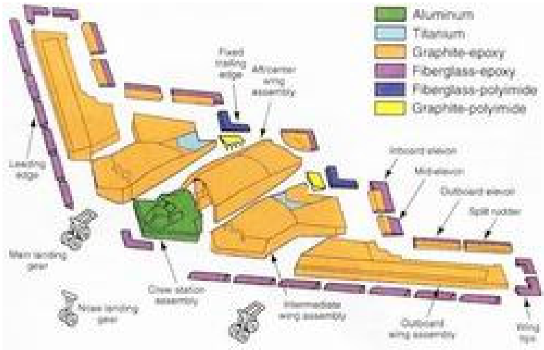


Figure 4.1.The Place where the Composites Materials used for Airplane
(Source: WEB_19, 2005)

4.3. General Advantages of Composites

1. To get different mechanical properties, different combinations and different layers of composites can be used.
2. Composites have endurance on corrosion, air conditions and chemicals.
3. Because complicated pieces can be produced in one part, they can maintain a decrease in the number of parts. And by decreasing the details and parts in combining, production time decreases, too.
4. High endurance/density rate
5. High modulus/weight rate

4.4. General Disadvantages of Composites

1. The fact that the raw materials expensive high quality graphite fiber can be used in planes costs 50$ per unit.
2. Composites' properties that are laminated are not ideal all the time; there is low endurance about thickness and cutting low layers.
3. Quality of material depends on the quality of the production techniques, there's no standard quality.

4. Because of weak materials, composites can get damaged easily and repairing them may cause new problems.

5. Materials have limited shelf life. Some types of composites need to be kept in cold.

6. Hot drying is needed.

7. Before mending, composites need to be cleaned very well and need to be dried. In some circumstances this may hard to do.

8. Some drying techniques can take a long time.

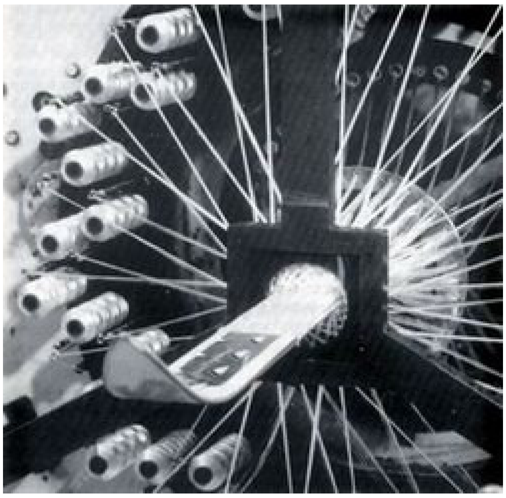


Figure 4.2. Producing Snow Skates with Composite Materials
(Source: WEB_19, 2005)

4.5. Matrix

In composites not only matrixes with polymer, but also metal, ceramic materials can be used as matrix. Except using other matrixes, the 90% of the composite materials are produced with matrix with polymer. Matrixes materials are usually produced with plastic so composite materials are usually defined as reinforcement plastics. The first mechanical properties that a Matrix ensures are high hardness and high endurance values. A good material needs to be hard, but its performance shouldn’t fall because of the behaviors of a weak material. Matrixes with polymer, which have these properties, are found in two forms as; termoset and thermoplastic materials. (WEB_19, 2005)

4.5.1. Termoset Matrixes

Composite materials with termoset are commonly the most used matrixes. Termoset plastics are liquid; chemical reactions and heating make them hard and lusty. Termoset polymers' polymerization period is different than thermoplastics; it is a period that has no turning back. They don't get softer again in high temperature. Termoset matrixes dissolve under chemical effects and they are long-lived also under the unusual air conditions. Polyester, epoxy, vinyl ester, phenol, silicon, polyamide, polyurethane are the commonly used matrixes. (WEB_19, 2005)

Polyester is the most preferred kind of termoset matrix that is specially used in construction and sailing branches. There are two kinds of composite materials used in polyester matrix; orthoftalic, which is more economic, and isotonic polyester that has better qualifications like enduring against water. Polyester matrix needs catalyze and items that fastens it to complete the polymerization period.

4.5.2. Thermoplastic Matrixes

However there are various kinds of thermoplastics polymers, polymers that are used as matrix are limited. Thermoplastic are hard in low temperature, but when they are heated they get softer. Except their usage is limited in accordance to termoset, high breaking fullness, long-lived materials, recycle capacity and safety working condition caused by not needing of organic solvent in the process of getting hard are advantages. Besides, shaped thermoplastic parts can be reshaped by giving heat after the process. Reinforced thermoplastics prepared with this method are preferred in automobile sector because of their ability of pressing and being suitable for recycle

4.6. Reinforcement Materials (Fibers)

Fibers' physical shapes used in composites are an important factor on the new materials properties. Reinforcements are basically found in 3 different forms; clipped, continuing and non-continuing fiber. (WEB_19, 2005)

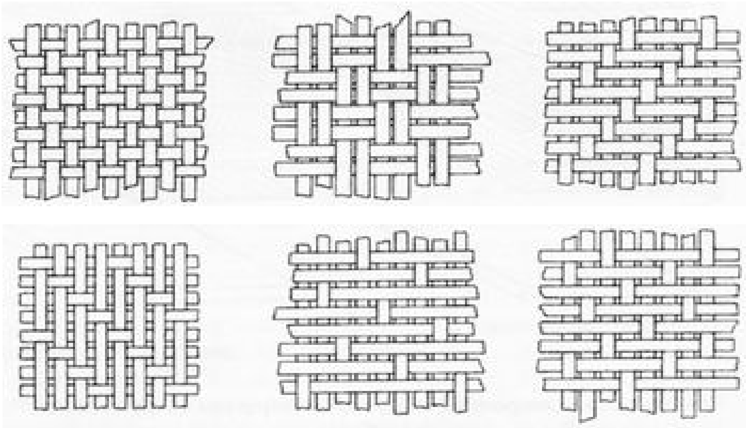


Figure 4.3. Weaving Type of Fibers
(Source: WEB_19, 2005)

In some circumstances to increase endurance and to have it in an equal way in all cases, fibers are weaved as fabric. Weaved fiber fabrics are prepared with continuing fibers and they have various types that are improved for different aims. However fiberglass is the most used and valid reinforcement material, in advanced composite materials, pure graphite fibers are used. Graphite fiber is stronger and lighter than fiberglass, but on the other hand its production cost is higher, too. It is used on the skeletons of air vehicles and sports vehicles rather than metals. Boron fiber is not only stronger than graphite fiber, but also it is more expensive (WEB_18, 2005)

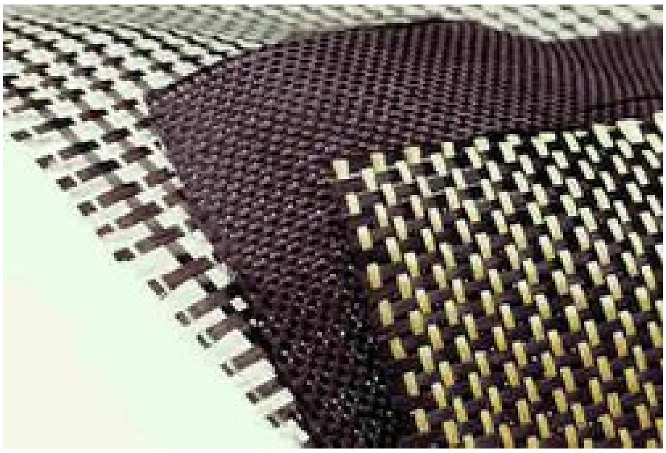


Figure 4.4. Sample of the Graphite Fiber
(Source: WEB_19, 2005)

4.7. Basic Fiber Types Used in Composite Materials

1. Fiberglass
2. Graphite fiber (PAN-Polyacrylonitrile and pitch rooted)
3. Aramid (Aromatic Polyamide) fiber (commercial name: Kevler Dupont)
4. Fiber Boron
5. Fiber Oxide

Among these fibers, glass, graphite and Aramid fibers are commonly used. These three fibers are hard, strong, and can be produced in continuing style. Fiberglass is the most known and used fiber between fiber-reinforced composites. Fiberglass is produced in a special designed oven that has little holes under it. Melted glass is pushed through these holes. After this, thin fibers are gotten cold and they are rolled to a wheel. Then they are transported as composite raw materials. Chemicals with silan, which form a thin film on fibers and which increases sticking power between fiberglass and matrix, began to be used later. (WEB_19, 2005)

In spite of losing 50% of their endurance in the process, fibers are so lusty. Fiberglass has still the property of higher endurance than Aramid and graphite fiber. Fiber fabrics are usually produced with continuing fiberglass.

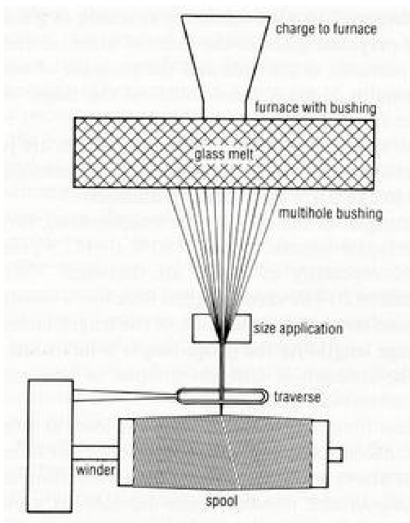


Figure 4.5. Production of Fibreglasses (Phillips, 1989)
(Source: WEB_19, 2005)

A Glass- the most preferred glass type used in bottles and windows but rarely used in composites

C Glass- shows high chemical resistance, used in places like water tanks.

E Glass- the most preferred glass type used in reinforced fibers. It has low cost, good isolation and low water absorbing rate properties.

S+R Glass- a material with high cost and high performance. Only used in plane

The most popular and the most used fiber is Dupont Firm’s traded brand, Kevlar. There are two kinds, Kevlar 29 and Kevlar 49. Kevlar 29 has the ability of high impact endurance and for this reasons usually it is used in bulletproof vest. (WEB_19,2005)

Table 4.2. Compare the Most Popular Fibers

Material	Density (g/cm^3)	Tensile Strength (MPa)	Module (GPa)
E- Glass	2.55	2000	80
S- Glass	2.49	4750	89
Aluminum	3.28	1950	297
Carbon	2.00	2900	525
Kevlar 29	1.44	2860	64
Kevlar 49	1.44	3750	136

4.8. Production Techniques In Composite Materials

There are lots of techniques to produce composite materials in every shape with demanded properties. Here are some:

4.8.1. Hand Lay-Up

Interfaced fabrics prepared by weaving or prepared with clipped fiber are put on the model with hand lay-up. The filament layers absorb liquid matrix. Before laying up the filament, model is cleaned and jelkot is applied on it. After jelkot gets hard, filaments are laid up. Matrix is using at the end for materials’ being ready. In this process filaments’ absorbing is important. In hand lay-up technique, except the most used epoxy and polyester, vinyl ester and phenol matrix are preferred, too. Hand lay-up requires high labor force, but it is suitable for a little number of productions.

4.8.2. Spray-Up

Spraying up is accepted as the hand lay-up way with equipment. Clipped filaments are sprayed up to the model's surface by a special gun filled with matrix. And there is something for harness is put in this mix. Fibers' clipping process is occurred by a clipper, which is working independently on the gun. After the spraying-up process, the surface is made smooth by a roll and then the product is ready. (Source:WEB_19,2005)

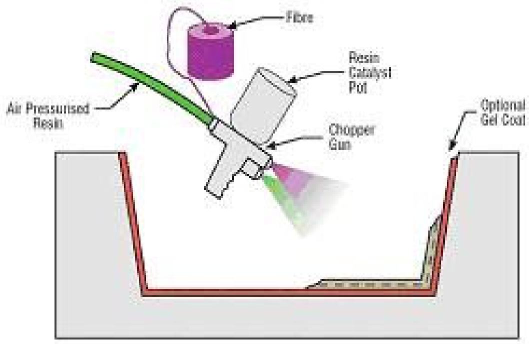


Figure 4.6. Spray-Up method

Figure 4.7. Spray gun

(Source: WEB_19, 2005)

4.8.3. Filament Winding

This technique is suitable for the special shaped products' serial production. Filament winding is continuing filaments' being rolled to a turning model which is working by pulled with a wheel after filaments are gotten wet with matrix. If continuing filaments are rolled to the model with different angle, products with different mechanical properties occur. After filaments with equal quantity are rolled, product begins to get harder. Then the turning model is separated. Products produced with this technique are usually used as cylindrical, pipes, car shafts, plane water tanks, yacht colons, and circular pressure tanks. (WEB_18, 2005)

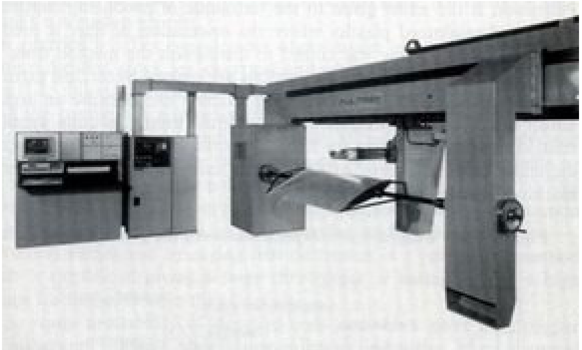


Figure 4.8. Machine of Filament Winding

(Source: WEB_19, 2005)

4.8.4. Matrix Moulding Model Injection

In this composite producing technique, you need to use a two-parted model. Besides, hand lay-up system is faster and long-lived in accordance to this production technique. Models' being produced with composite materials makes the cost remain lower than the steel model's cost. By this technique, complicated parts can be produced. In Concorde planes and F1 cars some parts are prepared by this method.

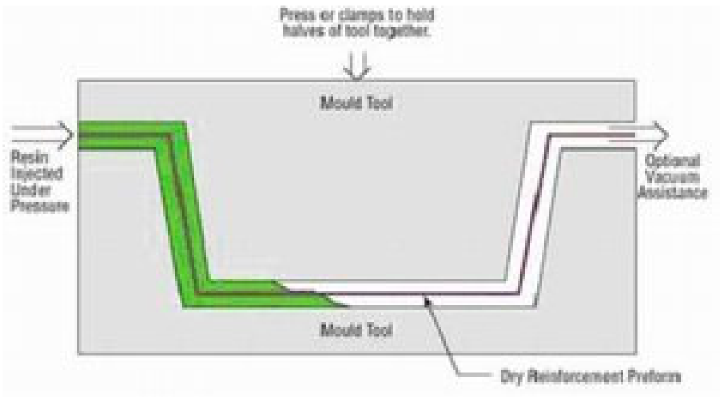


Figure 4.9. Method of RTM

(Source: WEB_19, 2005)

4.9. Composite Materials' Usage Areas

Composite materials begin to be used in new sectors with an increasing rate day by day. Composite materials' improvements were canalized by the needs of plane industry for a long time, but newly these composites are used for new sectors for different purposes. (WEB_19, 2005)

4.9.1. Aeronautic Industry

Advanced composite materials are able to find new usage areas especially in Aeronautic sector. Composite materials mechanical properties and their lightness make them to be used not only in the planes and helicopters' indoors, but also in their structural parts.

4.9.2. Sailing Industry

Sailing boats bodies; CTP, Balsa and glass on the polymer foam covered with Aramid graphite weaving, yachts, platform steps behind crafts; CTP sailing boats colons; Kevlar Epoxy.

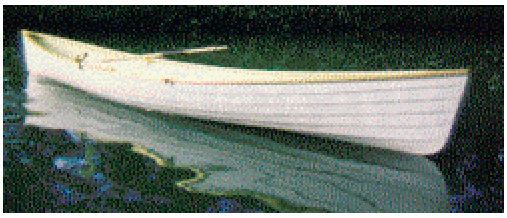


Figure 4.10. Sailing with CTP
(Source: WEB_19, 2005)

4.9.3. Sports Equipments

Composite materials are popularly used in sports equipment sector and every day this sector is taking part more and more. Graphite and fibreglasses are especially used for decreasing weight so as to increase movement ability and endurance.

Composites have abilities about impact endurance and material density, which are important for surfs, canoes and yachts. Mountain bikes are being produced with graphite fiber for the best solid/weight rate.

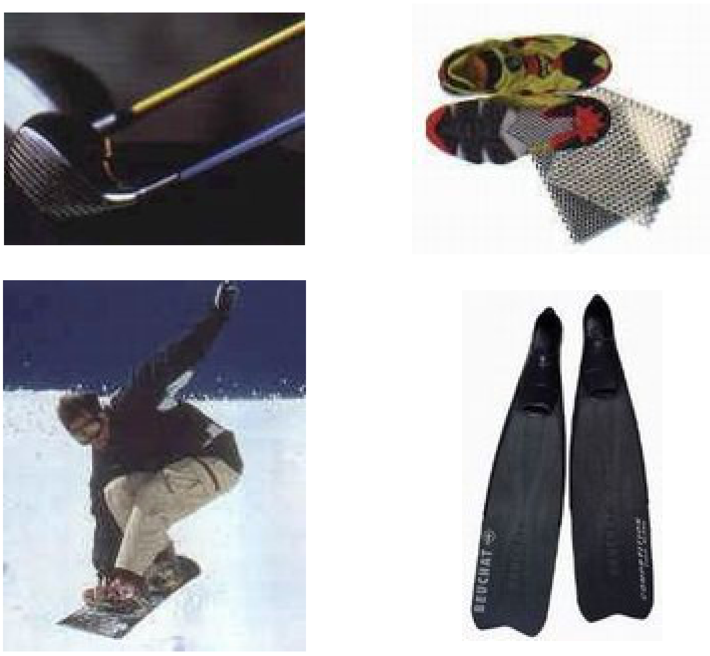


Figure 4.11. Sports Equipments
(Source: WEB_19, 2005)

4.9.4. Transportation

Train; composite materials prepreg and weaving materials are used in train construction to decrease costs and weight. Decreasing weight on the skeleton not only makes energy saving but also add something about in improving faster vehicles. Materials' being solid in train means that the skeleton requires no supports so as to increase the place for passengers. In train construction usually prepreg plates are used which can change easily and fast. And this makes panels, which damaged singularly to change fast. (WEB_19, 2005)

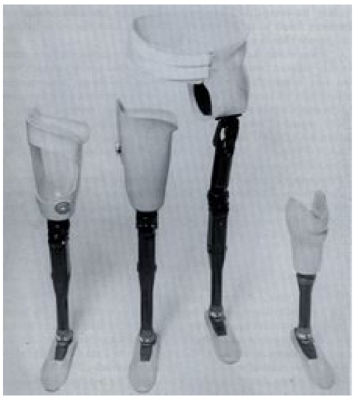


Figure 4.12. Artificial Leg
(Source: WEB_19, 2005)

4.9.5. Automobile

Automobile firms are required to produce lighter cars to answer consumers' needs under the impression of environmental conditions. Lighter cars define the cars that have a relatively smaller engine, that need less gas and the cars that can fasten and stop more quickly.

Figure 4.13. Front Panel of the GM
(Source: WEB_19, 2005)

F1 cars' designs of production are so special and these designs are applied fussiness. Cars' total weight shouldn't exceed 650kilograms. Design engineers need to find the best solution with the least weight. In F1 cars aluminum, a light metal is used before, but now composite materials can double the solidness with less weight. Also, producing complicated parts with composite materials can reduce the number of necessary parts. (WEB_19, 2005)

4.9.6. Musical instruments

In London College of Furniture and some other places, musical instruments are trying to be produced with advanced composite materials.

Figure 4.14. Carbon-epoxy Violin
(Source: WEB_19, 2005)

CHAPTER 5

PHASES OF DESIGN PROCESSES OF PRO X

5.1. Base Engineering Data

PRO X is the cabin air conditioner, which is designed by Safkar A.Ş. for Street Car Project. The volume of the inside of the cabin is 35 m^3 and there are 3 engineers and electronically devices controlling the system. According to the technical drawing details of the streetcar project, the calculations that are done considering the technical data about the door, window, ceiling materials and isolation showed that the air conditioner providing 6000 Kcal/h of heat supply is efficient for this system. (For detailed calculation see APPENDIX A)

5.2. Components Used in the Cooling Cycle of PRO X

PRO X is a mono-block type of air conditioner which is made of 1 condenser unit, 2 evaporator units, 1 radial condenser fan, 2 axial evaporator fans, 1 drier, 1 compressor, 1 electrical motor.

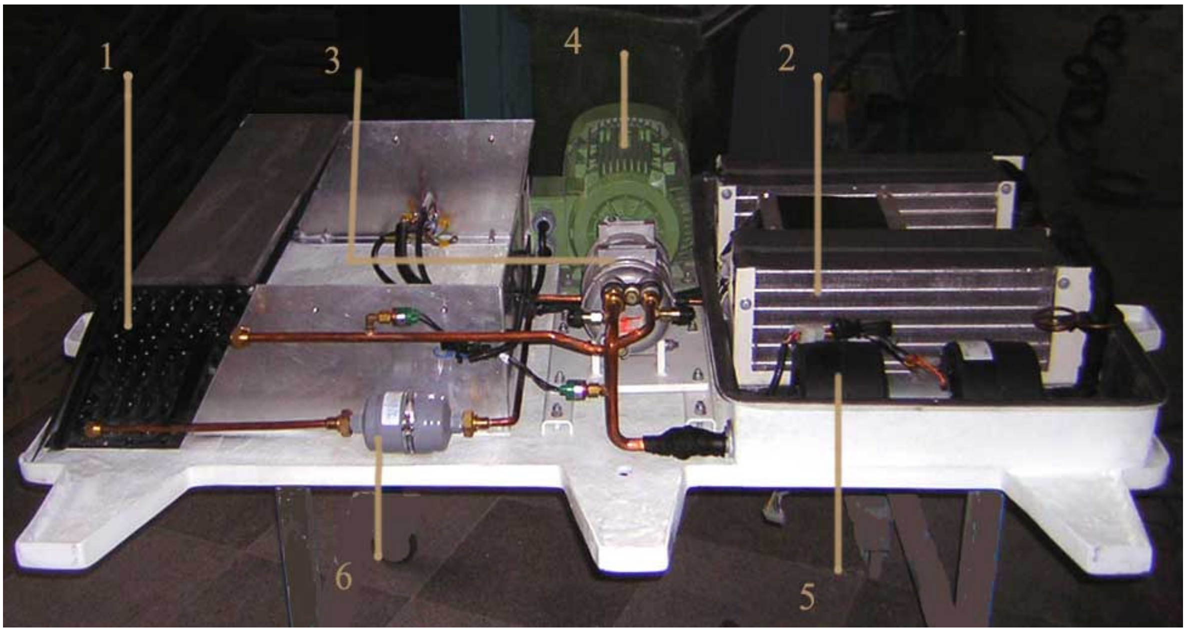


Figure 5.1. List of PRO X components 1.Condenser Unit, 2.Evaporator Units', 3.Compressor, 4.Electrical Motor, 5. Axial Evaporator Fans, 6.Drier

5.3. Functioning of the System

Generally, in systems with crank mechanisms, the compressor, which is the heart of the system, takes the turning moment pulls from the motor axe, which is needed for pressing the refrigerant. The magnetic clutch pulls in the flywheel of compressor by the turning moment, which in transferred from the motor axe with belt-flywheel mechanism to the magnetic clutch of the compressor. But in **PRO X**, instead of belt-flywheel mechanism-coupling mechanism is used. The fact that the compressor and the electrical motor is under the cover makes it possible not to use the gas tubes which take the gas from coils to the compressor. This process makes the assembly easier and it also reduces the costs.

Figure 5.2. Belt-flywheel Mechanism

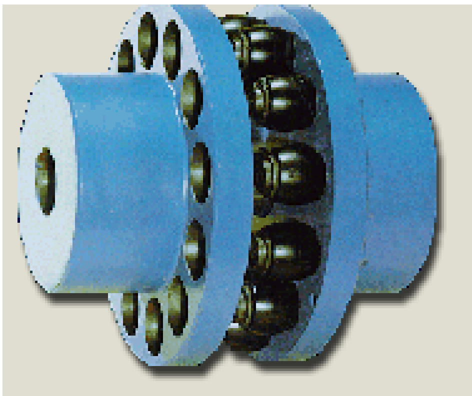


Figure 5.3. Coupling Mechanism

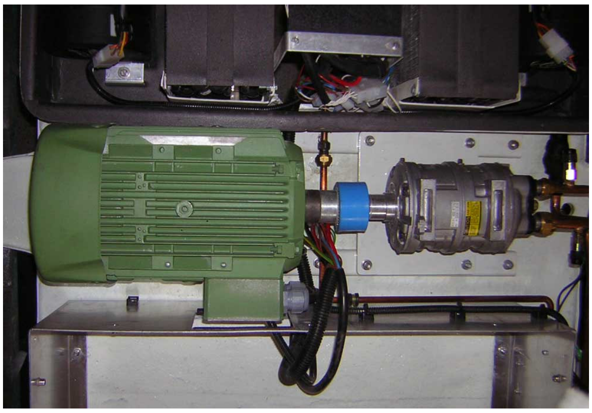


Figure 5.4. Application of Coupling Mechanism in PRO X Unit.

Cooling systems are designed in two ways considering the quality of the material and the way the material is carried. The cooling systems which are designed with the electrical and crank mechanisms are preferred by considering the quality, quantity and the period of the carriage of the material. In systems with crank mechanism, the compressor, which is the heart of the system, takes the turning moment, which is needed for pressing the refrigerant, from the motor axe. The magnetic clutch pulls in the flywheel of compressor by turning moment, which is transferred from the motor axe with belt - rim mechanism to the magnetic clutch of the compressor.

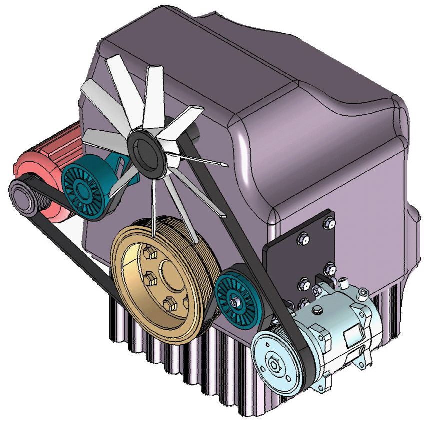


Figure 5.5. Application of Motor Axe with Belt - rim Mechanism.

The flywheel of the compressor and the magnetic clutch, which are turning together, start to press the refrigerant in the pistons. When the vehicle stops or the motor round-rate decreases, the capacity of the system reduces or the cooling system is out of use. In order to avoid this, the electrical motor, which is installed in the condenser unit, starts to activate and takes the part of the crank axe. When the engine stops or the motor round-rate decreases, electrical motor activates another compressor in order to avoid a decrease in the cooling capacity.

5.4. Electrical System

All the electronically spare parts in PRO X (condenser fan motor, evaporator fan motor, and the control panel) functions at 24V DC. Since the streetcar functions at 380V AC, 24V DC is changed into 380V AC by means of a transformer, which is placed in PRO X.

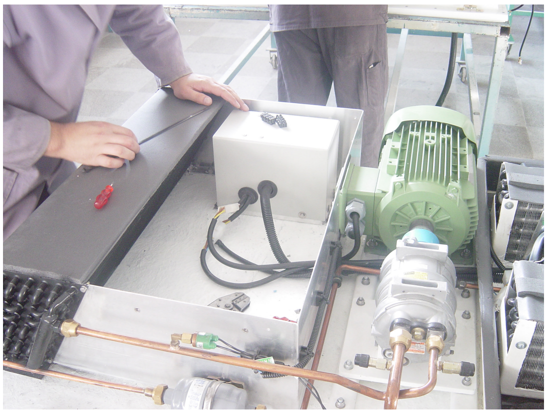


Figure 5.6. Application of 380V AC Transformer in PRO X Unit.

5.5. Ventilation System

5.5.1. Ventilation in Streetcar

The condenser and evaporator coils in PRO Y can also be used in PRO X due to the fact that both air conditioners have the same heat supply (PROY air conditioner is designed for 14 people and for the vehicles having the volume of $17m^3$.) The inside volume of the streetcar is $35m^3$, however some changes are made in the evaporator fan motors due to the length of the cabin. The hitting speed of the air to the human body in an air conditioner having good conditions of comfort is 5-10 m/s, however the hitting speed is 3,5 m/s in Pro X with the evaporator fan motors used in PRO Y. In order to avoid this, evaporator fan motors with the air flow-rate of 1500 m^3/s are used instead of the evaporator fan motors with the air flow-rate of 1150 m^3/s.

5.5.2. Ventilation in Cover

Besides the condenser and evaporator coils, it is the air passages, which determines the width of the device. The fact that the heat sources are side by side in the system gives harm to the polyester cover, which is exposed to heat more than an ordinary air conditioner. The number of the heat sources (a 4kw electrical motor, compressor, transformer, hot liquid and the condenser coil) makes the air passages indispensable in order to provide a healthier air circulation.

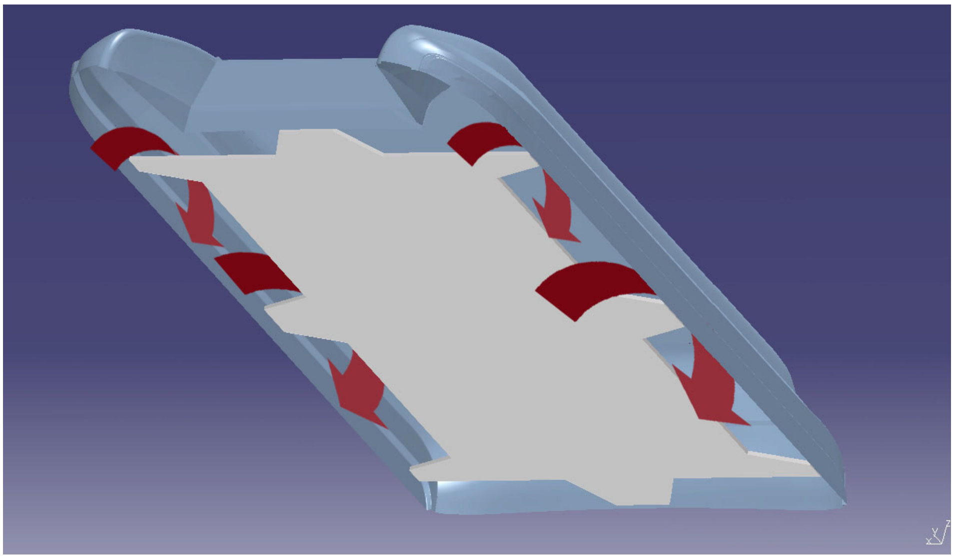


Figure 5.7. Ventilation in PRO X cover.

Another point considered during the designing period is that the device should be able to function without cover. The fact that the location of the air conditioner is different than the other air conditioner applications brings certain disadvantages. Some difficulties may be faced when dealing with a probable cover problem. For instance it may be difficult to cope immediately with a problem or there may be delays in regular services. Considering all these negative circumstances, it is absolutely necessary that an air conditioner function without cover. In order to run PRO X without cover, evaporator and condenser units must be isolated from each other. Unlike the other systems in which the condenser fan motor is assembled on polyester cover, the condenser fan motor used in PRO X is assembled on paddle box, which is under polyester cover. Not only paddle box enables activation without cover, but it also enables the proceeding, or the allowance of exposed air from the condenser fan motors running through the condenser coil. In this way, by-pass in the condenser unit is prevented. By-pass can be defined as the combination of hot air with cold air or absorbed air with exposed air. It is the evaporation unit, which avoids by-pass. The effect of by-pass in evaporating unit on cooling capacity is more important than the by-pass in condenser unit. It is crucial to avoid by-pass in evaporating unit in air-conditioning designs.

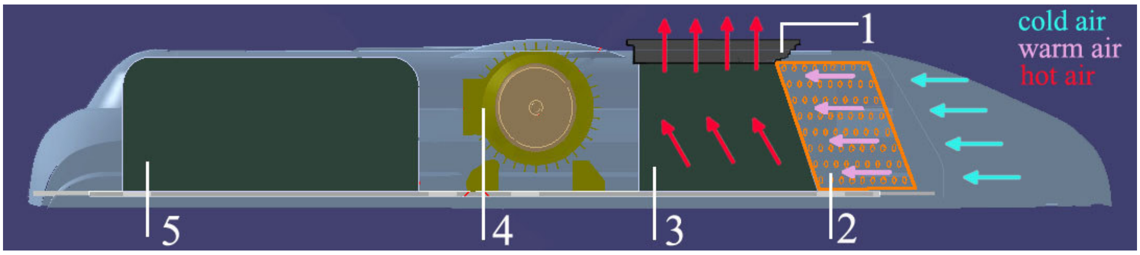


Figure 5.8. Application of By-Pass system in PRO X condenser unit.
1.Condenser Fan , 2.Condenser Coil, 3.Paddle Box, 4.Compressor , 5.Evaporators Unit

5.6. Design Criteria of Cover

The cover designed for PRO X does not take its measurements from components placed in it. R 6500 mm slope is given to the bottom surface of the cover in order to be able to fix it into the ceiling of the streetcar.

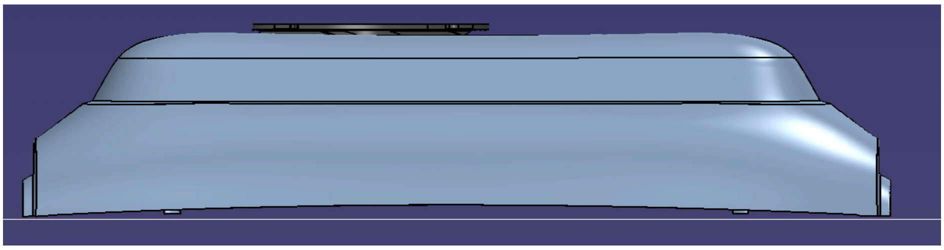


Figure 5.9. Back View of Cover

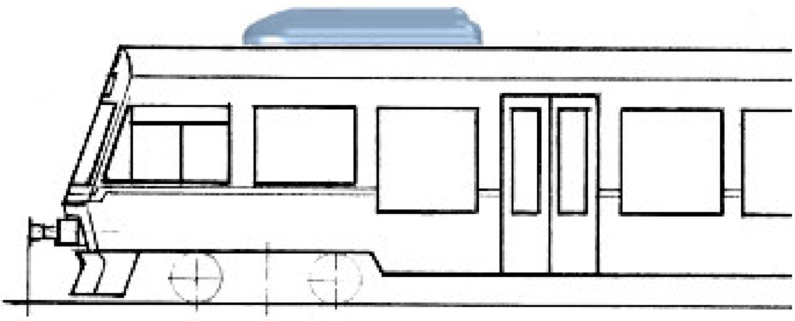


Figure 5.10. Left View of Cover on Train

Figure 5.11. Top View of Cover on Train

Figure 5.12. Perspective View of Cover on Train

The maximum height of PRO X is 320 mm due to the electrical motor. The standard height of the device is 300 mm, which is same as the height of the condenser and evaporator coils. Condenser, the width of the evaporator coil and the air passages, forms the width of the device.(For detailed technical drawings see Appendix B)

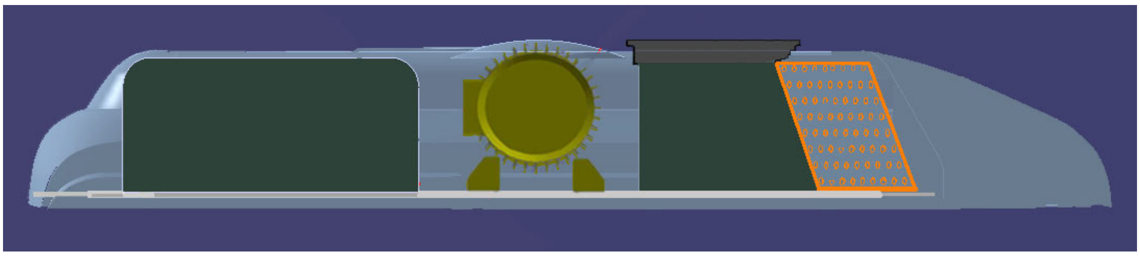


Figure 5.13. Left View of Cover

Same applications on cover such as variable thickness, rib etc. cause to increase the resistant of cover and also to prevent bends.

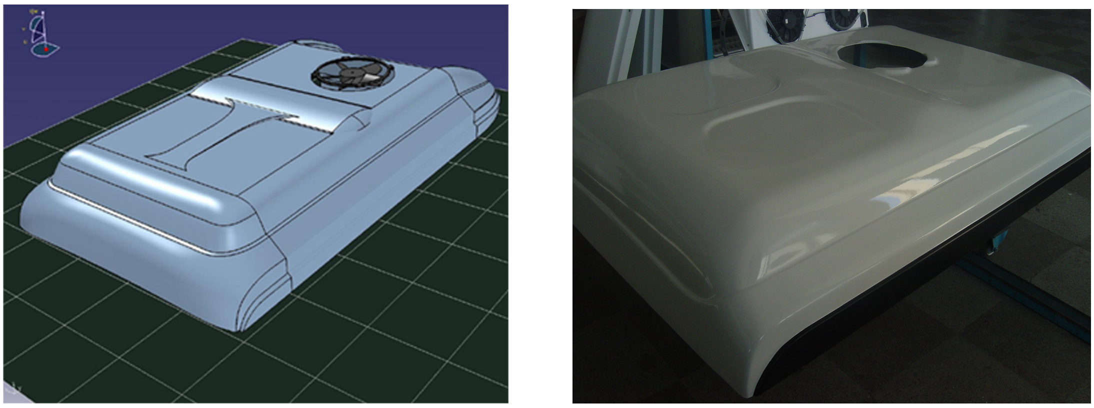


Figure 5.14. Render and Photo of PRO X Unit

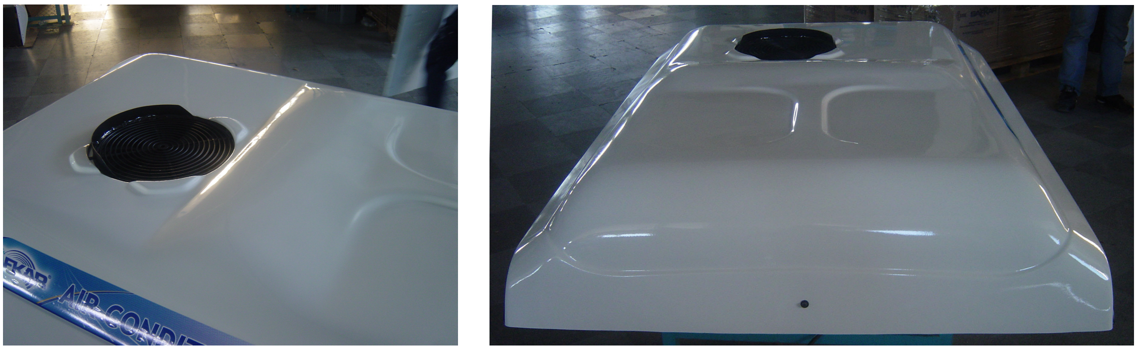


Figure 5.15. Photos of Parts on Cover that Increase the Resistance.

The shutter, which is designed for the front side of PRO X, enables the condenser coil to draw in the air much easier. The slope angle of the air passages opened on the shutter let the air be diverted to the coil after hitting the shutter.

Figure 5.16. Shutter of PRO X Cover Unit

The compressor, electrical motor, compressor bracket and transformer are used in the middle of PRO X. It shows that the weight is not distributed equally in the device. As a result of this, 1,5mm of pierced sheet iron is installed at the bottom of the polyester not to exceed the limits of resistance.

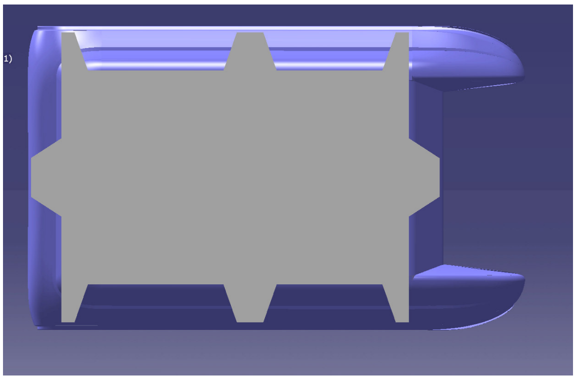


Figure 5.17. Pierced Sheet on Bottom Polyester for Preventing Bend

Figure 5.18. Perspective View of 3D Modeled PRO X Unit

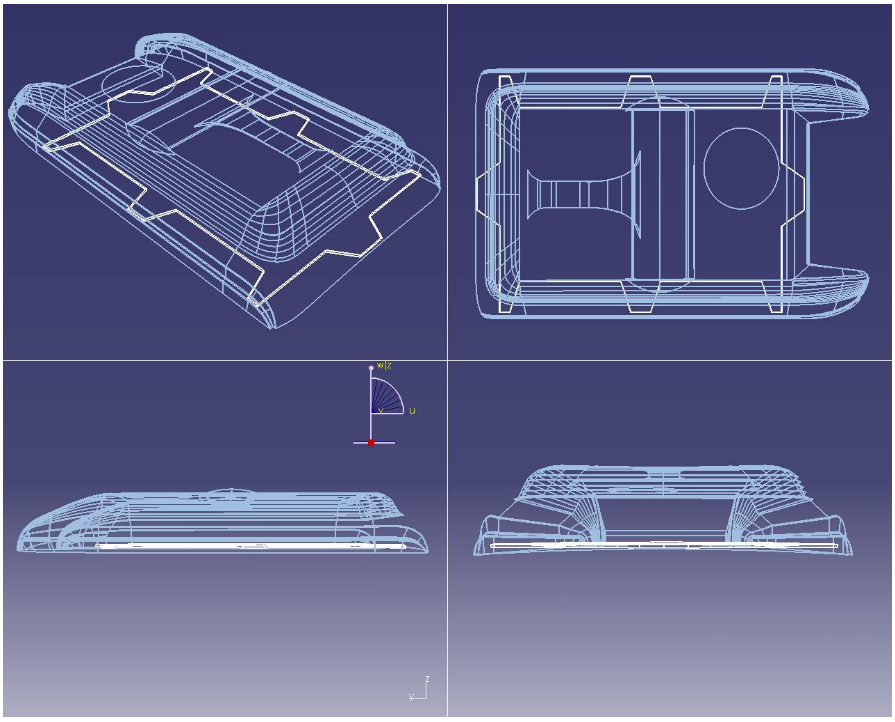


Figure 5.19. 4 Views of PRO X Unit

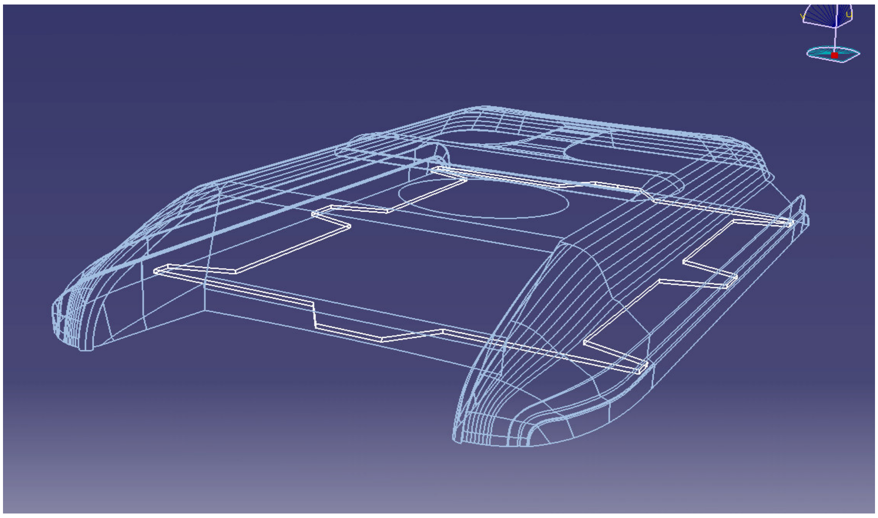


Figure 5.20. Render of Final Design Phase

The material used in PRO X is polyester. The production, process, and the cost of polyester are more advantageous compared to the other materials. The other advantages of using this material are that organic surfaces can be obtained, it is light and it can easily be painted.

5.7. Mould Production System

1. Apply some releasing agent to the prepared mould or requested model, and allow drying.
2. Weigh enough gelcoat to leave 300-400 gr/m² of the model
3. For spray gun, adjust regulator exit pressure should be 3.5 - 4 atm and nozzle diameter of the gun should be 2.5-3 mm. (WEB_20,2005)

Figure 5.21. Polijel Applications on PRO X Cover Mould by Spray Gun.

4. With the gun working distance should be 30-40 cm, if brush application, try not to accumulate gelcoat at300-400 gr/m² gelcoat must cover surfaces so that the first layer's thickness should be about 0.250 - 0.350 mm. (WEB_20,2005)

Figure 5.22. Polijel Application on PRO X Cover Mould by Hand lay-up.

5. After applying transparent gelcoat on the model, about half an hour later, gel will start. When gelled, touch it with your finger, you feel that gel starts from the

bottom and the top layer is still liquid, but if pressed a bit stronger gelcoat can be dissipated.

6. Half an hour later, this time the second gelcoat is colored with a little pigment paste and apply carefully 300-400 gr/m² on the first transparent layer. If you work with brush tries to use it very smoothly, press it gently. Then allow curing for 24 hours. (WEB_20, 2005)

7. Apply some surface tissue with enough the mould polyester that cure agents have been added no bubbles and allow to gel about 2-4 hours. Later, 300-450 and 600 gr/cm² fiberglass is applied on at the same time; try not to drop polyester around and then leave to cure. (WEB_20, 2005)

8. You can continue this process till its thick enough. The mould thickness should be 2-3 times thicker than the product's

Figure 5.23. Polyester PRO X Cover taken out of Mould

9. If you produce a wide and impact able mould, especially try to work with polyester economically and before applying the last fiberglass, strengthen around the mould by using a piece of wood or polyurethane foam or metal profile. However, the profile process should be repeated in the middle in every m². Afterwards apply the last fiberglass that should cover the frame.

Figure 5.24. Strengthen Around PRO X Mould by Using Metal Profile

10. The mould has been left to cure for two days, should put in a oven at 45-60ºC for 3 hours or in the summer time, leave it under the sun for 3 hours. Then it is taken a cool place to cool down. Afterwards you can remove the model (WEB_20, 2005)

Figure 5.25. Drying Phase of PRO X Mould under the Sun

CHAPTER 6

CONCLUSION

In this thesis, in which the effect of engineering criteria on industrial design criteria in cooling system and air conditioner used in trade vehicle is analyzed, it is shown that when and under which circumstance the designer uses these criteria to sort the problem throughout the design process. The way the designer sort the problem out and uses the criteria mention can be easily distinguished by analyzing the design process of PRO X air conditioner which is examine in the thesis.

Although, engineering and industrial design criteria's faced on every step of the project during design process are so intricate, all technical components of air conditioner are evaluated and applied based on engineering criteria's. Capacity calculations, efficiency diagram of selected compressor and electrical motor, heat capacities of used evaporator and condenser coils are criteria's required mathematical and engineering background. Importance and usage of these criteria's are detailed in the thesis.

Because of the fact that chosen air conditioner in the thesis was designed for streetcar not for vehicles, one of the industrial product design criteria, seeming the cover, as a part of vehicle, is the weakest point in thesis due to not giving much more opportunity to carry the line of vehicle. But, changing height of air conditioner due to width, length and even rib gives opportunity to apply on minibus because of the capacity of air conditioner. Taking, one of components, electrical motor and compressor out of system and also removing the air canals, which is used, for discharging heat of these equipments gives opportunity to apply on midi bus as a new air conditioner with new dimensions.

The other positive point of the thesis is the fact that each step of theorical applications (3D modeling and drawing in computer, heat calculations) and practical applications (preparing the model, making the mold, assembling and disassembling) are under control of designer and reflected to the thesis.

Observation method is used for production and case study method is used for design of PRO X equipment. Drawing of all design phases on computer, choosing air-conditioner components and design of cover are explained step-by-step and supported with technical documents and photos. But production and assembly examined by observations of designer and also it is supported with photos.

To sum up; although, engineering criteria's gives the answer of first question about air conditioner, this study puts out that it is not possible to design air conditioners and put into the market only taking into account engineering criteria's. The design, which is created in terms of engineering and industrial design criteria, should become mature and show vitality with the designer, aesthetic point of view.

REFERENCES

Aktaş,D., Özdemir,M. "Yaz İklimlendirme Sistemlerinde Kanal ÇaplarınınBilgisayar Ortamında Hesaplanması,"TEKNOLOJİ",Cilt7,(2004),no 3,384

Bu J.U.,Kim T.Y.,"Slicon Based Thermal Comfort Sensing Device", "Transducers'95", Eurosensors 9.page 104-7,1995.

Jung.D,Park.B.,"Evaluation of Supplementary Refrigerants for Automoble Air-Conditioner Charged with CFC12" ,International Journal of Refrigeration 22,1999, page 558-568

Doğan,H.,"Havalandırma ve İklendirme Esasları",**Seçkin Yayıncılık,**Ankara,2002.

Esen,D.,Hoşöz,M., "Geliştirilen BilgisayarProgramı Yardımıyla R22 ve R134a KullanılanOtomobil Klimasının Performans Analizi",VI. Ulusal Tesisat Müh. Kongresi ve Sergisi,page 2

James M.,David a., "Trade in Refrigerant Selections",Past, Present ,and Future, ASHRAE/NIST Refrigerants Conferance,1997

Hannifin,P.,"Thermostatic Expansion Valves",Bulletin 10-9,2005,page2

Kaynaklı,Ö.,Yiğit,A.,"İnsan Vucudu İçin Isı Dengesi ve Isıl Konfor Şartları"D.E.Ü. Müh.Fakültesi Fen ve Mühendislik Dergisi, 5, 2003, No:2 page 9-17

Köktürk,U.,"Pratik Havalandırma Tesisleri Klavuzu",Birinci Cilt,**Arpaz Matbaacılık,**İstanbul.

Lee,G.H.,"Performance Analysis and Simulation of Automobile Air Conditioning System",International Journal of Refrigeration 23,2000,243-254

Tian,C.,"Instability of Automotive Air Conditioning System With aVariable Displacement Compressor" ,International Journal of Refrigeration ,12,2002,1

WEB_1, 2003.http://theory_uwinnipeg.co,22/6/2005,http://theory_uwinnipeg.co/mad-tech/node71 html

WEB_2, 2004.www.daikineurope.com,13/7/2005,www.daikineurope.com/faq/items/sensible-latent-heat.jsb

WEB_3, 2005.http://theory_uwinnipeg.co,19/10/2005,http://theory_uwinnipeg.co/mad-tech/node73 html

WEB_4, 2005.http://theory_uwinnipeg.co,19/10/2005,http://theory_uwinnipeg.co/mad-tech/node72 html

WEB_5, 2005.http://theory_uwinnipeg.co,19/10/2005,http://theory_uwinnipeg.co/mad-tech/node74 html

WEB_6, 2005.http://theory_uwinnipeg.co,19/10/2005,http://theory_uwinnipeg.co/mad-tech/node76 html

WEB_7, 2005.http://theory_uwinnipeg.co,19/10/2005,http://theory_uwinnipeg.co/mad-tech/node77 html

WEB_8, 2005. www.daikineurope.com,30/4/2005,www.daikineurope.com/about-airco/whatdoes-it-do/default.jsp

WEB_9, 2005. www.daikineurope.com,30/4/2005,www.daikineurope.com/about-airco/why-air-co/personal-performance/default.jsp

WEB_10, 2004.http://presonal.city.ed.hk14/7/2005,http://presonal.city.ed.hk/bsapplec/heat.html

WEB_11, 2004.www.investors.about.com,12/4/2005,www.investors.about.com/library/weekly/aa081797.html.

WEB_12, 2002.www.ashrae.org.2/8/2005.www.ashrae.org/templete/Assetdetail/assetid/25232

WEB_13, 2004.www.automobileindia.com.5/8/2005.www.automobileindia.com/car-airconditioning

WEB_14,2004.www.familycar.com.16/7/2005.www.familycar.com/Classroom/ac1.htm

WEB_15, 2004. www.karyer.com .22/10/2005.www.karyer.com

WEB_16, 2005. www.danfoss.com.6/11/2005.www.danfoss.com/filter-drier.html

WEB_17, 2004. http://www.arap.org.30/9/2005.http://www.arap.org/adlittle/3.html

WEB_18,2005.www.atlas.cc.itu.edu.tr.14/6/2005.www.atlas.cc.itu.edu.tr/ensicia/designophy/elkitabı/model0201php.

WEB_19, 2005. www.designophy.com.18/7/2005.www.designophy.com/polimer esaslı kompozit malzemeler ve ürün tasarımında kullanımları/Enşici A.

WEB_20, 2005.www.poliya.com.tr.12/10/2005.www.poliya.com.tr/ürünteknikbülteni/ctp/kalıpyapımı.html

APPENDICES

APPENDIX A

COOLING CAPACITY CALCULATION FOR WAGON A/C UNIT

CONDITIONS

OUTLET AIR TEMPERATURE	t_{outlet} = 50 ^{0}C	80 ^{0}C IN FULL SUN	
INLET AIR TEMPERATURE	t_{inlet} = 35 ^{0}C		

SIZE OF WAGON:	L =	6	mt
	H =	2,2	mt
	W =	2,75	mt

HEAT TRANSFER COEFFICIENT STATIONARY	K =	1,8	w/m^2 ^{0}K
HEAT TRANSFER COEFFICIENT AT SPEED OF 120 km/h	K =	2,8	w/m^2 ^{0}K

1 - NUMBER OF PASSANGERS	n =	3	pcs

WINDOWS: DOUBLE GLASS SAFETY WINDOWS, HAVING 2 PANELS, EXTERIOR ONE OF 8 mm THICK,
INTERIOR ONE OF 5 mm THICKNESS WITH 6 mm AIR LAYER BETWEEN THE PANELS.
SHATTERPROOF, TINTED GLASS WITH 15-25% LIGHT ABSORBTION AND HEAT REFLECTION.

CALCULATIONS OF HEAT TRANSFER

A - CALCULATION FOR 3 pcs PASSANGER, 2,8 w/m^2 ^{0}K HEAT TRANSFER COEFFICIENT

TOTAL HEAT TRANSFER: $Q_{total} = Q_{passenger} + Q_{transfer} + Q_{radiation}$

$Q_{passenger} =$ n x q_{human} $q_{human} = 100$ Kcal/h

$Q_{passenger} = 300,0$ kCal/h FOR 3 pcs PASSANGERS

$Q_{transfer} =$ K x A x Dt Dt = $t_{outlet} - t_{inlet}$

Dt = 15 ^{0}C

A = 2 (L. H) + 2 (L. W) + 2 (H. W)

A = 130,9 m^2

$Q_{transfer} =$ 5.497,8kCal/h FOR K = 2,8 w/m^2 ^{0}K

$Q_{radiation:}$ $qRs = es \times s\ (Ts / 100)^4$

Surface emitance es =0,84 FOR GLASS (see ASHRAE 1995 C.30.6)

Constant s = 5,67 W/(m^2 K^4)

Absolute temperature of the surface Ts =353,15 K (80 ^{0}C)

$Q_{radiation} = 740,8$ Kcal/h FOR 80 ^{0}C IN FULL SUN

TOTAL HEAT TRANSFER: $Q_{tota}l = Q_{passenger} + Q_{transfer} + Q_{radiation}$

$Q_{total} =$6.538,6 Kcal/h

Correction factor K = 1,2

$Q_{COOLING} =$K x Q total

$Q_{COOLING} = 7.846,3$ Kcal/h

$Q_{COOLING} = 9,1$ kWatt

B - CALCULATION FOR 3 pcs PASSANGER, 1,8 w/m2 0K HEAT TRANSFER COEFFICIENT

TOTAL HEAT TRANSFER: $Q_{total} = Q_{passenger} + Q_{transfer} + Q_{radiation}$

Q passenger = n x q human   q human = 100 Kcal/h

Q passenger = 300,0 Kcal/h FOR 3 pcs PASSANGERS

$Q_{transfer}$ = K x A x Dt   Dt = t outlet - t inlet

Dt = 15 ^{0}C

A = 2 (L. H) + 2 (L. W) + 2 (H. W)

A = 130,9 m^2

$Q_{transfer}$ =3.534,3 Kcal/h   FOR K = 2,8 w/m^2 ^{0}K

$Q_{radiation}$: qRs = es x s (Ts / 100)^4

Surface emitance es =0,84   FOR GLASS (see ASHRAE 1995 C.30.6)

Constant s = 5,67   W/(m^2 K^4)

Absolute temperature of the surface Ts = 353,15 K (80 ^{0}C)

Q radiation = 740,8 Kcal/h FOR 80 0C IN FULL SUN

TOTAL HEAT TRANSFER: $Q_{total} = Q_{passenger} + Q_{transfer} + Q_{radiation}$

Q_{total} = 4.575,1 Kcal/h   Correction factor K = 1,2

$Q_{COOLING}$ =K x Q_{total}

$Q_{COOLING}$ = 5.490,1 Kcal/h

$Q_{COOLING}$ = 6,3 kWatt

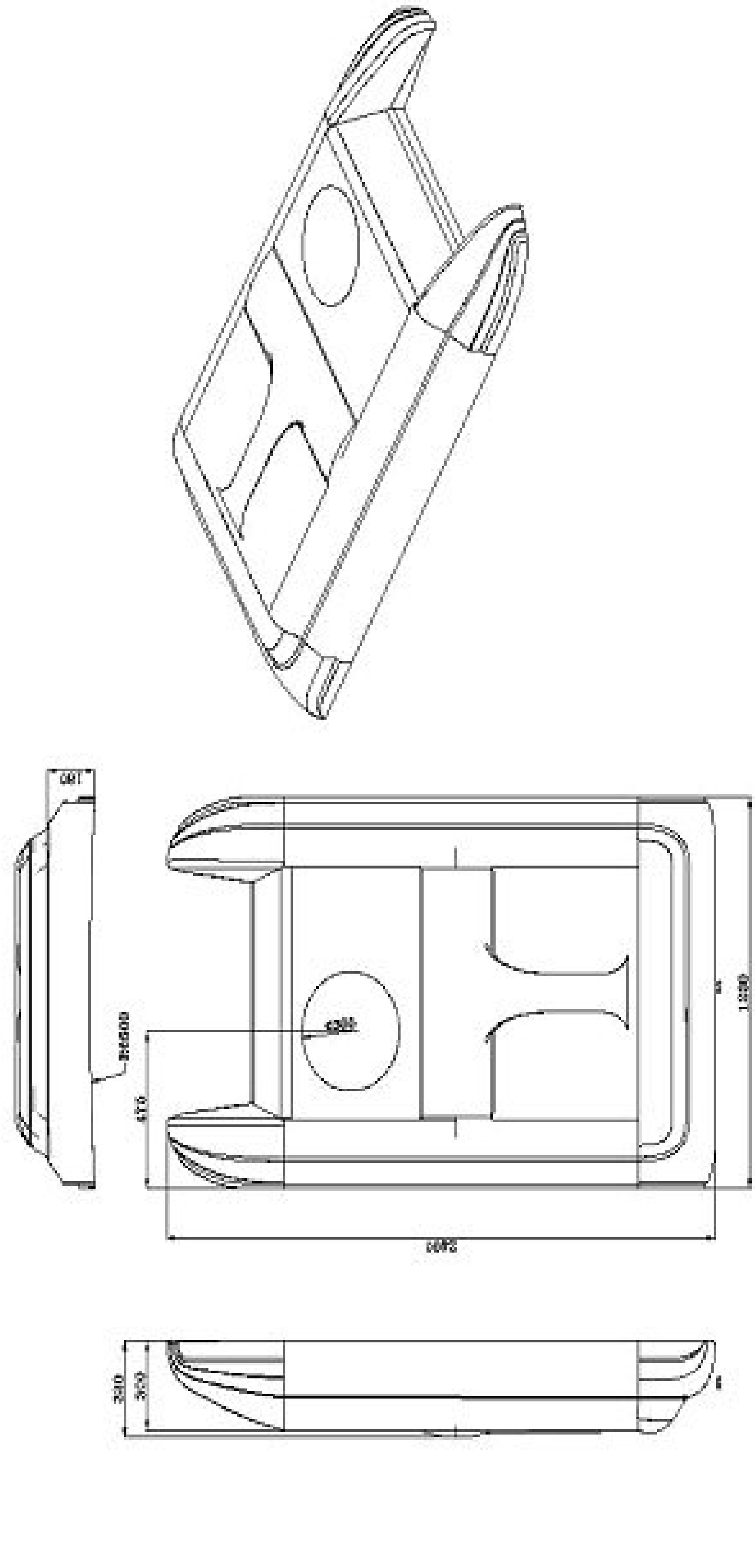
APPENDIX B

THERMAL CONDUCTIVITY

Material	**Thermal Conductivity** ***k*** **($W.m^{-1}. K^{-1}$)**
Iron	73
Steel	~ 46
Aluminum	210
Copper	386
Silver	406
Gold	293
Platinum	70
Asbestos	0.16
Red Brick	0.63
Cement	0.30
Felt	0.036
Glass	0.8
Fiberglass	0.04
Granite	2.1
Ice	2.2
Linen	0.088
Paper	0.13
Sand, dry	0.39
Soil, dry	0.14
Wood	0.13
Alcohol, ethylen	0.17
Mercury	8.7
Oil, engine	0.15
Water	0.58
Air	0.026
CO_2	0.017
Oxygene	0.027

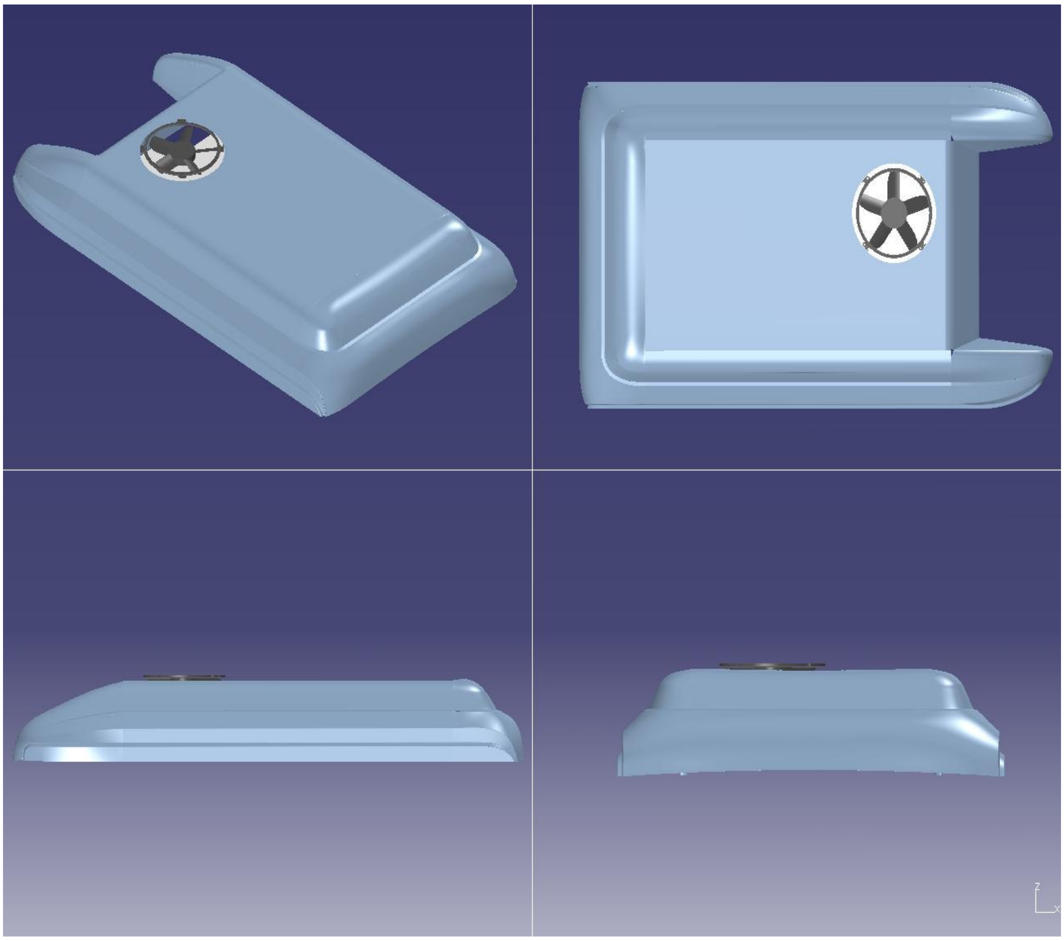
APPENDIX C

THECNICAL DRAWING OF PRO X UNIT



APPENDIX D

4 VIEWS OF RENDER PRO X UNIT



APPENDIX E

PHOTOS OF PRO X