

**PROTOTYPING AND VALIDATION OF 2, 2.3 TON 4 STAR
& 5 STAR PANASONIC SPLIT AC MODELS**

A THESIS

**SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE
DEGREE OF**

MASTER OF ENGINEERING

IN

THERMAL

SUBMITTED BY:

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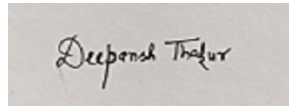
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Certificate

I hereby certify that the major project entitled “Prototyping and validation of 2, 2.3 Ton 4 star & 5 Star Panasonic split AC models” is genuine record of my own work carried out in completing project requirement for the degree of Master of Engineering in THERMAL Engineering at Thapar University, Patiala, under the guidance of Dr. KUNDAN LAL, Assistant Professor, Department of Mechanical Engineering, Thapar Institute of Engineering and Technology Patiala. I also like to thanks my industry mentor Mr. Amit Tyagi for support from Panasonic side so as to complete my thesis work.



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(Deepansh Thakur)

Abstract

Air conditioning system is a device consisting of components and equipment arranged in sequential order to satisfy the various space conditions required for comfort as well as industrial air conditioning. Prototyping and validating of AC plays an important role in the development and validation of new and existing models of AC. A prototype is an early sample, model, or release of a product built to test a concept or process. In this work prototypes of different and some newly developing models are made and then validated according to the norms of Bureau of Indian Standards (BIS). Generally, a prototype is made according to the new features and requirements of the customers, then this prototype is tested with different tests in the labs so that it should meet the specifications of the R&D team and BIS norms. As a part of ME Thesis work following models were tested & validated.

- 1) Development of Hot and Cold, 2 Ton, 4* & 5* AC Model
- 2) Development of 2.3 Ton, 4* AC model
- 3) Development of 2 Ton, 4* AC model
- 4) Development of 2 Ton, 5* AC model

Also, the following tests were performed according to: IS 1391 (PART 2) – BIS. These tests are performed so as to validate the prototypes.

- 1) Cooling capacity
- 2) Maximum operating
- 3) Freeze up tests
- 4) Sweat test
- 5) Heating test
- 6) Power consumption test
- 7) Noise test
- 8) Drip test

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Keywords

AC: Air Conditioner

IDU: Indoor Unit

ODU: Outdoor Unit

CS: Cooling system

CU: Condensing Unit

EER: Energy Efficiency Ratio

ISEER: Indian Seasonal Energy Efficiency Ratio

FL: Full Load

HL: Half Load

R&D: Research and development

BEE: Bureau of energy efficiency

A/F: Air Flow

RAC: Refrigeration and air conditioning

INTRODUCTION

1.1 Introduction to air conditioning

With the development of society and economy, the living standard of people is improving, and higher living conditions are demanded. Depending upon the requirement, air conditioning is divided into the summer air conditioning and the winter air conditioning. In the summer air conditioning, apart from cooling the space, in most of the cases, extra moisture from the space is removed, whereas in the winter air conditioning, space is heated and since in the cold places, normally the humidity remains low, moisture is added to the space to be conditioned.

The summer air conditioning thus uses a refrigeration system and a dehumidifier. The winter air conditioning uses a heat pump (refrigeration system operated in the reverse direction) and a humidifier. Depending upon the comfort of the human beings and the control of environment for the industrial products and processes, air conditioning can also be classified as comfort air conditioning and industrial air conditioning. Comfort air conditioning deals with the air conditioning of residential buildings, offices spaces, cars, buses, trains, airplanes, etc. Industrial air conditioning includes air conditioning of the printing plants, textile plants, photographic products, computer rooms, etc

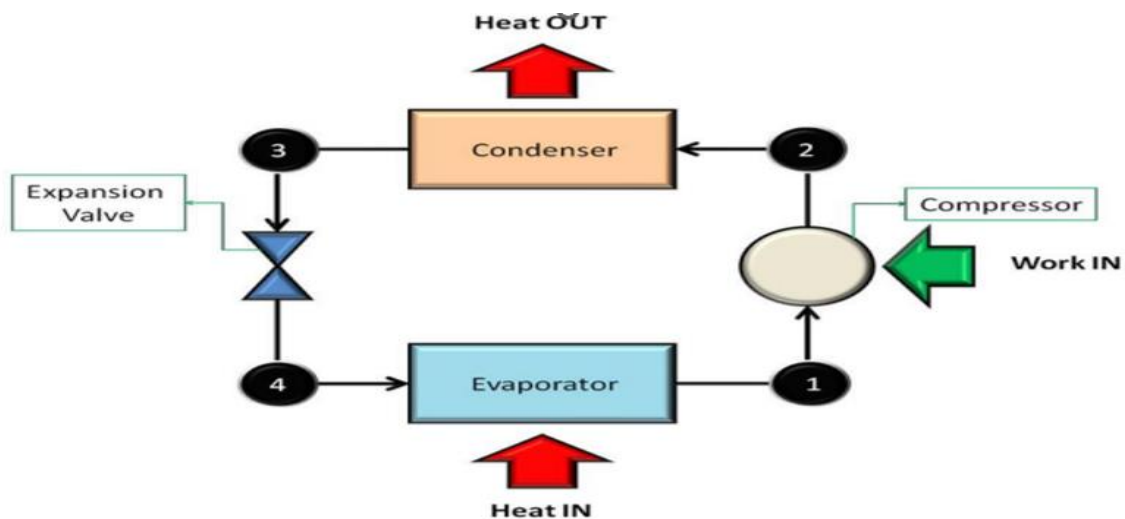


Figure 1.1 Schematic of a vapour compression refrigeration cycle (3)

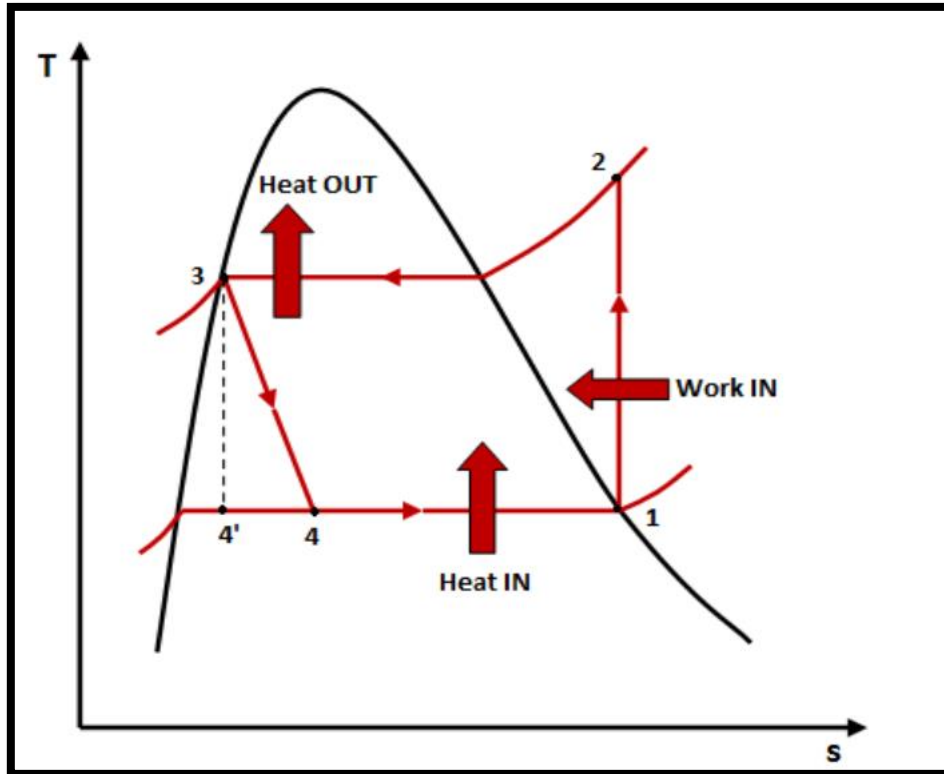


Figure 1.2 T-S Diagram for the ideal vapour compression refrigeration Cycle (3)

Ideal vapour compression refrigeration cycle consists of four processes:

- 1-2 Isentropic compression in compressor
- 2-3 Constant-pressure heat rejection in a condenser
- 3-4 Throttling in an expansion device
- 4-1 Constant-pressure heat absorption in an evaporator

In this process, warm air is forced to pass through an evaporator coil where air is cooled by a low-temperature two-phase refrigerant in the coil. If the evaporator surface temperature is lower than the air dew-point temperature, the air is dehumidified by the coil. The heat, which is transferred from warm air, changes the refrigerant from liquid to vapour. The compressor removes the low temperature and low-pressure refrigerant vapour from the evaporator coil and discharges that vapour at a high temperature and high pressure to a condenser. In the condenser, the heat of the refrigerant is removed by a coolant, which often is water or air, causing the refrigerant to return to a liquid state at that high pressure. The high-pressure liquid refrigerant passes through a throttling device and becomes a low pressure and low temperature two-phase, vapour plus liquid, state refrigerant. The refrigerant then passes into the evaporator to cool and to dehumidify warm air. After heat and mass are transferred, the lower temperature and lower

humidity air is sent to the air-conditioned space to balance heat and humidity load of air-conditioned space. It should be observed that the system operates on a closed cycle. The system requires input in the form of mechanical work. It extracts heat from a cold space and rejects heat to a high temperature heat sink. This refrigeration system can also be used as a heat pump, in which the useful output is the high temperature heat rejected at the condenser. Alternatively, a refrigeration system can be used for providing cooling in summer and heating in winter.

The refrigerant enters the compressor at state 1 as saturated vapour and is compressed isentropically to the condenser pressure. During the isentropic compression process the temperature of the refrigerant increase to well above the temperature of the surrounding medium. The refrigerant then enters the condenser as superheated vapour at state 2 and leaves as saturated liquid at state 3, as result of heat rejection to the surrounding. The temperature of the refrigerant at this state is still above the temperature of the surroundings.

The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve. During this process the temperature of the refrigerant drops below the temperature of the refrigerated space. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from refrigerated space. The refrigerant leaves the evaporator as saturated vapour and re-enters the compressor, completing the cycle.

Generally, air conditioner can be classified into; window unit air-conditioners, central unit air-conditioner, and split unit air-conditioner. In this air conditioner, all the component, namely; the compressor, condenser, expansion valve evaporator and cooling coil are enclosed in a single box. Window unit air conditioners are installed in an open window. The interior air is cooled as a fan blows it over the evaporator. On the exterior the heat drawn from the interior is dissipated into the environment as a second fan blows outside air over the condenser. A large house or building may have several such units, allowing each room to be cooled separately. The central unit air conditioning unit is for cooling big building houses, offices, entire hotels, cinema hall, and factory etc. If the whole building is to be air condition, HVAC engineers find that putting individual units in each of the room is very expensive initially as well in the long run. The central air conditioning unit comprising of huge compressor that has the capacity to produce hundreds of tons of air conditioning. The split unit air conditioning system comprises of two parts the outdoor unit and indoor unit. The outdoor unit, fitted outside the room, house component like the compressor, condenser, and the expansion valve. The indoor unit comprises the evaporator, and cooling fan. In the split system, one does not have to make any slot in the

wall of the room. Depending upon the requirement, air conditioning is divided into the summer air conditioning and the winter air conditioning. In the summer air conditioning, apart from cooling the space, in most of the cases, extra moisture from the space is removed, whereas in the winter air conditioning, space is heated and since in the cold places, normally the humidity remains low, moisture is added to the space to be conditioned. The summer air conditioning thus uses a refrigeration system and a dehumidifier. The winter air conditioning uses a heat pump (refrigeration system operated in the reverse direction) and a humidifier. Depending upon the comfort of the human beings and the control of environment for the industrial products and processes, air conditioning can also be classified as comfort air conditioning and industrial air conditioning. Comfort air conditioning deals with the air conditioning of residential buildings, offices spaces, cars, buses, trains, airplanes, etc. Industrial air conditioning includes air conditioning of the printing plants, textile plants, photographic products, computer rooms, etc. Human thermal comfort in buildings is one of the major issues. In commercial buildings, it can affect the efficiency and productivity of workers. Meanwhile, thermal comfort in residential buildings can improve the quality of daily life, which also affect the efficiency and productivity of occupants while they are at work. Due to this reason, air conditioners are now becoming a standard accessory for household application. Sukri et al. (2012) highlighted that air-conditioning contributes highest energy demand for typical commercial buildings about 50-60%. The same situation also occurs in transportation sector where the air-conditioning system consumes the largest of energy among accessories equipped in typical land vehicles (Sukri et al. 2016). In residential buildings, percentage of energy used for space conditioning is also significant, of up to 70% from total building energy consumption, especially for extreme hot and cold countries.

The residential energy consumption and percentage of energy used for space conditioning in few countries (2015):

Table1.1 Shows the residential energy consumption of different countries

Countries	Residential energy consumption (%)	Space conditioning share (%)
Saudi Arabia	50	70
USA	22	52
UK	28	62
Spain	15	42
European Union	26	68

The inverter air conditioner is more energy efficient because it comes with an advanced direct current (DC) inverter technology to drive highly efficient DC motor in the compressor and enable a wider output power range for more energy saving and higher power. This type of DC inverter technology has dramatically reduced power consumption of up to 50%, compared with conventional alternating current motor driven compressor. With addition of other latest advanced technologies such as dual human activity sensor, sunlight sensor and temperature wave, the energy saving can be increased of up to 65% compared to the same capacity of standard non-inverter type.

1.2 The need for air conditioning

Although some people might regard air conditioning as a luxury, in certain areas having air conditioning is a must. One does not feel comfortable if the temperature and humidity level is too high. Air conditioning affects not only personal comfort, but also economics. If people feel comfortable, their productivity is generally better than if they work under uncomfortable conditions. Apart from comfort air conditioning required for comfort of persons, air conditioning is required in many industries to provide conditions that some processes require. The life and efficiency of electronic devices increases at lower temperatures. Computer and microprocessor-based equipment also require air conditioning for efficient operation. Thus, air conditioning is and will be more and more needed in our world. Human thermal comfort in buildings is one of the major issues. In commercial buildings, it can affect the efficiency and productivity of workers. Meanwhile, thermal comfort in residential buildings can improve the quality of daily life, which also affect the efficiency and productivity of occupants while they are at work. Due to this reason, air conditioners are now becoming a standard accessory for household application.

1.3 Working principle of air conditioning system

There are many methods to implement air conditioning, such as the vapour compression refrigeration process and the absorption refrigeration system. The most common method in practice is the vapour compression refrigeration process. Simple vapour compression refrigeration cycle consists of four main components, which are cooling coil or evaporator, compressor, condenser and an expansion valve as shown in figure 1.1.

In this process, warm air is forced to pass through an evaporator coil where air is cooled by a low-temperature two-phase refrigerant in the coil. If the evaporator surface temperature is

lower than the air dew-point temperature, the air is dehumidified by the coil. The heat, which is transferred from warm air, changes the refrigerant from liquid to vapour. The compressor removes the low temperature and low-pressure refrigerant vapour from the evaporator coil and discharges that vapour at a high temperature and high pressure to a condenser. In the condenser, the heat of the refrigerant is removed by a coolant, which often is water or air, causing the refrigerant to return to a liquid state at that high pressure. The high-pressure liquid refrigerant passes through a throttling device and becomes a low pressure and low temperature two-phase, vapour plus liquid, state refrigerant.

The refrigerant then passes into the evaporator to cool and to dehumidify warm air. After heat and mass are transferred, the lower temperature and lower humidity air is sent to the air-conditioned space to balance heat and humidity load of air-conditioned space. It should be observed that the system operates on a closed cycle. The system requires input in the form of mechanical work. It extracts heat from a cold space and rejects heat to a high temperature heat sink. This refrigeration system can also be used as a heat pump, in which the useful output is the high temperature heat rejected at the condenser. Alternatively, a refrigeration system can be used for providing cooling in summer and heating in winter.

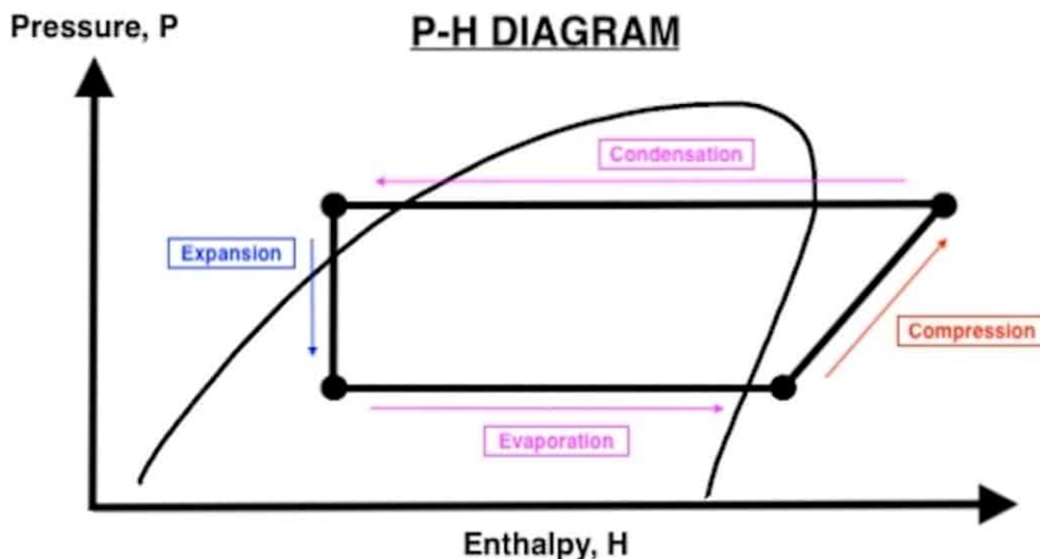


Figure 1.3 P-H Diagram for the Ideal Vapour compression refrigeration cycle (1)

Ideal vapour compression refrigeration cycle consists of four processes:

- 1) Isentropic compression in compressor
- 2) Constant-pressure heat rejection in a condenser
- 3) Throttling in an expansion device
- 4) Constant-pressure heat absorption in an evaporator

1.4 Types of air conditioners used

1.4.1 Window air conditioner

The window air conditioner provides cooling only when and where needed and is less expensive to operate. In this air conditioner, all the components, namely the compressor, condenser, expansion valve or coil, evaporator, and cooling coil, are enclosed in a single box which is fitted in a slot in the wall of the room, or often a window sill. Room air conditioners are generally available in capacities varying from about 0.5 TR to 3 TR.

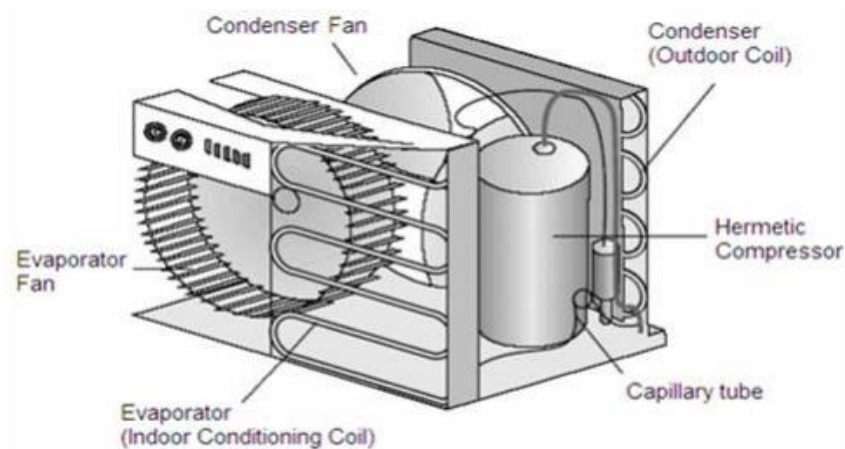


Figure 1.4 Shows the detailed view of a window air conditioner (3)

1.4.2 Split air conditioning systems

The split air conditioner comprises of two parts: the outdoor unit and the indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. The indoor and outdoor units are connected by refrigerant piping. Split-systems are popular in small, single-story buildings. Flexibility is the overriding advantage of a split system.

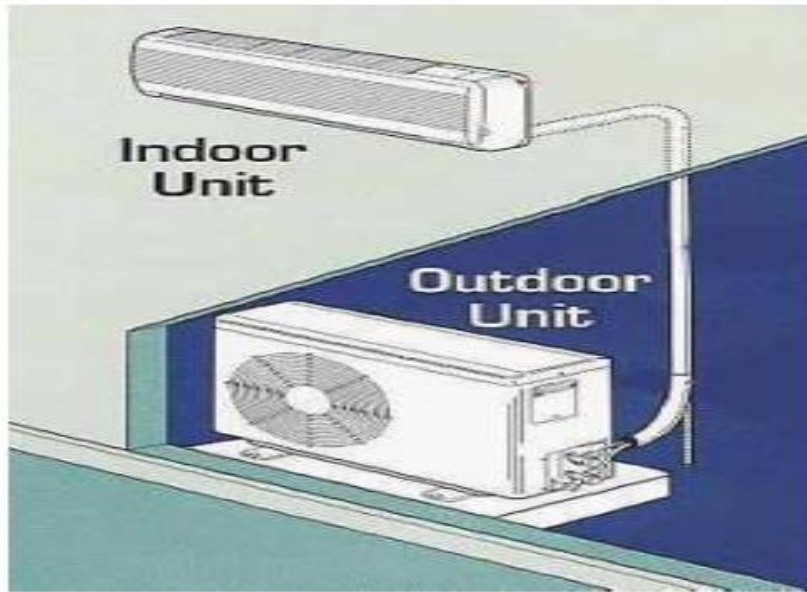


Figure 1.5 Shows the Installation view of split air conditioner (3)

1.5 Design and construction of split air conditioner

The split unit air conditioner consists of two assemble units separated from each other, but interconnected by refrigerating piping.

The two units are: • Indoor unit • Outdoor unit

Outdoor and Indoor Unit Components

Table1.2 Shows the major outdoor unit components are mentioned above

SN	Outdoor Unit
1	Compressor
2	Condenser
3	Fan
4	Fan motor
5	Capillary tube
6	Grill
7	Motor mounting bracket
8	Cabinet
9	Capillary

Indoor Unit Components

Table 1.3 Major Indoor unit components are mentioned above

SN	Indoor unit
1	Evaporator
2	Blower
3	Blower motor
4	Blower mounting bracket
5	Electronic control unit
6	Cabinet
7	Air filter
8	Fins or louvers(vertical and horizontal)
9	Display
10	Infrared signal receiver
11	Remote controller
12	Air

Basic Components of Air Conditioner:

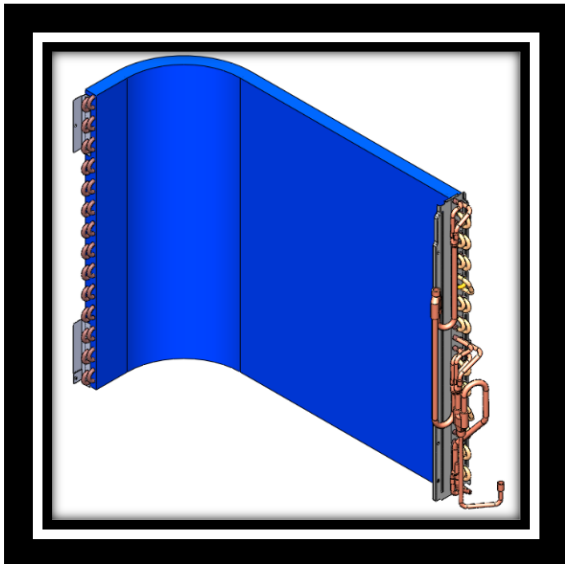


Figure 1.6 (Condenser Coated)(Panasonic)

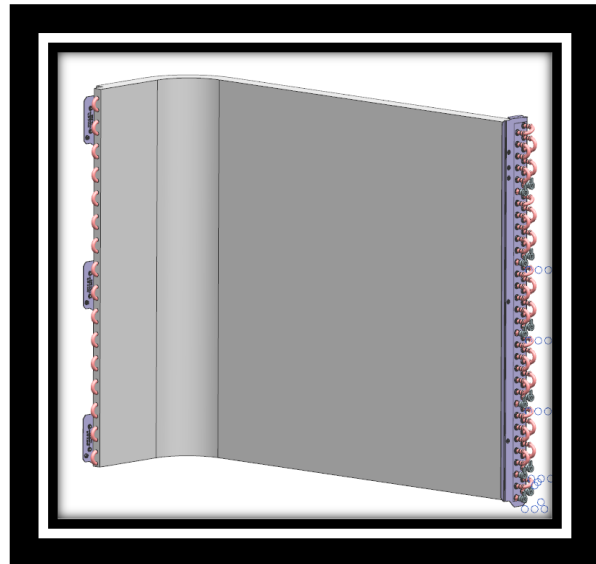


Figure 1.7(Condenser Bare Fin)(Panasonic)



Figure 1.8(Compressor)(Panasonic)

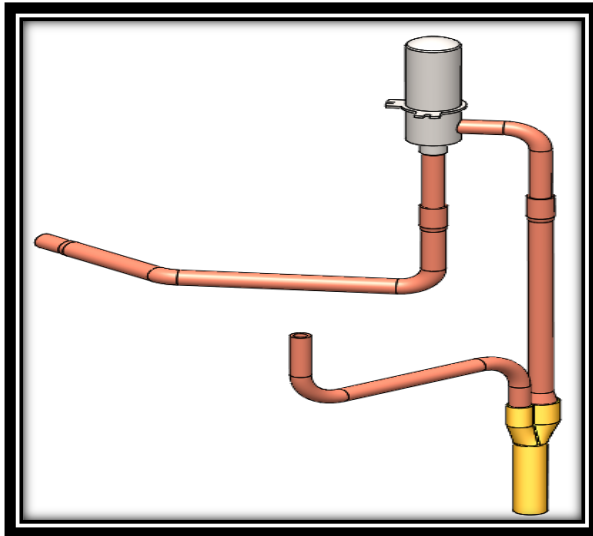


Figure 1.9(Expansion valve)(Panasonic)



Figure 1.10(Evaporator)(Panasonic)



Figure 1.11(Cross Flow Fan)(Panasonic)

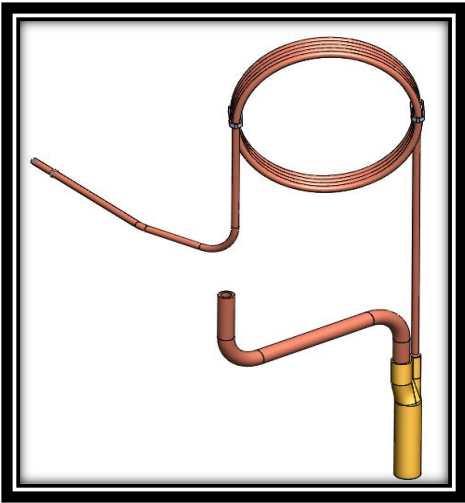


Figure 1.12(Capillary)(Panasonic)



Figure 1.13(Controller)(Panasonic)

CHAPTER-2

LITERATURE REVIEW

The scope of air conditioning is vast, and its applications are very diverse. Literally, thousands of scientists and engineers have contributed to its development. A substantial amount of work has been done on various aspects of air-conditioning Systems.

Air conditioning system is widely used for providing thermal comfort in many domestic and commercial applications. The improvement of living standards and demand for human comfort has caused an increase in energy consumption associated with a higher level of CO₂ emissions. Air conditioning applications' amount of energy occupies 30 % of total world energy consumption. Therefore, a continuous energy-saving effort from cooling systems will contribute to worldwide energy efficiency. Reduction of energy used for air conditioning units can be made by reducing compressor power consumption, increasing condenser heat rejection capacity, and lowering the condenser and evaporator pressure difference. One of the appliances that consume a huge amount of energy in everyday life is an air conditioner.

Nowadays, the air conditioner can be seen operating everywhere on the planet, from residential, commercial as well as industries and the usage has been extensive. It is one of the major electrical energy consuming appliance in residential. Globally, it accounts for more than 50% of building energy usage. According to a report by U.S. Department of Energy (2008), the nation's total energy consumed in residential and commercial buildings accounted for 40% of total U.S. energy used. In residential, the most common air conditioner type used is split-type, mainly because of its simplicity and flexibility.

In Malaysia context, the number of an air conditioner installed in residential has increased over the last few decades. The results of national census showed that a total number of households with air conditioner has dramatically increased from 13,000 (1970), 229,000 (1990), 775,000 (2000) and the number is even higher in 2018. They also reported that a survey done in Johor Bahru in 2009 indicated that 65% of households owned air-conditioning systems. The air conditioner is known to be an energy-intensive appliance that is essential to human's comfort. One of the primary parameters that influences the energy consumption of the air conditioner beside having high efficiency compressor is the amount of refrigerant charge. Any discrepancy from the optimal charge will degrade air conditioner performance as well as deteriorate the system's reliability. Domanski et al. found that systems that run with 30% undercharged of

refrigerant used as much as 17 to 23% energy. Majority of the cooling appliances are running without a proper refrigerant charge due to leakage and improper charging during installation. It is common that the refrigerant charge in the air conditioning system is not at the optimal level. This is due to improper charging during installation and leakage over its operation.

Proctor sum up based on tests of more than 4,000 residential cooling system in California, 62% are improperly charged.

Meanwhile, Domanski et al. highlighted that only 18% of systems installed in the United States had the correct refrigerant charge. The optimal level of refrigerant charge is determined in accordance with the cooling capacity of a refrigeration system. The system performance is always linked to the appropriate refrigerant mass charge into the system. The information from the appliance's catalogue mainly indicates the approximate weight of refrigerant to be charged and did not determine the performance of the unit with different refrigerant charge.

Previous studies by researchers concluded that undercharge or overcharged system would have a significant impact on the performance and causing it to operate with higher electrical input to produce a cooling effect. Therefore, there is a need to understand the performance of the air conditioner if it is not properly charged for the means of optimal operation and cost saving.

All of these researches used a large capacity air conditioner. Therefore, in this research, a small capacity split-unit type air conditioner using R22 refrigerant is used to determine the effect of improper refrigerant charge on its performance. The results of total cooling capacity, total electric power consumption, and coefficient of performance will be presented.

2.1) Research Gap:

As technology changes so the products (appliances) needs upgradation and changes so as to increase the efficiency and improve the quality of the product. These are the shortcomings which needs to be improved and are mentioned below:

- 1) Power Consumption in Hot and Cold, 2 Ton, 4* & 5*AC Model was coming out very high and cooling capacity need to be improved.
- 2) First time in India, Panasonic develops 2.3 Ton, 4* AC model.
- 3) Cooling capacity in 2 Ton, 4* AC model need to be improved.
- 4) New Development of 2 Ton, 5* AC model.

2.2) Research objectives

The main objective of this project work is to make a prototype of the split AC, then validate it as per the norms of the BEE and also fulfill the requirements of the R&D team. As the ratings of the BEE changes almost every year so the existing model will not fall in the rated category of its mentioned rating. With the help of R&D team different prototypes are made and are validated according to the IS Standards and also according to the standards of the company. Validation consists of many tests which are used to validate the model and are mentioned in this work in detail. Along with that if there are some feature addition in some models of the Ac so that feature is being checked with the help of prototyping and validation.

This work majorly depicts:

- 1) Development of Hot and Cold, 2 Ton, 4* & 5* Panasonic AC Model**
- 2) Development of 2.3 Ton, 4* Panasonic AC model**
- 3) Development of 2 Ton, 4* Panasonic AC model**
- 4) Development of 2 Ton, 5* Panasonic AC model**

CHAPTER-3

TESTS PERFORMED FOR VALIDATION

These are the various tests which are performed according to IS 1391 (part 2) – BIS. These tests are used so as to validate the AC models and are also used for development purpose. List of tests are mentioned below in detail:

- 1) Cooling capacity
- 2) Max. Operating
- 3) Freeze up tests
- 4) Sweat test
- 5) Heating test
- 6) Power consumption test
- 7) Noise test
- 8) Drip test

The other tests mentioned in the previous slide are done according to the R&D specs of the company not as per is standards.

3.1) Cooling capacity

The Split air conditioner shall have nameplate rating determined by tests conducted at the standard rating conditions specified below:

- a) Room air temperature
 - 1) Dry bulb temp: 27°C 2) wet bulb temp: 19°C
- b) Outside air temperature: 1) dry bulb temp: 35°C 2) wet bulb temp: 24°C
- c) Test Voltage — Rated voltage
- d) Test Frequency — Rated frequency
- e) Fan/blower speed — Speed declared by manufacturer.

Requirements: The capacity of the production unit as determined on the room side shall be not less than 95 percent of the name plate rating.

Sl. No.	Rating cooling capacity (W)	Maximum Power Consumption (W)
(1)	(2)	(3)
i)	3500	1270
ii)	5200	1900
iii)	7000	2540
iv)	8700	3170
v)	10500	3800

Figure 2.1 showing the power consumption rating of split air conditioner (14)

This test required the setup in which this can be performed and is called as the **Balanced Ambient Room Type Calorimeter**.

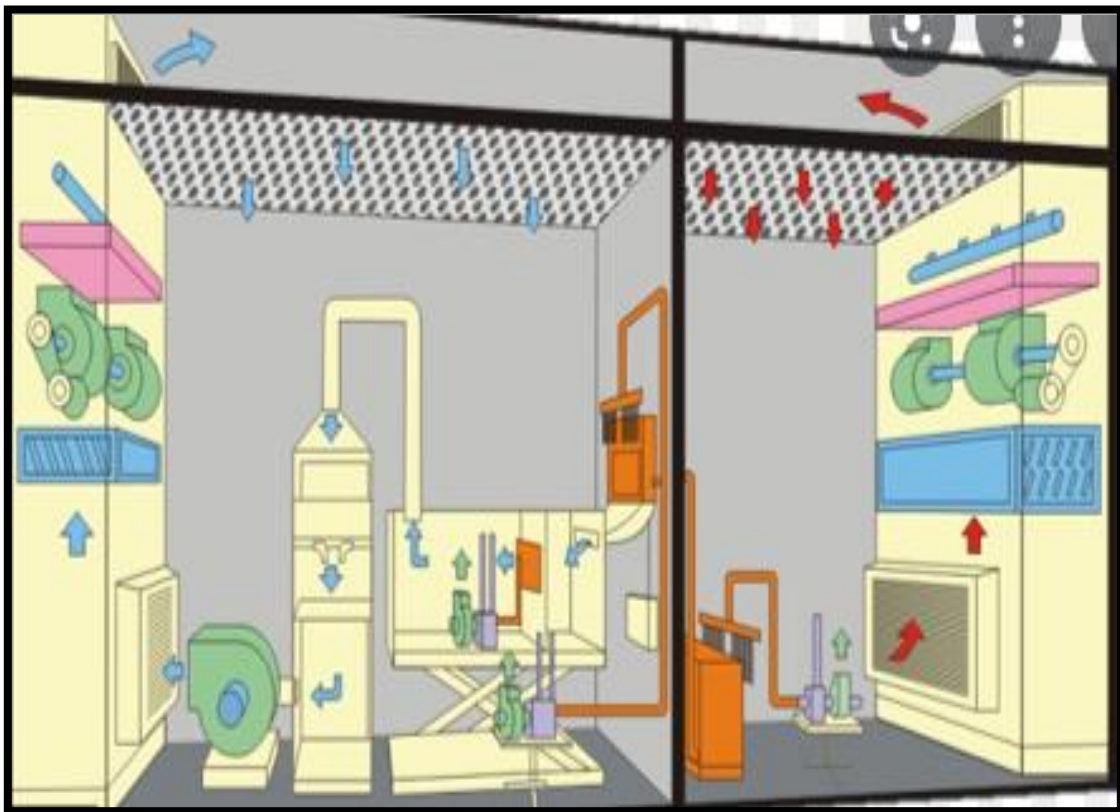


Figure 2.2 Experimental setup of calorimeter (Panasonic)

3.2) Maximum operating test

The maximum operating tests shall be conducted under: Room air temperature: 1) Dry bulb temp: 35°C 2) wet bulb temp: 24°C

b) Outside air temperature: 1) Dry bulb temp: 46°C 2) wet bulb temp: Not applicable

c) Test Voltage — Rated Voltage

d) Test Frequency — Rated frequency

e) Fan/blower speed — Speed declared by manufacturer

Requirements: During one entire test, the split air conditioner should operate without visible or audible indication of damage and without tripping. The split air conditioner fan/blower motor should operate continuously for the first 2 h of the test without tripping of the motor overload protective devices.

3.3) Freeze-up test condition:

Freeze up tests shall be conducted under the conditions specified below:

a) Room air temperature: 1) dry bulb temp: 21°C 2) wet bulb temp: 15°C

b) Outside air temperature: 1) dry bulb temp: 21°C 2) wet bulb temp: Not Specified

c) Test Voltage — 85 percent and 115 percent of Rated Voltage

d) Test Frequency — Rated frequency

e) Fan/blower speed — Speed declared by manufacturer.

Requirements: At the end of 4 h of operation, any accumulation of ice or frost on the evaporator shall not cover more than 50 percent of the indoor side face area of the evaporator coil.

3.4) Enclosure sweat test conditions:

The enclosure sweat test shall be conducted under the conditions given below:

a) Room air temperature: 1) Dry bulb temp: 27°C 2) Wet bulb temp: 24°C

b) Outside air temperature: 1) Dry bulb temp: 27°C 2) Wet bulb temp: Not applicable

- c) Test Frequency — 50 Hz
- d) Test voltage — Rated Voltage
- e) Fan/blower speed — Speed declared by manufacturer

Requirements: During the test, no condensed water shall drip, run or blow off the unit.

3.5) Heating capacity test conditions:

The heating capacity rating shall be conducted under the conditions given under:

- a) Room air temperature: 1) dry bulb temp: 20°C 2) wet bulb temp: Not specified
- b) Outside air temperature: 1) dry bulb temp: 7°C 2) wet bulb temp: 6°C
- c) Test Voltage — Rated voltage
- d) Test Frequency — Rated frequency

3.6) Power Consumption Test for Cooling:

Requirements: The rate of power consumption for air conditioners tested under the conditions shall not exceed 115 percent of the rated energy for heating by heat pump. Rating is already mentioned in the fig 2.

3.7) Noise test:

For noise test, the air conditioner shall be installed in a noise measuring room shown in Fig. 2.4. The split air conditioner shall be operated in the cooling condition. The noise level in the indoor side shall not exceed the value given in fig 3 and the noise level in the outdoor side shall be measured in accordance with IS 4758 and shall not exceed the value given in fig 2.3

Table 3 Noise Level

Rating Cooling Capacity (kW)	Maximum Noise Level in dBA	
	Indoor side	Outdoor side
Up to 5.2	58	68
More than 5.2	62	70

NOTE — During starting and stopping, there should not be any touching or abnormal noise.

Figure 2.3 Showing the noise ratings that should be maintained in split air Conditioner (14)

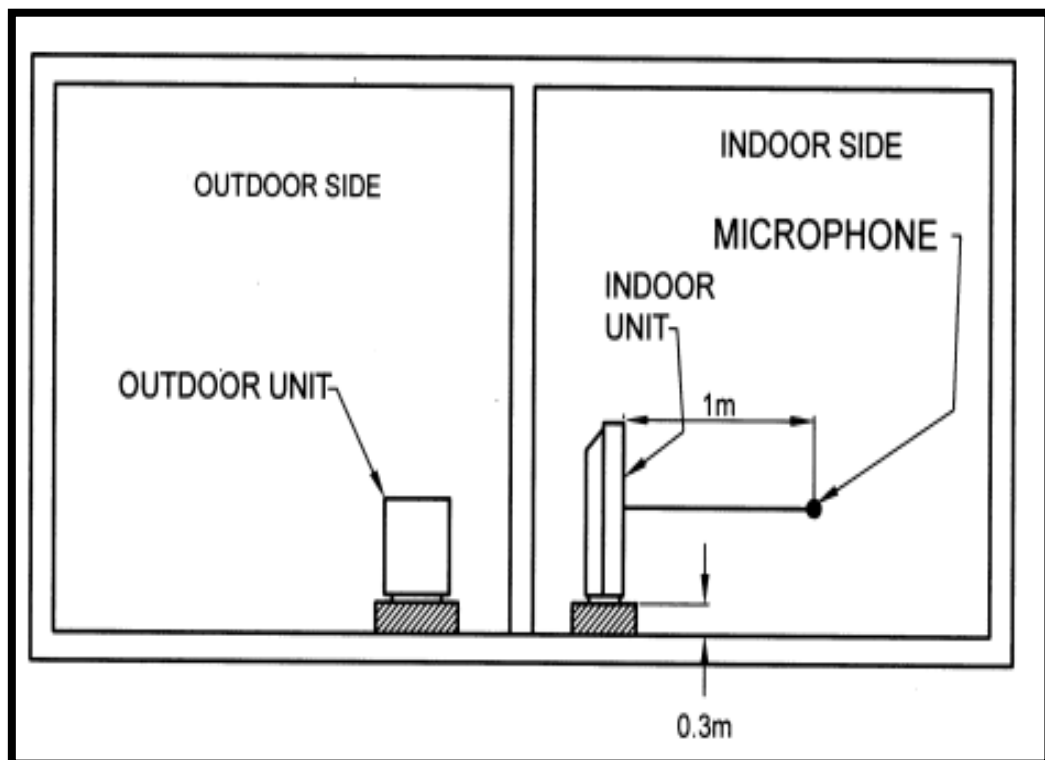


Figure 2.4 Showing the experimental setup of noise room (14)

3.8) Drip test

The unit should be operated for 6 h with the room side air inlet covered to completely block the passage of air so as to attempt to achieve complete blockage of the evaporator coil by frost. After 6 h operating period, the unit should be stopped and the air inlet covering removed until the accumulation of ice or frost has melted by itself. The unit should then be turned on again, with the fans operating at the highest speed, for 5 min.

Requirements: During the test no ice shall drop from the unit, and no water shall drip or blow off the unit on the room side.

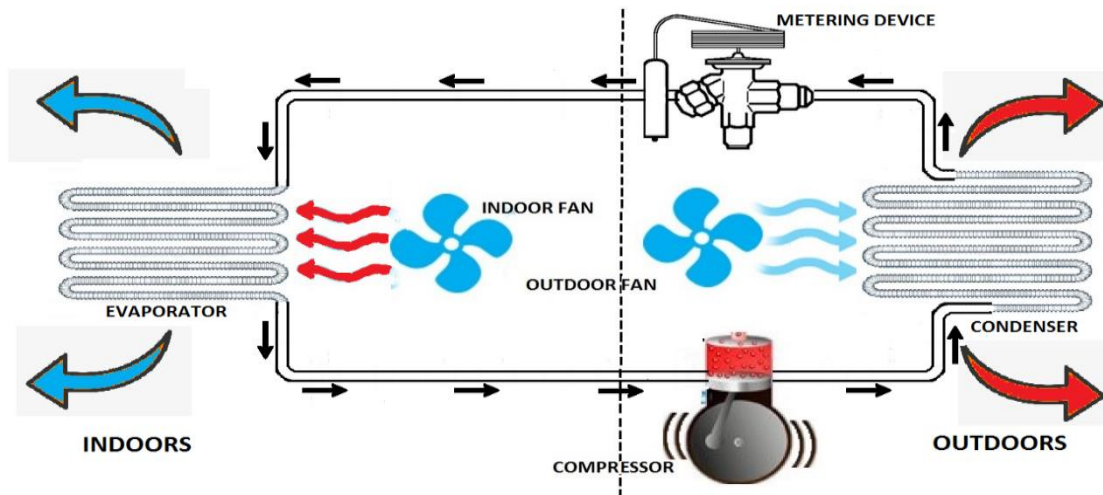


Figure 2.5 Shows the detailed view of RAC cycle (5)

2.1 According to the various research papers and IS standards we have conclusions mentioned under:

RESEARCH PAPER	COCLUSIONS USED
Design and Construction of Split Unit Air Conditioner [1]	Design Specification and Design Consideration
Study on Running Performance of a Split-type Air Conditioning System Installed in the National University Campus in Japan [2]	Air Flow Calculations

Study, modelling, analysis, evaluation, selection & performance improvement of air conditioning system [3]	Detailed Study of Air conditioner with some experimental studies
Study on Performance Evaluation Method of a Split Air Conditioning System Based on Characteristic Curve of the Compressor Mass Flow Rate [4]	Operating conditions in heating and cooling, Measuring Mass Flow Rate (kg/min)
Performance Enhancement of Split Air Conditioner During Evaporative Cooling Application [5]	The comparison performance of evaporative cooling air conditioning system with conventional air conditioning system.
Economics analysis of an inverter and non-inverter type split unit air-conditioners for household application [6]	Results of an inverter and non-inverter type split unit air-conditioners
Study on Power Consumption and Energy Performance of Split-Type Air-Conditioners [7]	Effect of the Outside Temperature on Power Consumption of the AC
The Effect of Refrigerant Charge on the Performance of a Split-Unit Type Air Conditioner Using R22 Refrigerant [8]	Study of total cooling capacity as a function of refrigerant charge, Total electric power consumption as a function of refrigerant charge
Review of Design of Air Conditioning System for Commercial and Domestic Applications [9]	This work offers tremendous significant for developing new technologies pertains to save energy. In order to achieve hot/cool air at initial cost, no harmful effect and safer in environment aspect.
Research and analysis of air-conditioning system with cooling air and supplying warm-water [10]	Experiment results show that the device is extra effective than traditional structures. The maximum COP is about 5.3 at refrigeration mode, the COP is 5.7 at static heating mode of heating.

<p>A Simplified Air-conditioning Systems Model with Energy Management [11]</p>	<p>A simplified of air-conditioner system Simulink model is used to approximate energy required for cooling a specific room at indoor temperature set point 25o C. Two case studies are compared; Case I: Normal Operation; Case II: Energy Saving Operation which the air - conditioner is off for 15 minutes.</p>
<p>Improvement of performance of air conditioning system with modification in condenser [12]</p>	<p>The experimental results clearly say that with the modification in condenser of air conditioning system, the cooling capacity and the performance increased considerably.</p>
<p>Experimental study on comparison of energy consumption between constant and variable speed air conditioners in two different climates [13]</p>	<p>Results show that a variable speed (inverter) air-conditioner is more efficient than a constant speed air-conditioner.</p>

METHODOLOGY

In modern days, technology changes rapidly and also there is a urgent requirement of the modern technologies which will meet the requirements of the modern days. Also, during their development, their validation is must. So, to validate them various prototypes are made firstly then their validation is done. Air conditioning system is widely used for providing thermal comfort in many domestic and commercial applications. The improvement of living standards and demand for human comfort has caused an increase in energy consumption associated with a higher level of CO₂ emissions. Air conditioning applications' amount of energy occupies 30 % of total world energy consumption Here 4 prototypes are mentioned along with their validation. Project is divided in 4 stages as it is a development of 4 AC models So starting with development of 1st model:

4.1) Development 1: Development of hot and cold, 2 Ton, 4* & 5* AC Model:

It has following parameters which are:

- **Condenser dia.:** 7 mm
- **Capillary used:** 1.6 x 600 mm
- **Gas used** – R 32,1050 gm
- **IDU RPM:** 1530, **ODU RPM:** 1300

Star Rating	Window AC ISSER VALUE RANGE		SPLIT AC ISSER VALUE RANGE	
	NON-INVERTER	INVERTER	NON-INVERTER	INVERTER
1 Star	2.50 – 2.69	2.50 – 2.69	2.70 – 2.89	3.10 – 3.29
2 Star	2.70 – 2.89	2.70 – 2.89	2.90 – 3.09	3.30 – 3.49
3 Star	2.90 – 3.09	2.90 – 3.09	3.10 – 3.29	3.50 – 3.99
4 Star	3.10 – 3.29	3.10 – 3.29	3.30 – 3.49	4.00 – 4.29
5 Star	3.3 – More	3.30 – More	3.50 – More	4.50 – More
Year	(2016 – 2017)	(2018 – 2019)	(2016 – 2017)	(2018 – 2019)

Figure 4.1 ISEER star rating values for inverter & non-inverter AC models (BIS)

Sr No	Parameters	Minimum Requirement	Performance Results				Performance Results				
			Condenser LO				Condenser LF				
			IDU 1530				IDU 1530			1530	1380
			FL	HL	HL	Heating	FL	FL	HL	Heating	Heating
88Hz	39Hz	38Hz	90HZ	83Hz	82Hz	37Hz	90HZ	91HZ			
1	Cooling Capacity (W)		6500.4	3122.6	3038.1	6427.2	6364	6600	3261	6460.5	6428.1
2	Power (W)		2101.2	716	694.4	1896.8	1924.4	1844.7	675.6	1954.6	2052.4
3	EER		2.979	4.359	4.375	3.38	3.31	3.34	4.83	3.31	3.13
4	ISEER		(4)				4.51				
5	Current (A)		9.27	4.94	4.79	8.37	8.49	8.36	4.66	8.6	9
6	Air Flow(CMM)		18.27	19.67	19.66	19.4	18.31	18.32	19.12	19.41	17.10
7	Suction(-C)		7.7	15.6	15.8	-0.9	8.5	8.6	15.8	-0.6	-0.4
8	Discharge(-C)		86.3	49.3	48.6	62	87.0	86.0	55	72.4	76.5

Figure 4.2 Experimental results of all parameters during validation (Own work)

Hence in this development, various parameters are mentioned which need to be in proper range so that the model qualifies for the required rating standard.

4.2) Development of 2.3 Ton, 4* AC Model:

Our requirements For Full load:

Below mentioned details are the requirements for the development of 2.3 Ton 4* AC model. These required values are achieved by doing the calculations in the standard sheet of ISEER.

Table 4.1 Shows the required parameters for validation

Capacity (Greater Than)	Power (Less Than)	Gas (R-32)	Discharge
8000 W	2400 W	1080 gm	84°c

Full load cooling capacity test:

Here the below mentioned parameters are selected for the validation of the model and are changed according to the requirement for the validation.

Capillary Chosen – 1.8 x 750 mm, **ODU RPM** – 1200, **IDU RPM** – 1250

Frequency of controller – 71 HZ

Results:

Table 4.2 shows the results obtained after change in parameters

S. No	Parameters	Numerical value
1	Cooling Capacity	7610 W
2	Suction temperature	11°C
3	Discharge temperature	84.5°C
4	Power consumption	2186 W
5	EER (Energy Efficiency ratio)	3.4
6	Current Consumption	9.75 A
7	Air flow ratio (A/F)	20

Condition of cooling capacity is not achieved hence changes are required for the validation of that model.

Changed capillary: 1.8 x 800 mm

Firstly, the capillary of the AC is changed so that the cooling capacity will enhance, In case of capillary change no major increase in power happens. Here the length of the capillary increased so that the cooling capacity will increase.

Results:

Table 4.3 shows the results coming out after capillary change

S. No	Parameters	Numerical value
1	Cooling Capacity	7642 W
2	Suction temperature	11°C
3	Discharge temperature	84.8°C
4	Power consumption	2187 W
5	EER (Energy Efficiency ratio)	3.50
6	Current Consumption	9.79 A
7	Air flow ratio (A/F)	20

Still the cooling capacity is not achieved, also the difference between the obtained cooling capacity and required cooling capacity is very high so the frequency of the controller need to be increased.

Change controller frequency to: 72 HZ, **Capillary:** 1.8 x 700 mm

Results:

Table 4.4 shows the results after controller frequency changes to 72 HZ

S. No	Parameters	Numerical value
1	Cooling Capacity	7785 W
2	Suction temperature	11°C
3	Discharge temperature	84.5°C
4	Power consumption	2195.5 W
5	Current Consumption	9.89 A
6	Air Flow Ratio	20.2
7	EER (Energy Efficiency ratio)	3.54

Still conditions are not achieved but the cooling capacity is increased by good amount, also the discharge value is very high which need to be controlled so in this case two changes need to be done:

- 1) Cooling capacity need to be increased.
- 2) Discharge value need to be decreased.

Change controller frequency to: 73 HZ, capillary: 1.8 x 600 mm

Results:

Table 4.5 Shows the results after controller frequency changed to 73 HZ

Capacity	Suction	Discharge	Power	Current	A/F	EER
8400 W	11°C	84°C	2100 W	9.97 A	20.2	4

Here All conditions are achieved hence this model is considered to be validated when the half load test will also be done successfully.

For Half Load Conditions:

Our requirements for half load are mentioned below:

Cap >3800 W, Power < 1200 W, Frequency:33 HZ

Results:

Table 4.6 Shows the values of parameters after frequency changed to 33 HZ

S. No	Parameters	Numerical value
1	Cooling Capacity	3850 W
2	Suction temperature	16°c
3	Discharge temperature	56°c
4	Power consumption	940 W
5	EER (Energy Efficiency ratio)	4
6	Current Consumption	3.96 A
7	Air flow ratio (A/F)	20

All required conditions are achieved hence this model is considered to be validated, the ISEER value achieved is mentioned below:

ISEER :4.26

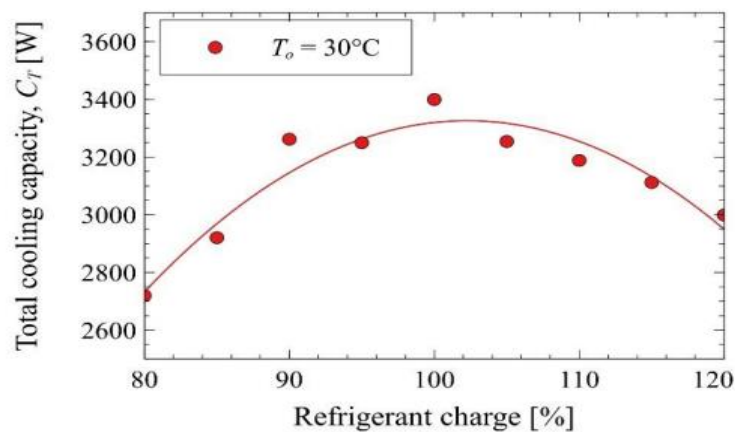


Figure 4.3 Variation of cooling capacity with refrigerant charge (8)

This graph clearly shows that when the refrigerant % was less and high so the cooling capacity was not maximized, at optimum value of refrigerant the cooling capacity is maximized.

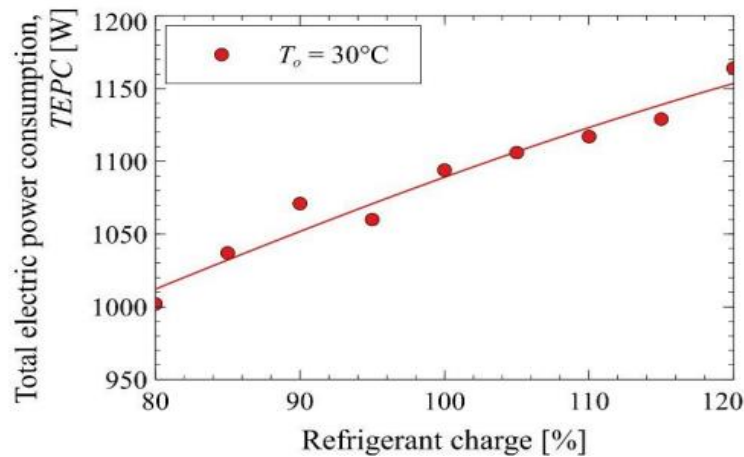


Figure 4.4 Variation of power consumption with refrigerant charge (8)

This graph shows that when the refrigerant percentage is high so the power consumption is also high i.e. the refrigerant % is directly proportional to power consumption.

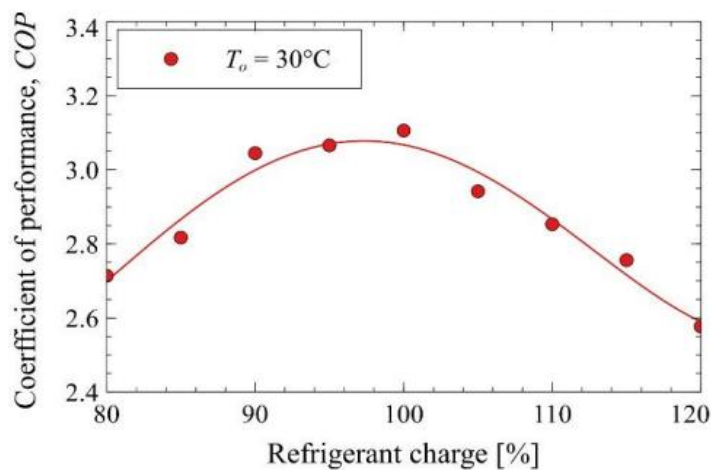


Figure 4.5 Variation of COP with refrigerant charge (8)

In this graph it is clear that at optimum value of refrigerant the COP can be maximized.

4.3) Development of 2 ton, 4* model:

Our requirements for full load:

Our requirements for full load are mentioned below and are to be achieved for the model validation. Also, these values are achieved by doing the calculations in the excel sheet of ISEER. The basic target of doing the calculations is to achieve the maximum cooling capacity with minimum power consumption.

Table 4.7 shows the required values of all parameters

Capacity (Greater Than)	Power (Less Than)	R32 (Gas)
6250 W	2400 W	1050 gm

Full load cooling capacity test:

These are the parameters chosen for the validation of the model.

Capillary chosen – 1.7 x 800 mm, ODU RPM – 1200, IDU RPM – 1500

Frequency of controller – 83 HZ

Results:

Table 4.8 shows the values after controller frequency changed to 83 HZ

S. No	Parameters	Numerical value
1	Cooling Capacity	6057 W
2	Power Consumption	1913.1W
3	Suction temperature	9°C
4	Discharge temperature	84°C
5	EER (Energy Efficiency ratio)	3.17
6	Current Consumption	8.54 A
7	Air flow ratio (A/F)	19

Clearly the conditions are not achieved hence changes are required so as to validate the AC Model.

Changed capillary: 1.7 x 850 mm

Results:

Table 4.9 shows the values after capillary changed to 1.7 x 850 mm

S. No	Parameters	Numerical value
1	Cooling Capacity	6177 W
2	Power consumption	1914.5 W
3	Suction temperature	7.7°c
4	Discharge temperature	85°c
5	Current Consumption	8.49 A
6	Air flow ratio	18.55
7	EER (Energy Efficiency ratio)	3.25

Still required conditions not achieved hence changes are required, so the controller frequency is to be increased and the results are shown below:

Change Frequency of controller: 85 HZ

Results:

Table 4.10 Shows the values obtained after controller frequency changed to 85 HZ

Capacity	Power	Suction	Discharge	Current	A/F	EER
6288 W	1975W	7.4°c	85.5°c	8.8 A	18.51	3.18

Hence All Conditions are Satisfied for Full load, so the conditions of the half load test needs to be satisfied so that the model is considered to be validated.

Our requirements for half load:

These are the conditions which are required for the validation of the model

Cap: > 3100 W, **Power:** < 1270W

Half load test:

The initial parameters for the half load test are mentioned below:

Freq: 37 HZ, **ODU RPM:** 1000, **IDU RPM:** 1500

Results:

Table 4.11 Shows the values at 37 HZ controller frequency

Capacity	Power	Suction	Discharge	Current	A/F	EER
3121 W	660.7W	15.7°C	52.6°C	4.65 A	19	4.73

Hence All conditions are achieved so the model is considered to be validated and the ISEER value achieved is mentioned below:

ISEER: 4.22

4.4) Development of 2 ton, 5* model:

Table 4.12 shows the requirements For Full load

Capacity (Greater Than)	Power (Less Than)	R32 Gas
6270 W	2400 W	970 gm

Full load cooling capacity test:

The parameters chosen for the validation of the model is mentioned below:

Capillary chosen – 1.6x750 mm, **ODU RPM** – 1150, **IDU RPM** – 1540

Frequency of controller – 75 HZ

Results:

Table 4.13 shows the results obtained at 75 HZ controller frequency

S. No	Parameters	Numerical value
1	Cooling Capacity	6800 W
2	Power consumption	1535.9W
3	Suction temperature	21°C
4	Discharge Temperature	93.9°C
5	Current Consumption	7.34 A
6	Air Flow Ratio	19.75
7	EER (Energy Efficiency ratio)	4.42

Conditions are not achieved hence changes are required and are mentioned below:

Add gas: 30 gm: $970 + 30 = 1000$ gm

Results:

Table 4.14 Shows the results at 1000 gm gas

S. No	Parameters	Numerical value
1	Cooling Capacity	6900 W
2	Power consumption	1550 W
3	Suction temperature	17.4°C
4	Discharge temperature	84°C

5	Current Consumption	7.45 A
6	Air flow ratio	19.63
7	EER (Energy Efficiency ratio)	4.45

Clearly required conditions are not achieved hence changes are required.

Capillary change to: 1.6 x 850 mm

Results:

Table 4.15 Shows the parameters for 1.6 x 850 mm capillary

Capacity	Power	Suction	Discharge	Current	A/F	EER
7200W	1560W	12°c	85°c	7.45 A	19.55	4.61

Hence All required conditions are achieved and now proceed further for the half load test.

For Half load:

Our requirements – Cap > 3000, Power < 1270, Freq – 33 HZ

Results:

Table 4.16 Shows the values at controller frequency 33 HZ

S. No	Parameters	Numerical value
1	Cooling Capacity	3150 W
2	Power consumption	700W
3	Suction temperature	18°c
4	Discharge temperature	52°c
5	Current Consumption	4.14 A
6	Air flow ratio	19.57
7	EER (Energy Efficiency ratio)	4.5

Hence all conditions are achieved, also ISEER value is ISEER: 4.89

CHAPTER-5

RESULTS & DISCUSSION

A prototype is prepared and the validation of that model as per the specifications of the BEE and R&D team is performed. During their development as discussed earlier in the methodology, many changes were made to meet our requirements and then required results are achieved. Results which are achieved are:

1) RESULT OF HOT AND COLD, 2 TON, 4* & 5* MODEL:

ISEER RATING 3*: 4, ISEER RATING 5*: 4.51

2) RESULT OF 2.3 TON, 4* MODEL:

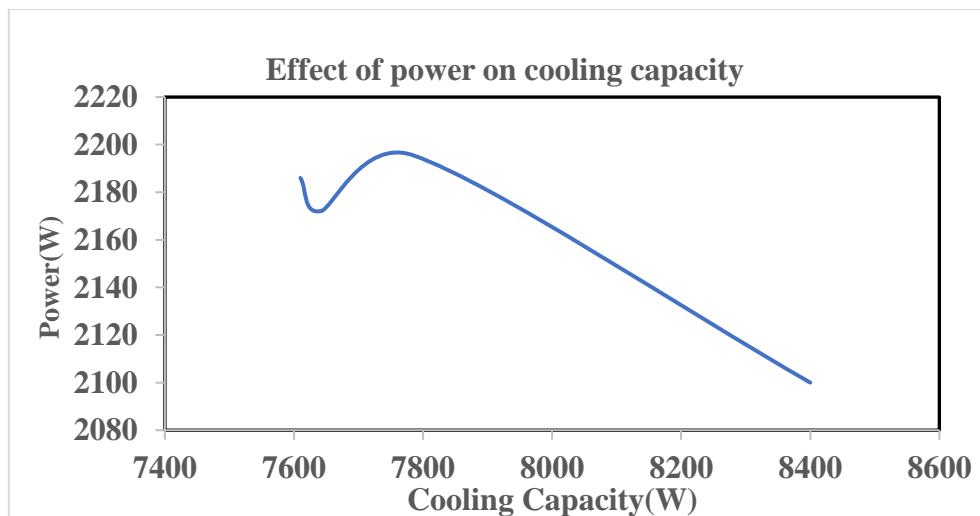


Figure 5.1 Effect of power on the cooling capacity

Figure 5.1 that initially the power input was high and cooling capacity was not as per requirement. So, after the optimization and the changes made in the parameters the power input is reduced and the cooling capacity is increased.

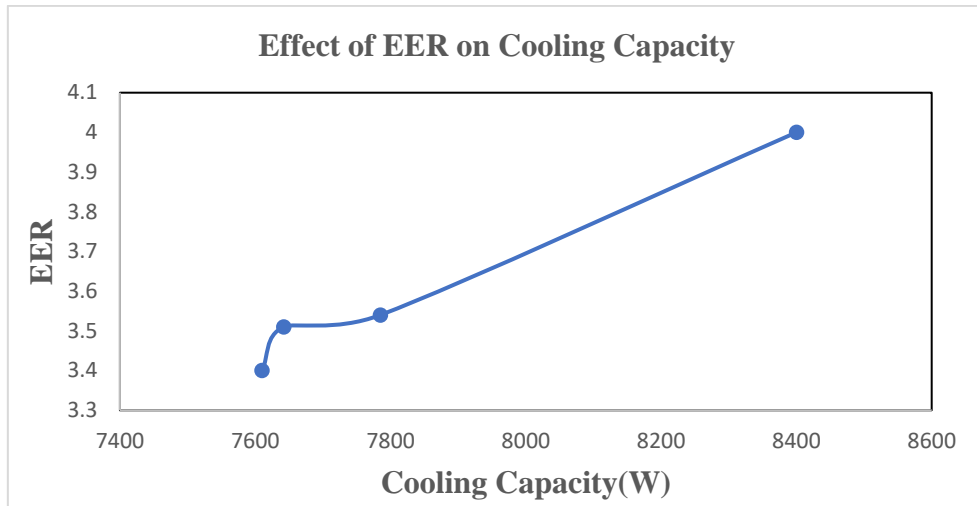


Figure 5.2 Showing the effect of EER on the cooling capacity

This graph shows that the result of optimization is that the EER and the Cooling capacity, both have increasing trend & is exactly our requirement.

ISEER RATING: 4.26

3) RESULT OF 2 TON 4* MODEL:

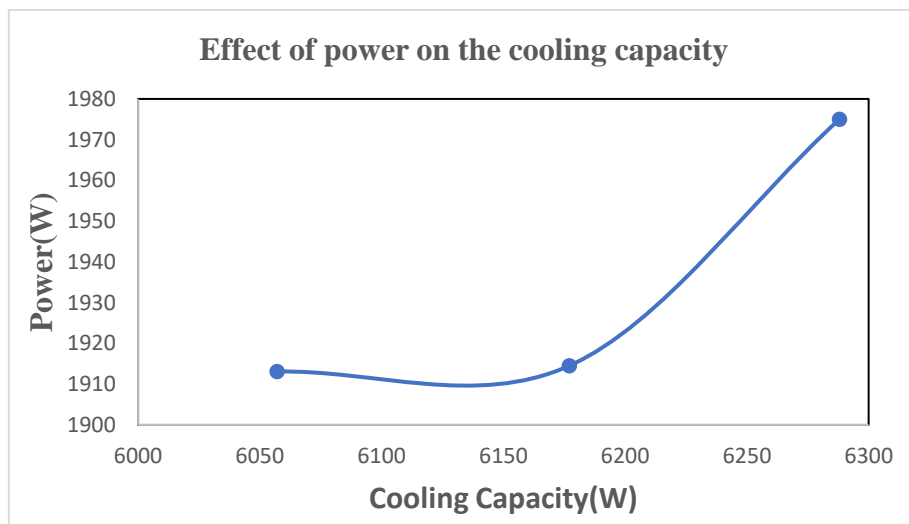


Figure 5.3 Shows the effect of power on the cooling capacity

Clearly it is shown in the graph that initially the power input was high and cooling capacity was not as per requirement. After the optimization and the changes made in the parameters the power input is reduced and the cooling capacity increased.

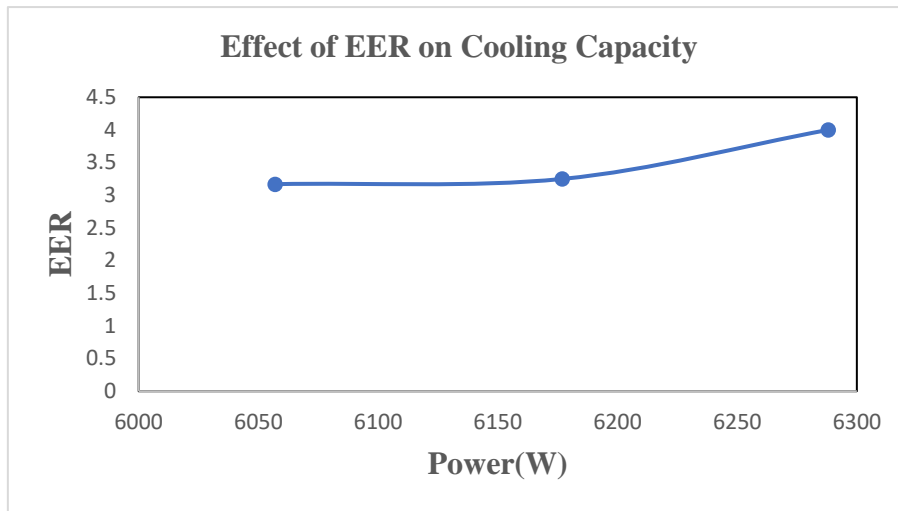


Figure 5.4 Shows the effect of EER on the cooling capacity

This graph shows that the result of optimization is that the EER and the Cooling capacity, both have increasing trend & is exactly our requirement.

ISEER RATING: 4.22

4) RESULT OF 2 TON 5* MODELS:

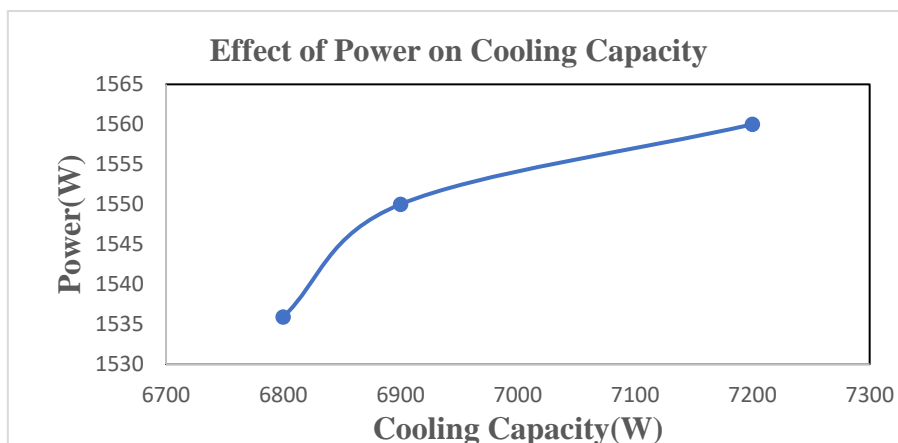


Figure 5.5 Shows the effect of power on the cooling capacity

Clearly it is shown in the graph that initially the power input was high and cooling capacity was not as per requirement. So, after the optimization and the changes made in the parameters the power input is reduced and the cooling capacity is increased.

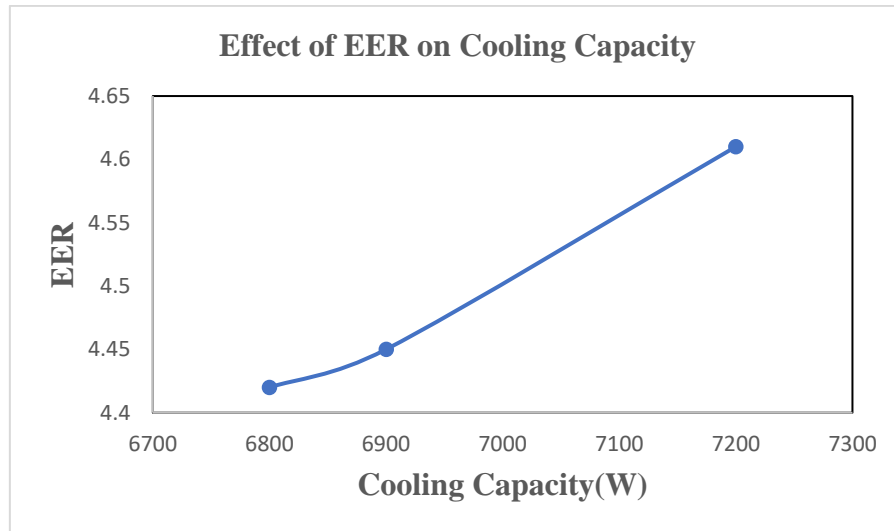


Figure 5.6 Shows the effect of EER on the cooling capacity

This graph shows that the result of optimization is that the EER and the Cooling capacity, both have increasing trend & is exactly our requirement.

ISEER RATING: 4.89

In all the graphs, Initially the power input was high and cooling capacity was not as per requirement. So, after the optimization and the changes made in the parameters the power input is reduced and the cooling capacity is increased. Another graph shows that the result of optimization is that the EER and the Cooling capacity, both have increasing trend & is exactly our requirement.

Outcomes:

- 1) Power Consumption in Hot and Cold, 2 Ton, 4* & 5*AC Model was coming out very high and cooling capacity need to be improved and is achieved by validation.
- 2) First time in India, Panasonic develops 2.3 Ton, 4* AC model. All the required values of cooling and ISEER are achieved by optimization and validation.
- 3) Cooling capacity in 2 Ton, 4* AC model need to be improved and is achieved.
- 4) New Development of 2 Ton, 5* AC model is done and required parameters are achieved.

CONCLUSION AND FUTURE WORK

In this work known as 'Prototyping And Validation of AC', new models of AC are prepared and are validated according to the IS standard specs and the company specs. In order to validate the existing models of AC according to the new star ratings this part plays very crucial role. Also, in case of development of totally new model we have to prepare the proto first and then validate this proto if this proto verifies all the aspects, then the go ahead for this model's production will be given by the R&D team.

- 1) Power Consumptions in Hot and Cold, 2 Ton, 4* & 5*AC Model are coming out 2101 W, 1844 W and cooling capacities are 6500 W, 6600 W.
- 2) First time in India, Panasonic develops 2.3 Ton, 4* AC model. Value of Cooling capacity is 8400 W and ISEER is 4.26.
- 3) Cooling capacity in 2 Ton, 4* AC model is 6288 W and ISEER is 4.22.
- 4) New Development of 2 Ton, 5* AC model is done and cooling capacity is 7200 W and ISEER is 4.89.

FUTURE SCOPE: These AC models can be optimized and validated more effectively by using the more effective types of condensers, compressors, evaporators and expansion devices. More and more work is to be done on the new developments of all the parameters mentioned above. Also new refrigerant needs to be invented which matches all the characteristics of R-32 and will be more efficient than it. Along with that more validation and optimization needs to be done so as to further reduce the power consumption and increase the cooling capacity.

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