Republic of the Philippines
Bicol University
COLLEGE OF ENGINEERING
MECHANCICAL ENGINEERING DEPARTMENT
Legazpi City, Albay

DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS

A Project Study
Presented to the Faculty of Mechanical Engineering Department
Bicol University College of Engineering
Legazpi City, Albay

In Partial Fulfillment
of the Requirements for the Degree in
Bachelor of Science in Mechanical Engineering

RALPH P. ASI
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JEREMIAH E. RAZAL

APRIL 2023

Republic of the Philippines
Bicol University
COLLEGE OF ENGINEERING
MECHANCICAL ENGINEERING DEPARTMENT
Legazpi City, Albay

RECOMMENDATION FOR ORAL EXAMINATION

This Project Study is entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"** prepared and submitted by Ralph P. Asi, Hans Syrill Q. Caponga, and Jeremiah E. Razal, in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering is hereby recommended for final oral defense

ENGR. Agerico U. Llovido, PME, RMP

Adviser

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RESULT OF ORAL EXAMINATION

Result of Oral Examination of the Project Study of Ralph P. Asi, Hans Syrill Q. Caponga, Miles Galilee S. Maglinte, and Jeremiah E. Razal in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering

Title : **DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS**

Date :

Place : Bicol University College of Engineering
Mechanical Engineering Department

PANEL OF EXAMINERS	**ACTION TAKEN**
Chairman:	
ENGR. JOSEPH DEL VILLAR	______________
Panel Members:	
ENGR. NICO O. ASPRA	______________
ENGR. MARY JOY M. ORTIZ	______________

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APPROVAL SHEET

Upon recommendation of the Project Study Committee, this study is entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"** prepared and submitted by Ralph P. Asi, Hans Syrill Q. Caponga, Miles Galilee S. Maglinte, and Jeremiah E. Razal, is hereby approved in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

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ACCEPTED and APPROVED in partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering.

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Dean, BUCENG

ACKNOWLEDGEMENT

We would like to acknowledge and give our warmest thanks to the people who supported and helped us in our work. The study would not have been possible without the following people.

First and foremost, we would like to thank GOD for everything and for blessing us with a sharp mind, healthy body, loving and caring people around us, and the perseverance to keep on going.

To our thesis adviser, Engr. Agerico U. Llovido, PME, RMP, for his continued guidance and support to our study.

To Engr. Nico O. Aspra, for giving us insights on training units and his support to our study.

To the members of the evaluation committee, Engr. Joseph Del Villar, Engr. Nico O. Aspra, and Engr. Mary Joy M. Ortiz, for their shared wisdom and expertise about our subject matter that made a significant improvement to our study.

To Engr. Gerhard-German A. Gaveria, RMP, for helping us improve our trainer design and for his unmatched technical skills on machine fabrication.

To our classmates, for supporting our study and making it possible.

To our parents, for their unwavering support and love. Their efforts gave us the motivation to push through and to keep doing our best every single day.

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CERTIFICATION OF THE ADVISER

This is to certify that all the suggestions, comments, and recommendations of the Adviser and Panel of Examinees had been incorporated in undergraduate thesis entitled, **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"** prepared and submitted by **Ralph P. Asi, Hans Syrill Q. Caponga, Miles Galilee S. Maglinte and Jeremiah E. Razal** in partial fulfilment of the requirement for the Degree of Bachelor in Science in Mechanical Engineering.

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CERTIFICATION OF THE EDITOR

This is to certify that the undergraduate thesis entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"** prepared and submitted by **Ralph P. Asi, Hans Syrill Q. Caponga, Miles Maglinte S. Galilee** and **Jeremiah E. Razal** in partial fulfilment of the requirement for the Degree of Bachelor in Science in Mechanical Engineering, was edited by the undersigned.

ROSABEL AVENGOZA

Editor

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ABSTRACT

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Author(s):	**RALPH P. ASI** **HANS SYRILL Q. CAPONGA** **MILES GALILEE S. MAGLINTE** **JEREMIAH E. RAZAL**
Type of Document:	**Project Study**
Institution:	**Bicol University** **COLLEGE OF ENGINEERING** **Legazpi City, Albay**
Degree:	**Bachelor of Science in Mechanical Engineering**

Machines are one of the best things that men made. It consists of interrelated parts with separate functions with a single purpose that is to do work. Men made machines to make work easier or effortless but in order for a man to make a machine work for him, he must first understand to how do it work and how to make it work. A trainer is machine that allows a person/trainee/student understand how a specific machine works and how to operate it.

This study was conducted for the following purposes: to design and develop an air conditioning trainer using the basic fundamentals of refrigeration systems, to fabricate an air conditioning trainer using a secondhand window-type air conditioning unit as its main components and make it a fully functional as a trainer, to create an appropriate format for the user manual that a person/trainee/student can easily understood the purpose, operation, maintenance, safety and repair of the air conditioning trainer, and to determine its performance based from people's opinion on specific categories.

After the fabrication of the trainer, the PROTOTYPE AIR CONDITIONING TRAINER was subjected to temperature recording and pressure recording to test the trainer temperature and pressure sensor if they were showing accurate data, recording of different parameters in power supply to find out the power consumption of the system, and ambient temperature recording and indoor temperature recording to find the COP of the system. The results of these test showed that the trainer's measuring instruments provides very close to accurate data in temperature, pressure and power supply parameter readings. Also, the clientele satisfaction survey showed that the respondent are satisfied with the trainer's quality, safety, and mobility.

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Chapter 1

BACKGROUND OF THE STUDY

This chapter presents the introduction, statement of the problem, objectives of the study, the scope and delimitation and significance of the study.

Introduction

Heating, ventilation, and air conditioning (HVAC) is a technology that controls the temperature, humidity, and purity of the air in a closed space to provide thermal comfort and acceptable indoor air quality. Air conditioning was widely used in the Philippines to cool industries and buildings, both commercial and residential. According to the Philippines air conditioning market by type 2025, air conditioning is in demand due to the changing tropical weather in the Philippines, as well as rising heat and humidity (IndustryARC, 2023).

The trend shows great opportunity to provide air conditioning services. Student technicians and engineers must be prepared to practice air conditioning services after they accomplish their academic requirements in school.

To be capable of doing air conditioning services, student technicians and engineers must have the knowledge and skills in conduct air-conditioning services and to do that they need to have a hands-on experience on AC servicing. A school laboratory is where students learn to apply their textbook knowledge by using appropriate equipment, tools, machines, and training units. Training units is a machine where a trainee can practice his/her textbook knowledge in an actual machine. To practice air conditioning services and to have further knowledge on air conditioning systems, an air conditioning trainer can help a student learn more about AC systems and servicing.

However, some school laboratory does not have access on specific equipment like training units and one these school is Bicol University, Mechanical Engineering Department.

The design and development of the Prototype Air Conditioning Trainer is made to provide the Bicol University, Mechanical Engineering Department an air conditioning unit that will help students have a hands-on experience on air conditioning systems and servicing. The training unit will help students investigate air conditioning at a basic level where student can use pressure – enthalpy and pyschrometric charts for calculations and for them to discover the enthalpy change.

According to CHED Memorandum Order (CMO) No. 97 Series of 2017, the policies, standards, and guidelines for the Bachelor of Science in Mechanical Engineering (BSME), the Air Conditioning Trainer, Refrigeration Trainer, and Mini Steam Power Plant are required laboratory and equipment apparatus for the ME laboratory. ME laboratory is one of the major subjects in which students should be knowledgeable. It is difficult for students to learn when there is no instructional material that shows the components of an AC.

The air conditioning trainer unit can be used as demonstration and diagnostic unit of air conditioning components at the same time provides data for the determination of theoretical and actual coefficient of performance (COP). This performance can be used to determine the efficiency of a specific air-conditioning unit (Dalisay and Guardian, 2021).

The study aims to design and develop a prototype air conditioning trainer that will satisfy the laboratory equipment needs of mechanical engineering student. Providing detailed information of the training unit, its purpose, valuable learning outcomes, accurate pressure and temperature data, and comfortable space where a student can work. Therefore, the training unit should be able to provide satisfaction to students and to serve its purpose.

Moreover, the design of the training unit is set-up in a base to secure components safety and stability and is easily mobilized as caster wheel are installed to its base. Components were well arranged to help students understand its structure. Measuring devices are well calibrated to give out accurate data that is really important for calculations. Diagrams were well presented to give student's further understanding of what is really happening in a refrigeration cycle, piping system, and wiring systems.

With the assistance of a trainer, the student can apply the theory written in the book to actually gaining knowledge and skills. This could lead to a better understanding of the system's components and how it works. This paper highlights the design, fabrication process, manual, testing of the made prototype, and user satisfaction rating. The statistical treatment is used to evaluate the data collected. The trainer will supplement and improve the department's teaching and learning processes.

Statement of the Problem

This study aims to design and develop a prototype air conditioning trainer for laboratory instructions. Specifically, the study sought answers to the following questions:

1. What is the design of the prototype air conditioning trainer?
2. What is the fabrication method to develop the prototype air conditioning trainer?
3. What is the format of the user manual that can be developed in consonance with the prototype air conditioning trainer?
4. What is the satisfaction rating of the user on the prototype air condition trainer?

Statement of the Hypothesis

H_0: The trainer has no impact on student's satisfaction towards training units

H_I: The trainer has an impact on student's satisfaction towards training units

Objectives of the Study

With the statement of the problem of the study presented in the section above, the thesis intended to execute and meet the following objectives in conducting the thesis.

- To design a prototype air conditioning trainer.
- To fabricate the prototype air conditioning trainer.
- To develop the format of the user manual in consonance with the prototype air conditioning trainer.
- To determine the satisfaction rating of the user of the prototype air conditioning trainer.

Scope and Delimitation of the Study

This study specifically aims to design and fabricate a prototype air conditioning to provide students with a laboratory equipment that would help them understand more about refrigeration cycle. This study also aim to determine the format for the user manual that would aid student understand refrigeration cycle, operate, maintain, repair and install components of the trainer and evaluate the performance of the air conditioning trainer through a clientele satisfaction survey.

It bounds only to proving whether the trainer is:

a. Able to provide a functional air conditioning trainer to student of Bicol University
b. Able to give the learning outcomes needed by the students to understand further about refrigeration cycle

c. Capable of teaching students air conditioning servicing

d. To determine the satisfaction rating of students towards training units

The research is limited only to the design, fabrication, and format of the manuals for trainer will be made by the researchers.

This study is limited to the technical design and operational procedure of the Prototype Air Conditioning Trainer. This trainer would be intended to operate like a window-type air conditioning unit with measuring instruments installed to obtain readings and could be moved without lifting through the use of caster wheels. The performance evaluation is limited only through a clientele satisfaction survey.

Significance of the Study

The study would make some important contributions to engineering specifically in the field of mechanical engineering. If done successfully, the study would give spotlight to alternative air conditioning trainer units as an option in providing affordable yet effective trainer unit for laboratory instructions. It would provide students a hands – on experience on a machine that is key to quality education in engineering. Also, this study would provide a solution to the lack of trainer unit used for laboratory instructions. The findings of this study may provide valuable insights for designing and developing air conditioning trainer for laboratory instructions and not just air conditioning trainer units but also other trainer units. The study would be beneficial to students taking their course in air conditioning and ventilation systems, people who practices air conditioning systems and schools offering mechanical engineering program and practices.

Mechanical Engineering Students. They would learn air conditionings systems in an actual face to face interaction with the machine. Also, students could apply their knowledge in air conditioning systems and practice proper maintenance and safety procedure.

Mechanical Engineering Professors. Air conditioning practitioners could easily taught air conditioning systems to students. They could also taught students proper safety and maintenance procedure.

Schools Offering Mechanical Engineering Programs. Schools could provide their students with a trainer unit that builds an avenue to students to practice their knowledge into application that is key to quality education.

TESDA Training Centers. The trainer unit would be beneficial to TESDA Courses like Refrigeration and Air Conditioning Services NC II. The trainer unit would provide TESDA Trainee an avenue to practice their skills in installation, repair, and troubleshooting of air conditioning units.

The Researchers. The study provides them a place to explore their deep knowledge about air conditioning systems and inner creativeness for the design of the air conditioning trainer. This provides the researcher to practice their craftsmanship for the fabrication, organization of different air conditioning unit components, critical thinking, and discipline to create a prototype air conditioning trainer for laboratory instructions.

Future researchers. This study could be a basis for fabricating other air conditioning trainer units using different air conditioning unit and innovate this idea into a more functional trainer like connecting the trainer to a computer for high speed data collection and computations. Furthermore, this study would help to create a stage for alternative trainer units and provide a solution for unavailability of trainer units for laboratory instructions.

End Notes

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Chapter 2

THEORETICAL AND CONCEPTUAL FRAMEWORKS

This chapter presents the review of literature and studies. Here are literatures that describe the different designs of air conditioning trainer that can be made out of different air conditioning units/components, and the development and study efforts made toward its continued research and development. Also included in this chapter are the synthesis of the state of the art, gap bridged by the study, and theoretical and conceptual frameworks.

Related Literature

According to Hasan's (2013) theory, trainers can be used to achieve competencies because the trainer can be used for training in understanding practice work as happens in the industry. In addition, with that equipment in trainer AC Split R32, the interaction between the teacher and the student can be minimized. So that the teacher can act as a facilitator and the student can understand well with independent or team learning using the provided worksheets and manual books of AC Split R32 Trainer Media. The split AC trainer learning media has advantages compared to previous research, including this split AC trainer learning media can help increase students' competence in the field of air conditioning, Split AC trainer learning media increases student learning motivation, media trainer is very minimalist and easy to push and place, media trainer can be easily disassembled, AC Split trainer learning media can help lecturers in providing practical learning in refrigeration, and air conditioning engineering courses, This trainer learning media has a learning job sheet making it easier to do practical learning, and this media trainer has a user manual so that the user can understand the function and know the specifications of each component.[1]

Tecquipment Ltd. (2022). An air - conditioning trainer unit allows students to investigate air conditioning at a basic level. Students can use P-H charts and psychrometric charts for their calculations and discover the enthalpy change. The unit features an air-cooled condenser unit connected to an evaporator located in an air duct. The air duct contains relative humidity and temperature sensors on both sides of the evaporator. A small fan provides air flow down the duct and can be manually adjusted. The refrigeration circuit features high and low pressure gauges, a pressure switch, sight glass, filter dryer and TEV valve. The circuit also includes pressure transducers that connect to the instrumentation. Four thermocouples placed around the refrigeration circuit allow observation of temperatures, these can be used for the calculation of potential superheating and sub cooling.[2]

Aswardi, Nellitawati, Ihsan, A. (2019) stated that the purpose of using trainers in schools is to make it easier for students in the learning process and can fulfill learning goals. The role of the trainer as a learning media has a significant influence on students, making students active andcreative in the learning process. They made an electric circuit media trainer to assist teachers in teaching Basic Electrical and Electronics subjects at SMK Negeri 1 Tilatang Kamang, a school in Indonesia.[3]

F. Bagheri (2016), stated that the Coefficient of Performance of Vehicle Air Conditioning and Refrigeration systems is generally low. The experimental and theoretical evaluations of this study also show a relatively low Coefficient of Performance for the current battery-powered anti-idling Vehicle Air Conditioning and Refrigeration system. Accordingly, the aim is to build a proof-of-concept demonstration of a high efficiency Vehicle Air Conditioning and Refrigeration system equipped with a variable speed compressor and variable speed fans that operates with the optimization-based proactive controller. A comprehensive investigation into the available high efficiency two-phase heat exchangers and variable speed compressor and fans in the market is the first step towards building the high efficiency system. As such, a high efficiency fan (variable speed), a high efficiency compressor (variable speed), an evaporator coil, and a condenser coil are purchased from reputable manufacturers with proven high efficiency products and the new Vehicle Air Conditioning and Refrigeration system is assembled. The new high efficiency Vehicle Air Conditioning and Refrigeration system is then equipped with a proactive optimization-based controller to represent a proof-of-concept demonstration.[4]

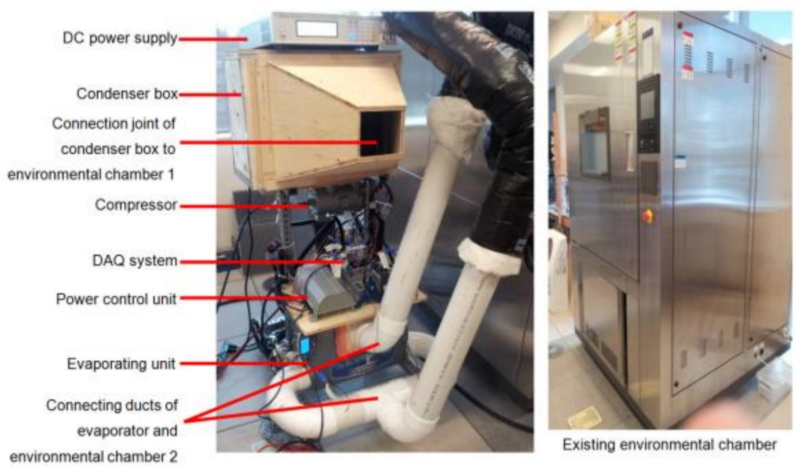

Figure 1. Vehicle Air Conditioning and Refrigeration System

A. Ademola (2019) stated that an air conditioning trainer kit is a practical technique to familiarize individuals with adequately maintaining and operating air conditioning units. The setup typically includes an air conditioning unit, a set of training materials, and an instructor. The kit is best to provide a realistic environment for students to learn how to properly service and repair air conditioning units. The air conditioner trainer kits simulate trainees' conditions when working with natural air conditioning units. It contains manual equips step-by-step instructions on suitably establishing and preserving air conditioning units.[5]

Figure 2. Commercial Air Conditioning Trainer

Samonte, F. and Torres, R. (2013). The necessity of laboratory equipment for quality instruction has encouraged researchers to develop car air-conditioner trainer. This study sought to: 1) assess trainer's acceptability and validity in terms of its design, construction, function, safety and relevance; 2) evaluate performance of experimental class with pre-test and post-test results using the trainer; and 3) compare the model price with other car air-conditioning trainers. Using statistical mean, the results revealed that the trainer is excellent based on the criteria set; thus, it is essential tool, and ready for use to facilitate actual learning experiences. The model was accepted and validated by the respondents from three technical schools. Evaluation of experimental class using t-test showed significant difference with pre-test and post-test computed value compared with tabular value; hence, the model is effective tool for learning process. The developed trainer is more affordable up to eight percent than a commercial trainer, a big savings without sacrificing quality of training for students. From the conclusion, larger size motor is recommended to drive compressor easily; electronic module to supplement the trainer should be developed relative to the demand of industry and TESDA standards; and instructors are encouraged to develop trainers to enhance teaching and learning process.[6]

Figure 3. Refrigeration Cycle

In the Design of a Laboratory Unit Air-Conditioning System of N. Kocyigit and M.E Sahin, where they created a HVAC laboratory unit which was used for training the students and the technical staff, can perform heating, cooling, humidifying and dehumidifying. The HVAC laboratory unit has a boiler with three electrical resistances for humidifying, a variable air volume blower (fan), two electrical resistances for preheating, a vapour compressed refrigeration system for cooling and dehumidifying, and two electrical resistances for final heating. The picture of laboratory HVAC system and its simplified scheme are shown in Figures 1 and 2, respectively.[7]

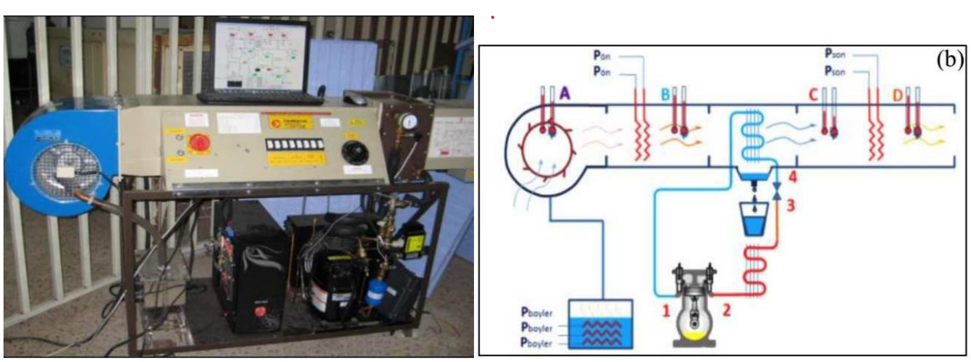

Figure 4. HVAC Laboratory Unit

Related Studies

Thermodynamics is one of the more difficult subjects, according to Bluestein (N.D.) of Indiana University-Purdue University, Indianapolis' Mechanical Engineering Technology department. Because refrigeration and air conditioning (RAC) systems are difficult to obtain and solve in thermodynamics, laboratory equipment development has simplified the process of providing the necessary data and observing how components function. The concepts of an AC trainer, according to Sudarsono (2018), can take the form of cutting components and installing them on a board, or it can be a live trainer that shows the process in each state. This medium will aid comprehension by presenting the components in their natural state. Lectures alone are insufficient to meet the needs of students. As a result, actual performances always replenish technical knowledge and skills.[8]

Figure 5. Trainer in Sudarsono (2018)

In Sudarsono (2018) conducted a research and development methods study to determine the feasibility of learning media air conditioner systems (AC). The research method includes the following steps: (1) potential and problem identification; (2) information gathering; (3) product design; (4) design validation; (5) design improvement; (6) product trialing; (7) product revision; and (8) test usage. The study group is made up of fourth-semester students from Muhammadiyah University of Purworejo's Automotive Engineering Study Program. A questionnaire and a test for validation were used as research instruments. It also uses interview and observation methods to collect information on media usage in the AC system. Figure 1 depicts the study's actual learning media. During the development stage, the material and media experts' validity was approximately 75%. When the system was used, the experimental group's results improved by 79.20, and the control group's results improved by 67.20. This suggests that AC's learning media are usable and can significantly improve learning outcomes.[9]

Yunesman et al. (2021), the unemployment rate in the province of Riau Islands is very high, with issues of poor work ethics and skills that are deemed adequate. In his research, he demonstrates the effectiveness of trainer simulator air conditioning in a vocational high school. For the experimental and control groups, a quasi-experimental design was used, with pre- and post-tests administered to students enrolled in the air conditioner course. Improving skills, academic knowledge, and personal qualities are among the working principles. The ability to find work is a person's employability skill. As a result, simulator training outperforms work-oriented training when it comes to developing employability skills.[10]

Air Conditioner Types

Dahlkvist (2013) states that the type of air conditioner unit used depends on the user's purpose and demand for both residential and commercial use. Figure 2 depicts the various types.

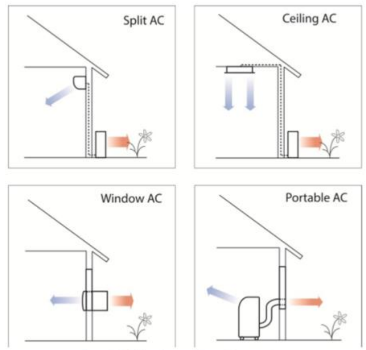

Figure 6. Different types of air conditioning system

Split air conditioners are divided into two parts: the indoor unit and the outdoor unit. The evaporator and one fan are located inside, while the compressor, condenser, and another fan are located outside. This is said to be the most widely used type on the market. The ceiling unit (cassette AC) is another unit that resembles split AC in that it has an outdoor unit but the indoor unit is located at the room's ceiling rather than in the wall.

Window air conditioning is a unit that is obviously mounted in the window. Inside the unit, the components can be seen, but they are separated. In this study, this type of ACU will be used for the trainer. A portable air conditioner's components, on the other hand, are compacted as one, but the unit is flexible enough to move to areas where a cooling system is required without extensive installation. It is an indoor unit that needs an exhaust air outlet to remove heat, and the exhaust air hose is usually connected to the outside of the room via a window.[11]

Refrigerant

Srinivas (2020) evaluated the performance of an air conditioner system using R22, R134a, and R410a refrigerants. The trainer used in the study is a duct type, as shown in Figure 3. T1 is at the compressor inlet, T2 is at the compressor outlet, T3 is at the condenser outlet, T4 is at the expansion device outlet, and T5 is the ambient temperature. A wet-dry bulb is also installed at the duct's inlet and outlet. Temperature and pressure readings are taken during the experiment and used in the computation. As a result, the carnot coefficient of performance of R22 is half of its theoretical COP, the theoretical COP of R134a is nearly equal to its carnot COP, and the carnot COP of R410a is nearly 70% of its theoretical COP. When it comes to performance, R22 is superior but contributes more to global warming, while R134a is less desirable. R410a is a better R22 replacement, and its refrigeration effect is greater than the other two refrigerants tested. R-22 is a hydrochlorofluorocarbon (HCFC) refrigerant that going to phased out due to its ozone depletion potential (ODP).[12]

Figure 7. Duct type air conditioner

Another study in Papade (2015), investigated the performance of an air conditioning system with and without a nanorefrigerant using R134a, a common refrigerant used in household refrigerators and air conditioners. Heat transfer is poor because it is undesirable and consumes a lot of power. As a result of its improved thermophysics, the nanoparticle increases heat transfer while decreasing power consumption. The nanoparticles are added to the lubricant (compressor oil) in the AC system, and when it is circulated, the system has a nanolubricant-refrigerant mixture. Aluminum oxide is the nanoparticle used. Before using refrigerant, the system was subjected to leak testing, which was accomplished by charging the system with nitrogen at a pressure of 200 psi. After the experiment has been checked, it is launched. The experimental studies show that having nanorefrigerant in the AC system still works normally. When POE oil was replaced with a mixture of POE oil and Al2O3 nanoparticles, performance increased by 14% while power consumption decreased by 20%.[13]

Self-Contained Mobile Air Conditioning Trainer

In Bluestein (nd), two senior students from the Mechanical Engineering Technology department created the specifications and laboratory experiment for the trainer, which was built at the Carrier Corporation in Indianapolis, Indiana. The components shown in Figure 4 on the right side and the actual on the left side were mounted on the trainer's 6-foot-by-3-foot wheeled cart: condenser, evaporator, compressor, expansion valve, and fan coil unit.

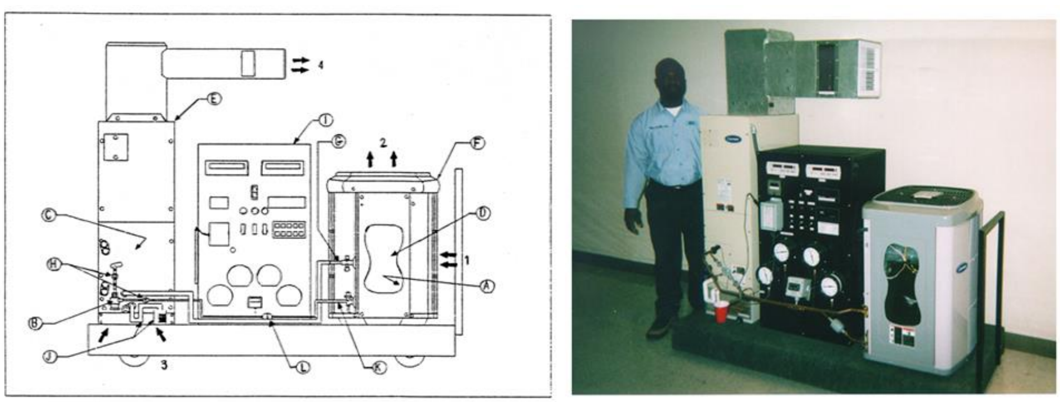

Figure 8. Trainer in Bluentein (n.d)

The process began at the fan coil unit's base (position 3), where air enters and is cooled as it passes through the evaporator coil (C) and exits through louvers. R-22 was used in the system, which passed through the evaporator coil and flowed through the suction line (G) to the compressor (D) on the outdoor unit (F). The compressed gas is discharged from the compressor and enters the condenser (A). The condensed liquid flows from (K) to the expansion valve (B), where the pressure drops and it enters the evaporator. Moisture condensed from the conditioned air is collected in a cup or basin (J).

In the center panel (I), pressure taps and thermocouples were installed to provide a correlation to the pressure-enthalpy (p-h) diagram that will be used to analyze its performance. The refrigerant pressures are available at the expansion valve's exit and entrance, as well as at the compressor's exit and entrance. The equipment includes a pressure-enthalpy diagram and a table of R-22 properties. A 220 volt power supply is used to power the air conditioner trainer. The trainer has been installed and is being used in the school's laboratories; it costs about $7,000, or 387,632 pesos.[14]

Portable Air Conditioner

Dahlkvist (2013) created a thesis on the fabrication of portable air conditioners in order to investigate the potential opportunities. The mechanical design process is used, which includes product discovery, project planning, product definition, conceptual design, product development, and product support. The study is both quantitative and qualitative, and it is primarily conducted in North America and Australia. It employs an Electrolux survey, an internet-based survey, and an interview. As a result of the discovery that the majority of existing portable air conditioners are large, difficult to handle, noisy, and inefficient, the components in this study are identified, explained, optimized for the new design, and assembled revolving around the center of the cylinder, as shown in Figure 5. It was a successful proposal, and the finished product was thought to stand out among existing portables.[15]

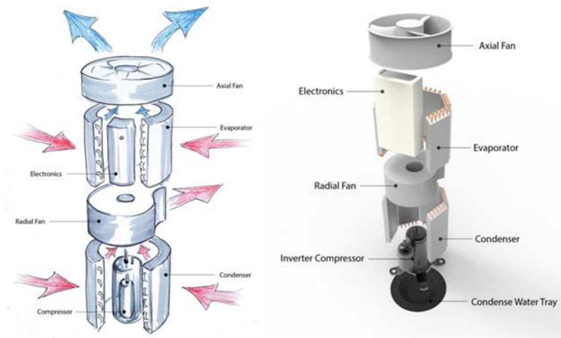

Figure 9. Portable Air Conditioner Unit

Split Air Conditioning Unit Trainer

Ismail (2021) carried out research to create an experimental rig to assess the performance of an air conditioner. One of its goals is to use a split-unit air conditioner trainer to assess the performance of both R-22 and HC-22 refrigerants. Following comparisons of several models that include planning, design, analysis, evaluation, and development, the virtual prototype model was chosen. The isometric drawing was showcased with the Solidworks 2019 software. Measuring, cutting, drilling, finishing, screwing, welding, assembling, and installing are all steps in the manufacturing process. The case rig is made of low-carbon steel, the wheel is made of stainless steel, the pipe is made of copper, and the air duct is made of aluminum. Some changes were made during the manufacturing process, as shown in Figure 6. The common arrangement of trainers is on the right, and the modification design is on the left. Modification includes moving the outdoor unit and installing an air duct around it to prevent hot air from entering the indoor unit is one of them.

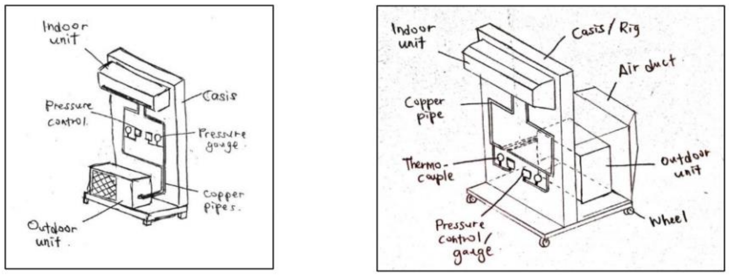

Figure 10. Modification design of the trainer in Ismail 2021

The parameters involved are pressure and temperature, which are located according to the process flow. Temperature is measured using K-type thermocouples that are spot welded. The refrigerant pressure is measured using pressure gauges. P1 is installed at the evaporator outlet, while P2 is installed at the condenser inlet. The study's objectives were met by the trainer.[16]

Another study employs split unit air conditioning as a trainer is in in Ningsih (2021) to serve as learning medium in the cooling and air conditioning engineering course at Universitas Sultan Ageng Tirtayasa's Electrical Engineering Vocational Education Faculty of Teacher Training and Education. In the research and development method, the SAM-1 (Successive Approximation Model 1) was used. This model depicts a clear stage of successful development in which everything is targeted in order to achieve the desired result. The model goes through three iterations, the first two of which are the processes of evaluating, designing, and developing. The product is evaluated and implemented in the third iteration. It collects data using instruments such as observations, interviews, and questionnaires that use a Likert scale for measurement. The expert panel consists of two instructors and one technician with experience in refrigeration and air conditioning.

Figure 11. Trainer in Ningsih (2021)

The CorelDraw 2019 application was used for the design in the study. The acrylic board, as well as the components, electrical system, and piping shown in Figure 7, were installed in an iron frame. The trainer is then put to the test. Another goal of the research is to create a job sheet for the introduction of split AC using information from book sources, which includes the components, materials in electrical and piping installation, and other materials that have a connection.

The results obtained after distributing questionnaires to the instructor and a small number of students who had used the system The study's final product is an AC split trainer with dimensions of 105 cm (l) by 180 cm (h), as well as the job sheet and manual book. The media trainer is highly qualified because the job sheet facilitates practical learning and the trainer has a manual that explains the function and specifications of the components.[17]

Window Air Conditioning Unit

Thippeswamy (2021) studied the window air conditioning unit in the trainer for experimental performance. For small-scale use, the fabricated trainer is built to the size of an industrial window air conditioner. The cooling chamber measures 59mm x 69mm x 59mm and is made of mild steel plating and 59mm x 69mm fiberglass. A 0.5-ton compressor, a thermostat, a temperature indicator with a 120-degree display, capillary tubes with diameters ranging from 0.5 to 2.28 mm, and a condenser and evaporator are all part of the system. The equipment is first tested without load, and then the cooling chamber is heated with two 60-watt and two 200-watt four-filament bulbs. Figure 8 depicts the experimental configuration of the window air conditioning trainer. Six thermocouple wires are installed in the equipment: one at the condenser inlet, another at the condenser outlet, a third at the evaporator inlet, a fourth at the evaporator outlet, a fifth at the cooling chamber temperature, and a sixth at the ambient temperature. These thermocouple wires are k-type, measuring up to 2800 degrees Celsius with an accuracy of 2.5% to 0.75%. The research focused on calculating theoretical COP, actual COP, Carnot COP, and system capacity, as well as evaluating performance parameters. The system was discovered to be capable of producing and maintaining different load conditions in the psychrometric test chamber during the experimental and computational phases. It is discovered that the experimental setup can generate the EER and validate the Bureau of Energy Efficiency's star rating.[18]

Figure 12. Trainer in Thippeswamy (2021)

According to Ismail (2020), providing quality education in Technical and Vocational Education and Training (TVET) institutions creates a high-income economy. In his study, he fabricated a Smart Window Air Conditioner Training Kit to aid in teaching practical skills in the field of refrigeration and air conditioning. It was created using the Analysis Design Develop Implement Evaluate (ADDIE) model, which consists of five stages: planning, design, implementation, and testing. The frame was designed to be 2 feet by 2 feet by 13 inches in size, made of 1.5 inches by 3 millimeters angular iron and 2 inches by 5 millimeters flat iron, and welded with a 2.5-mm arc type and rod welding. Figure 1 depicts the configuration, with the electrical wiring on the left side. Components such as compressors, condensers, evaporators, and fans are installed using self-drilling screws. Gas welding is used to join copper pipe and other plumbing components, such as pressure gauges and service valves.

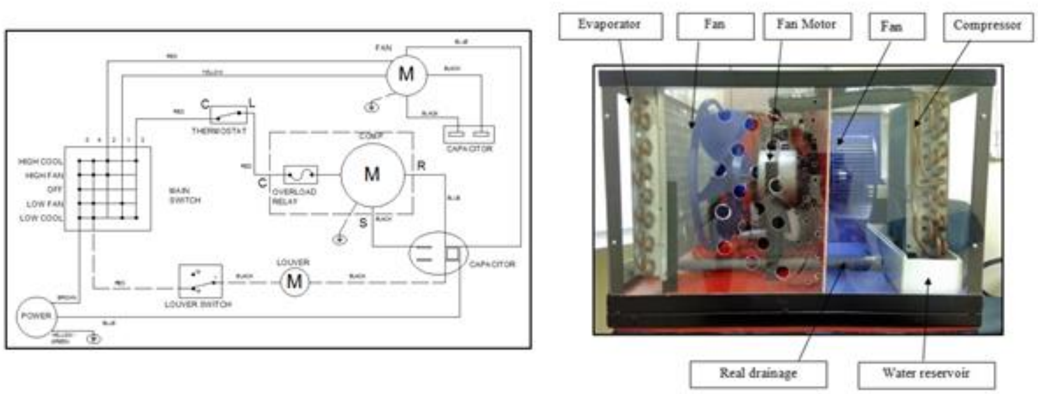

Figure 13. Electrical wiring and trainer in Ismail (2020)

The trainer was evaluated in the laboratory by experts with industrial experience and teaching experience in HVAC using questionnaires on its functionality and usability. For their training session, 20 vocational students experienced and tested the final product. The trainer, according to the respondents, is simple to use, saves space, is safe to use, and can be used as a teaching aid. The study's mean value is M = 4.48 (SD = 0.53), indicating that the training kit is appropriate for vocational students. The bill of materials includes size and quantity, and it costs RM1303 (equivalent to 16,523 pesos), saving thousands of pesos and helping students.[19]

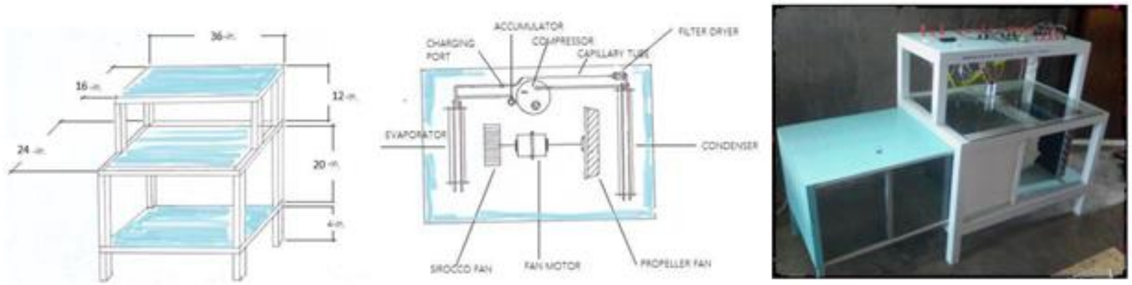

Figure 14. Trainer set-up in Dalisay et. al (2021)

In Dalisay et. al (2021) made a study to aid lacking of instructional material in the mechanical engineering department that needs to provide core knowledge and skills. The researchers used a window-type air conditioner trainer modified with a glass box simulation for the cooling area shown in Figure 10 to conduct a study with mechanical and agricultural engineering students at Romblon State University. It is made up of eight parts: the control panel board, the frame, the compressor, the evaporator, the condenser, the pressure gauges, the fan motor, and the testing room. The system employs R-22. The hermetic compressor used has a capacity of 12 horsepower. Metering devices and an electrical port were added for parameter and experiment activities. The study took temperature and pressure readings before and after cooling the controlled area, calculated the coefficient of performance (COP), and measured the power consumption (kW/hr.) of the trainer unit. The system's coefficient of performance (COP) is 3.2 for an indoor temperature of 24 degrees Celsius and an ambient temperature of 31.5 degrees Celsius, the highest value among the trials conducted, according to the results of the performance tests. It is more efficient in terms of air conditioning performance. The computed price for power consumption is P125.76 per day if the ACU power consumption is P5.24 per hour and the TIELCO prevailing price is P12.50 per KWhr. The developed unit, which costs P48, 500.00, can be used as a model to simulate the actual cooling environment of a window-type air-conditioning unit and thus as a tool to improve students' classroom learning.[20]

Synthesis of the State of the Art

This part of the chapter aims to summarize the review of the related literature and studies with the bearing on the study.

From the related literature that the researchers have gathered, the use of air conditioning trainer for laboratory instructions were significant to the learning process of an individual about the topic air conditioning system and refrigeration systems. Along with its use on laboratory practices, different designs of the trainer were developed and fabricated that varies depending to what kind of HVAC system does an individual needs to understand and to learn.

Studies provided impacts of different air conditioning unit to individuals who are studying air conditioning systems and refrigeration systems, results showed that individuals are more engaged on learning the topic thus it greatly improved their learning process, work ethics, and skill.

For different air conditioning trainer designs, refrigerants were put to a test to find out which refrigerant greatly affects the performance of the trainer unit positively. Both refrigerants were introduced to the system and tested both for system COP. Design of air condition trainer unit were evaluated by its COP, system capacity, and its performance parameters.

The review conclusions suggest that there is a continued pursuit for the design and development research on more efficient and highly performing air conditioning trainer.

This led to the researchers to make a unique, more efficient, and cost-effective air conditioning trainer that has the capability to deliver close to accurate data readings from measuring instruments and provide individuals a learning area where they can practice their textbook knowledge

Gaps Bridged by the Study

The gap identified in the synthesis of the art is on the application of refrigeration to theory to a machine. There has been little study found that explores the application of refrigeration theory to a machine. The prototype air conditioning trainer unit comes with a user manual and it contains the operation, maintenance, installation, and repair procedure of the trainer and its components.

Theoretical Paradigm

This study was guided by the theories of air conditioning theory, constructivist learning theory, and expectation confirmation theory.

The study's title alludes to the Air Conditioning Theory. In Electronoobs. (2021), an air conditioner has the same cooling effect as a refrigerator; the only difference is that the air conditioner lacks the exterior housing to enclose the cold ice water and instead relies on walls to bring down the high indoor temperature. Air conditioners use refrigerants to lower the temperature of the room, which go through phase changes (from liquid to gas) in the evaporator and absorb heat. The fan circulates air over the coils, dispersing the cold temperature in the room. To keep the cooling system running, the compressor will pressurize the refrigerant back into a liquid. The extra heat generated during compression will be expelled outside by the condenser coil and the second fan. As the gas cools, it condenses back into a liquid, and the process begins again. Figure 1 depicts the operation of the air conditioning system.[21]

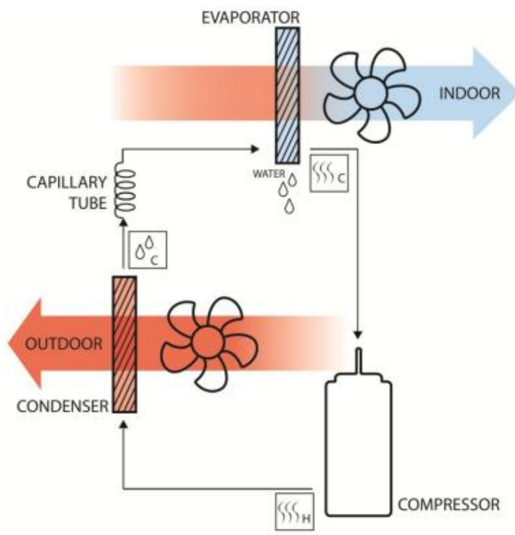

Figure 15. Air Conditioning Theory

Knowledge, according to Kurt (2021), is constructed through experiences, and constructivist learning theory focuses on individuals' learning journeys. When events occur, people will reflect on and integrate new ideas with their prior knowledge, resulting in a new understanding that will serve as their new foundation. The instructor or knowledgeable person and students share equal authority and responsibility for manipulating the material presented in a constructivist classroom, where the students and instructor share information about what they observed and discovered as they manipulated the material.[22]

The concept of air conditioning should be understood by TESDA trainees, mechanical engineering students, and others involved in this field. The AC trainer and laboratory manual compensate for the lack of this instructional material by demonstrating and generating an experience or showcase of what is written in the context of books. Based on what they know and understand, the individual will reconstruct their knowledge.

The design, according to Expectation Confirmation Theory, influences the actual taste of the product (Wetzel, 2019). Everything they see on the package contains factors that influence their perception and taste. People have many different expectations, which are validated by taste. It will obviously taste great when someone understands the product is good and serves its purpose; otherwise, it will not. It is the customer's satisfaction or dissatisfaction as a result of performance that is about to be compared to a predetermined performance standard. If a product outperforms expectations, customers will be pleased. The customer is likely to be dissatisfied if a product fails to meet expectations. The trainer will be turned into a product. This theory will serve as the foundation for a student survey to determine its rating in this study. The theoretical paradigm of the study was presented in Figure 2 by a systematic block diagram.[23]

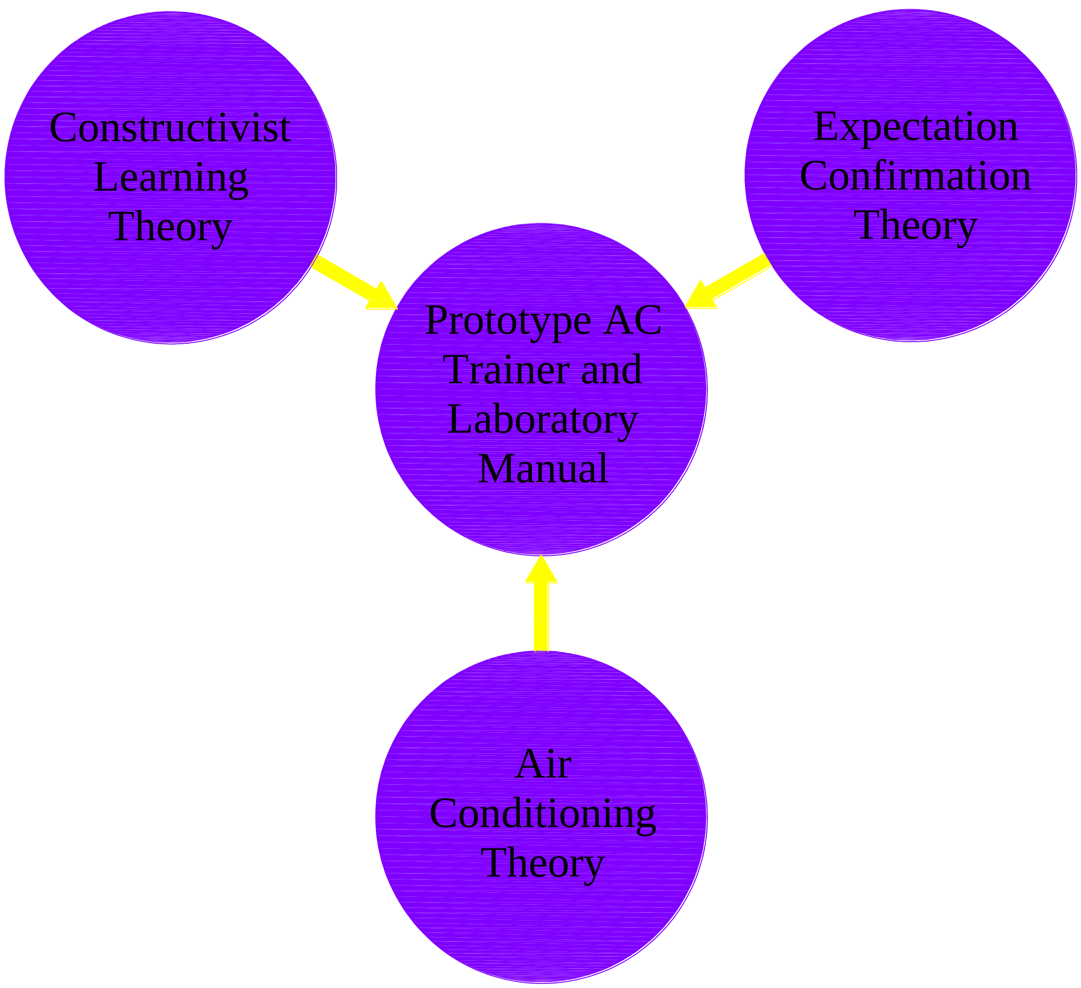

Figure 16. Theoretical Paradigm

Conceptual Framework

Inputs are items or pieces of information that are fed into a system in order for it to function. In this study, the inputs are divided into two categories: soft input and hard input. The soft input consists of theories or data derived from related literature and studies, which can be found more easily on the internet, as well as creative design ideas. Because of their research experience, this is the most efficient way to incorporate previous research findings into this study. The tangible material is the hard input, which includes the materials, tools, and equipment that will be used to build the trainer.

In the process, the researchers collaborate to create the concept design and will consult with expert professors and other individuals to improve its construction. The researchers will canvass all of the material needed in various stores to find what is economically viable. Following the completion of the trainer design, the product will be fabricated by a machinist expert along with the planned design.

When the device is finished, the researchers and adviser cooperate to test its functionality. After testing, the researchers and adviser have their comments; suggestions serve as a guide for the trainer's improvement and development. The researchers will also survey identified respondents for client satisfaction ratings.

In the output stage, the researchers finished building and creating the prototype AC trainer and laboratory manual. The researchers make sure that the study was beneficial and that the safety of future users will be ensured by the safety precautions.

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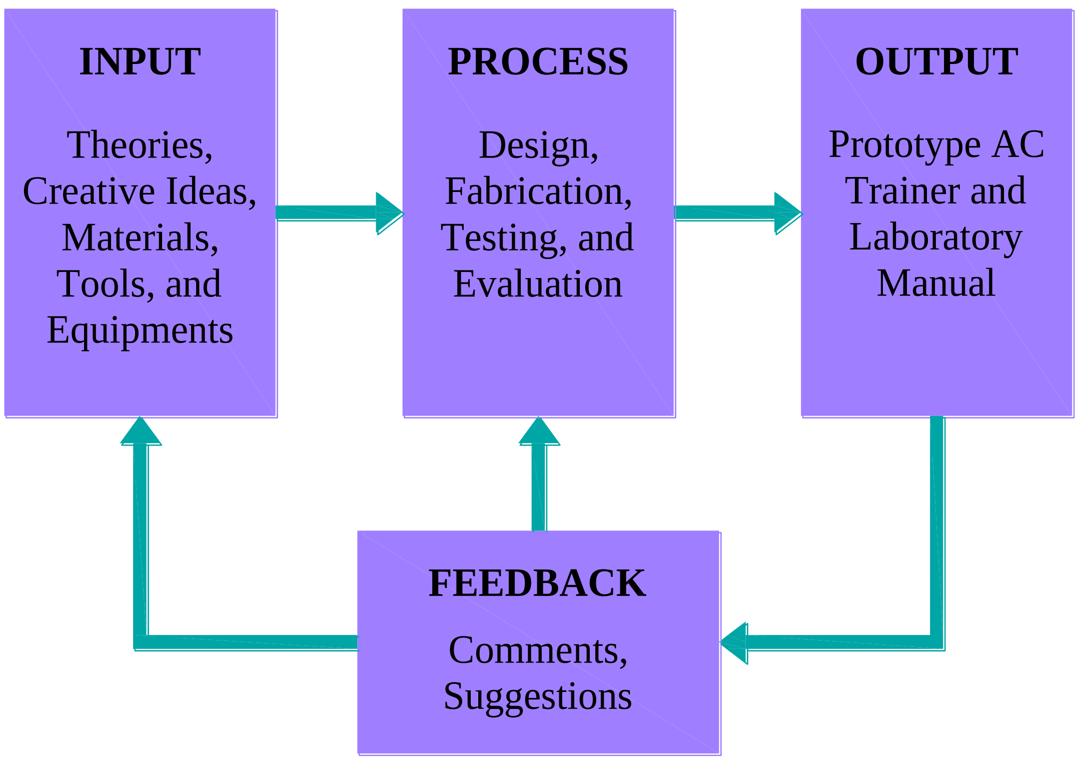

Figure 17. Conceptual Framework

Definition of Terms

Compressor - a pump or other machine for reducing volume and increasing pressure of gases in order to condense the gases, drive pneumatically powered machinery, etc.

Condenser - A condenser is an essential component within any HVAC system. Its purpose is to take in high-pressure refrigerant gas, emitted by the compressor, and convert it into liquid state.

Expansion Valve - devices used to control the refrigerant flow in a refrigeration system.

Evaporator - part of an air-conditioning system that removes heat and moisture from indoor air to cool it.

Vacuum Pump - a piece of equipment capable of generating a partial or low-pressure vacuum by pushing gas or air molecules out of a sealed chamber.

Manifold gauge - A chamber device that is used to control the flows of pressure or gases.

Circuit Breaker - an electrical safety device, a switch that automatically interrupts the current of an overloaded electric circuit, ground faults, or short circuits.

R22 Refrigerant - (also known as R22 freon and HCFC-22 freon) is a chemical used in both air conditioners and heat pumps to cool your home.

Digital Temperature Sensor – an electronic device that measures the temperature of its environment and converts the input data into electronic data to record, monitor, or signal temperature changes.

High Side - side of system which includes vapor into condenser and liquid to expansion valve**.**

Low Side - That portion of system from orifice in expansion valve through evaporator line or lines through compressor service valve to compressor reed valve.

Phenolic Board - a plate that has a resin core that has high-density and thermosetting cellulose fibers. They have a special coating that protects them from moisture.

Control Panel - an enclosure, typically a metal box or plastic molding which contains important electrical components that control and monitor a number of mechanical processes.

Multi-function digital meter - an electrical instrument installed in panels; this device measures various electrical parameters such as voltage, current, power factor and active power. A multi-function meter is usually involved in settings which require an exact, reliable measure of electricity.

Weighted Mean - The weighted mean is a type of mean that is calculated by multiplying the weight (or probability) associated with a particular event or outcome with its associated quantitative outcome and then summing all the products together.

User Manual - detailed information around operations, standards & guidelines, troubleshooting guides, functionalities & more.

Enclosure - an area that is sealed off with an artificial or natural barrier.

Wiring system – a network of wires that connect various accessories for the distribution of electrical energy from the supplier meter board to a variety of electrical energy consuming devices.

Piping system – network of pipes, fittings, and valves intended to perform a specific job (i.e. to carry or transfer liquid/vapor from one equipment to another).

End Notes

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CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter presents the research design parameters, materials and set - up, procedures, data collection, and statistical tools and analysis used in the study.

Research Design Parameters

The researchers employed two research methods in the study: the research and development method and the descriptive method (qualitative approach). According to Dowsett (2023), research and development (R&D) are widely used for business development. The process of exploring new ideas, methods, and technologies in order to create new products, services, or a solution to improve existing ones is most likely an innovation. R&D is divided into three categories: basic research, applied research, and experimental development. This study aims to develop an air conditioning trainer to meet the needs of the students through the development of prototypes; using experimental development under R&D. Mulyana (2016) defines research development as “a process or set of steps to develop a new product that already exists." In which all variables in the study are defined, as well as the statistical analysis process of the study and the instrument validity section, as well as the overall research.

In this study, the processes under the Research and Development (R&D) experimental method served as guides for the researcher in developing the air conditioning trainer. The descriptive research method was used to evaluate the finished prototype in terms of functionality, mobility, and safety by the selected respondents using a questionnaire. The performance of the trainer was evaluated by researchers and experts based on actual observation and calculation of the read temperature and pressure. The collected data is statistically analyzed for quantitative and descriptive interpretation. Qualitative research was applied in every step of this study, from obtaining the evaluation of the gathered data.

The parameters was used as the basis for the design and development of the trainer, which are discussed below:

PARAMETER 1: Design of the Prototype Air Conditioning Trainer

The design of the prototype air conditioning trainer was based on the integration of the wiring system, piping system, enclosure, and the table.

Step by Step Procedure:

1. Designing and creating the parts of the trainer
2. Consulting the adviser/fabricator
3. Assembling the parts according to the design

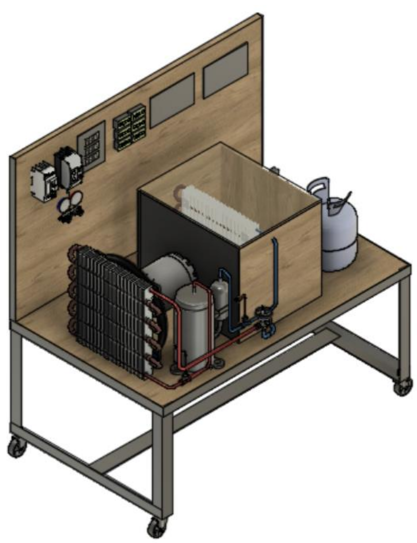


Figure 18. Computer Aided Drawing of the Prototype Air Conditioning Trainer

PARAMETER 2: Design of the Wiring System

Design of the wirings system was based on the air conditioning unit's existing wiring system. A circuit breaker was connected to prevent the system from overloading. A multi-function meter was also installed to observe electrical parameters.

Step by step procedure:

1. Designing the wiring system of the trainer
2. Consulting the adviser/fabricator
3. Implementation of the design

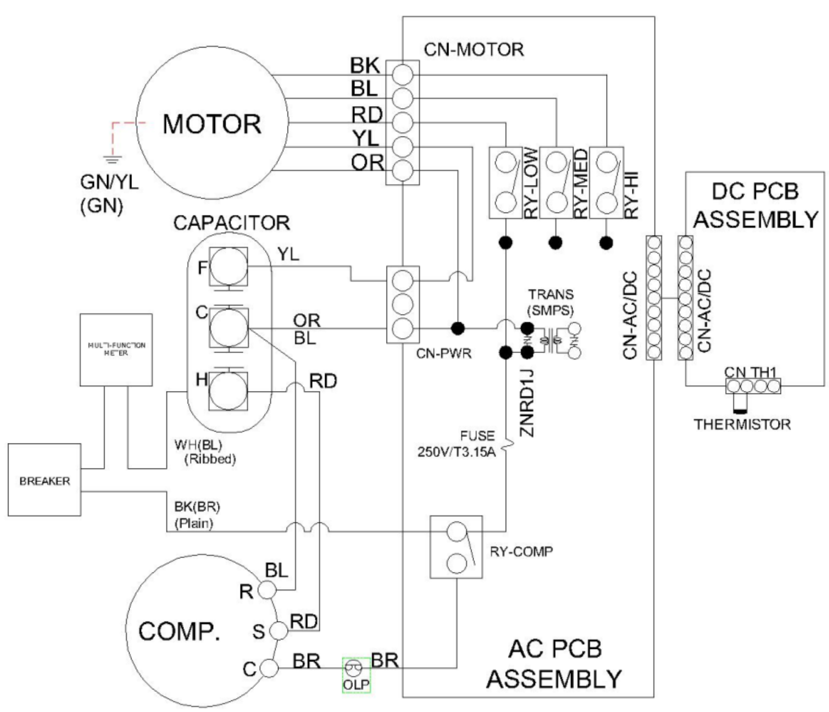


Figure 19. Prototype Air Conditioning Trainer Wiring Diagram

PARAMETER 3: Design of Piping System

Measuring instruments were present to measure pressure and temperature from stages 1 to 4. Also to measure, warm air out temperature and humidity and supply air temperature and humidity. These measured parameters is important in understanding the basic fundamental of refrigeration system.

Step by step procedure:

1. Designing the piping system of the trainer
2. Consulting the adviser/fabricator
3. Implementing the design

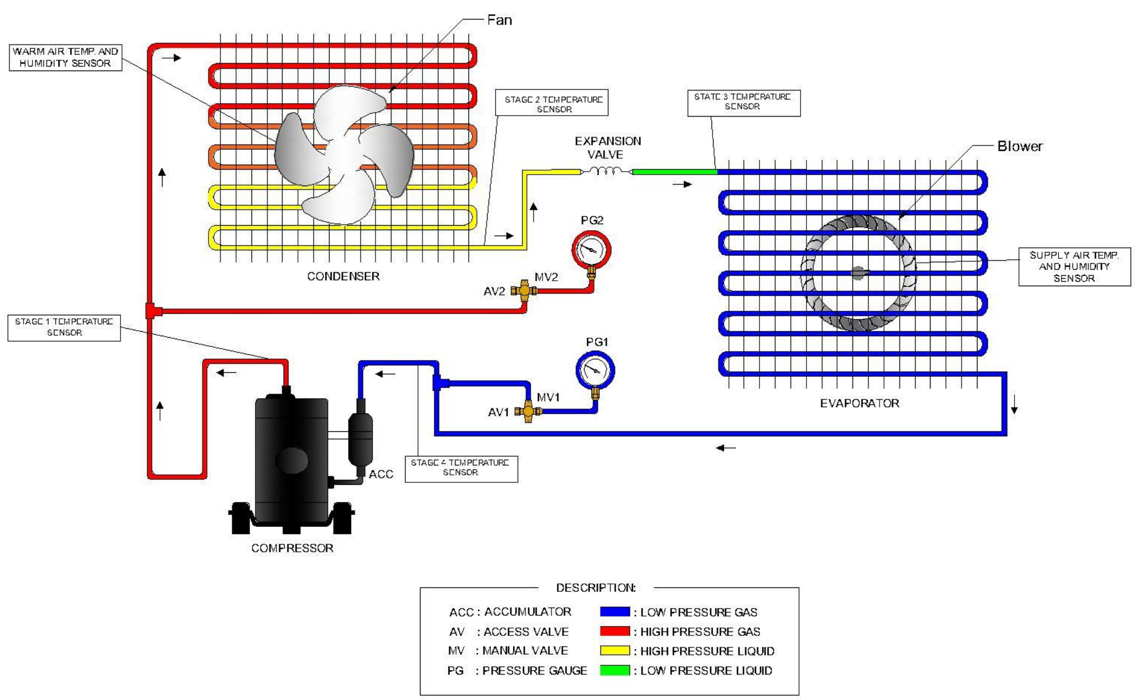


Figure 20. Prototype Air Conditioning Trainer Piping Diagram

PARAMETER 5: Design of the Enclosure

Computation for actual COP happens when temperature sensors reads supply air temperature and ambient air temperature. Volume of the room is important for the computation of cooling time of the room and the power consumed to make the room cold or reach the set temperature. To make it happen, an enclosure is designed to hold cold air for temperature and humidity readings.

Step by step procedure:

1. Designing of the enclosure
2. Consulting adviser/fabricator
3. Implementation of the design

Figure 21. Design of the Enclosure

PARAMETER 6: Design of the Table

The trainer's components was placed in the table's base and board. The researchers designed a table that can hold the trainer's components and have the mobility to be transported on one place to another. The table designed provides safety and stability for the trainer's parts.

Step by step procedure:

1. Designing of the enclosure
2. Consulting adviser/fabricator
3. Implementation of the design

Figure 22. Design of the table

PARAMETER 6: Experimentation and recording data

All the relevant measured data, such as temperature and pressure at different stages, and other factors was recorded and calculated, such as the theoretical values sought for validation of the device and the coefficient of performance (COP).

Step by step procedure:

1. Preparation of the experiment
2. Conducting
3. Recording

PARAMETER 7: Evaluation based on satisfaction of the user

This trainer was used by students as instructional material, and their experience or feedback for the device would serve as the satisfaction rating in terms of functionality, mobility, and safety.

Step by step procedure:

1. Demonstration of the device
2. Distribution of the survey questionnaire
3. Collecting and analyzing the answered questionnaire

Materials and Set-up

The researchers designed the schematic diagram and prototype through computer-aided drafting (CAD) software. The air conditioning system schematic diagram, which depicts the basic air conditioning cycle, would serve as a guide for the tangible component of the air conditioning system that was built into a base to create a trainer.

The following materials were gathered and utilized in the creation of the AC trainer prototype:

- LG LAO60RC Window-Type Air Conditioner

  Specifications:

  Cooling Capacity: 5,800 kj/hr

  EER: 10.8 kj/hw

  Power Input (Rating): 535 Watts

  Power Supply: 1230~60

  Temperature Control: Thermistor

  Airflow Direction Control: Manual

  Timer: 12hr. On/Off

  Remocon Type: Yes

  Quantity: 1

  The air conditioning unit was used as the main system for the air conditioning trainer.

- Rotary Vane Vaccum Pump

  Specifications:

  Voltage: 220~50/60Hz

  Power Source: Corded Electric

  Maximum Power: 0.25 Horsepower

Free Air Displacement: 1.8 CFM

Ultimate Vacuum: 5 Pa | 0.05 bar

Quantity: 1

The vacuum pump enables the compression of air inside the pump chamber to create suction for the removal of air molecules from the piping system of the trainer.

- Brass Gauge Manifold for R22

  Quantity: 1

  The gauge manifold serves as the pressure reader of the high side and low side of the system. Aids for charging the system with refrigerant and provides connection for the vacuum pump.

- Access Valve

  Quantity: 2

- Digital Temperature and Humidity Sensor

  Quantity: 6

  The sensors are responsible for the temperature and humidity readings for each stages of the refrigeration cycle also reads for warm air out and supply air of the system.

- 15A Circuit Breaker

  Quantity: 1

  An electrical safety device, a switch that automatically interrupts the current of an overloaded electric circuit, ground faults, or short circuits. This is also where the digital monitoring device for

AC Current, AC Voltage, frequency, power factor, electric power, and electric energy is connected.

- N52-2066 DIN-Rail Multi-Function Digital Meter

Specifications:

Accuracy: 1%±2 words

Range: AC voltage: 40.0-300.0 V

AC current: 0-100.0 A

Frequence: 45.0 Hz-65.0 Hz

Power Factor: 0.00-1.00 PF

Electric Power: 0-450000 W

Electric Energy: 0-99999 kwh

Speed: 2x per second

Installation: Din-Rail

Quantity: 1

The multi-function digital meter measures AC voltage, AC current, active power, power factor, frequency, and electric energy of the trainer at the same time.

- Freon R-22

  Quantity: 2 kilo

- Angle Bar

  Measurement: 1 in. x ¼ in.

Quantity: 3

- Phenolic Board

  Measurement: 4 ft. x 8 ft.

  Quantity: 1

  The phenolic board is water resistant, heat resistant, and also durable that is very suitable to withstand the trainer's weight and to hold its electrical components.

- Caster Wheel

  Size: 2 in. diameter

  Quantity: 4

  Installed to mobilized the trainer

- Welding Rod

  Quantity: 2 kilo

- Copper Tube

  Size: ½ in. diameter

  Quantity: 1

  Used as a pouch for the temperature and humidity sensor rod

Parts and Purpose

Parts	Description	Purpose
Wiring System	Composed of control panel, circuit breaker, and digital meter	To protect the system from overloading, to show electrical readings, and to gain control of the trainer.
Piping System	Consists of the evaporator, condenser, compressor, capillary tube, access valves, temperature and humidity sensor, and gauge manifold	To facilitate the flow of refrigerant throughout the system. Measuring instruments were installed to read different data readings.
Enclosure	Made of phenolic board that is a good insulator and moisture proof material	Room for the evaporator where supply air and ambient air of the room is measured.
Table	Steel structure was made of welded angle bars, base and board were made of phenolic board that is highly moisture resistant and sturdy.	This is where the trainer rests its components and to provide user comfort when using the trainer.

Table 1. Parts and Purpose of the Device

Research Procedures and Processes

The aim of this study is to design and prototype an air conditioning trainer for laboratory instructions for mechanical engineering students. With the use of survey questionnaire, the researchers used the data to determine the satisfactory of user in the study. The researchers used the R&D experimental process, the ADDIE model, to arrive at the study's outcomes. The processes include ADDIE, which stands for analyze, design, develop, implement, and evaluate.

The researchers in the conduct of the study followed the following procedure plan:

Collection and Analysis of Related Studies. The researchers gathered all the necessary information that they would get from the related literature and studies. The data and concepts gathered was used as a basis in formulating a research problem that would respond to the recommendation of the existing related studies.

Establishing a Research Problem. After gathering information from related literature and studies and analyzing the department's problems, the researcher developed a study, hypothesis, and problem statement that would address the existing problem.

Gathering and/or Looking for Desired Available Materials, Tools, and Services to Produce the Prototype. The researchers conducted a survey and canvasing to ensure the availability of the materials and services needed in the study. By using the information from the previous studies and the internet, as well as the person aligned with AC services, the list of materials and the estimated bills are made.

Design and Lay-out of the Wiring and Piping System. The design was made in AutoCAD software, aligning with the schematic diagram of the actual AC system.

Design and Lay-out of the Enclosure and Table. The design was made using Autodesk Fusion 360 software to make a 3D design of the lay-out.

Design and Lay-out of the Prototype. The design of the trainer was formed through the AutoCad software based on the measurements of the materials to be used, a 3D model, as well as labeling of the sizes in the design from the pen sketch.

Manufacturing/Fabrication. The researcher utilized the available materials to be found in the hardware store, marketplace, and online shopping to produce the design, and made in accordance with AC expertise.

Creation of AC Laboratory Manual. It is done with the help of internet sources and some configuration that is aligned to the made trainer to have a manual of how the prototype is used and for user safety. Also provided a learning outcome for learners.

Creation of Survey Questionnaires. Researchers created survey questionnaires for the respondents to gather the necessary data for the study when it comes to a satisfactory rating for the device.

Experimentation. After making the prototype, experiments was done to generate data outcomes that would be used in the study.

Improvement and Modification of the Device. A necessary adjustment or modification will be made if there is a setup that will need to change that affects the working condition of the device.

Gathering of Data. The experiment's data is recorded, and the answered survey questionnaire is also collected.

Analysis of Data. The gathered data was used to calculate the coefficient of performance of the AC trainer and, with the aid of the statistical tool, the weighted mean, to analyze the satisfaction rating for this device.

Finalizing the Results. The researchers finalize the data with an interpretation and recommendations for future researchers.

Publication of the research paper. The final paper was published and submitted to accomplish the term's completion requirement.

Developmental Processes

Stage 1: Analyze. It is the stage at which the researchers develop a strategy, observe the current situation in the department and the problems and issues it faces, and ask people what they would like to be studied. Organizing and comprehending the gaps that must be filled. It is developing a study plan.

Stage 2: Design. Creating a design for the prototype via software and finalizing the desired parts to facilitate fabrication would meet the study's objectives. This section also includes the preparation of tools, equipment, materials, and parts before constructing the prototype.

Stage 3: Develop. The researchers are now systematically developing the prototype with the help of experts. Based on the design agreed upon, the prototype was assembled using the identified materials, tools, and equipment. This stage is also referred to as prototyping.

Stage 4: Implement. This section of the study involves the implementation or testing of the product. This is an iterative phase in which the trainer is constantly revised, updated, or redesigned as needed based on its working stability, operation, and safety. The researchers developed a manual that would be included in this study to explain how the trainer works and what the dos and don'ts are.

Stage 5: Evaluate. The researchers demonstrated the prototype and distributed the questionnaire to the study's respondents, who were 4th-year mechanical engineering students at Bicol University.

Data Collection and Procedures

The data came from the researchers' observations and calculations on the performance of the prototype, as well as the responses of the selected students prior to the study. The advisers' and experts' knowledge of giving advice and insights about the events obtained during the air conditioning testing process is essential for the safety of the researchers and users. The internet, unpublished and published books for related studies and literature, as well as other related programs to pursue this study, were also included as data sources for this study. The researchers performed readings and conducted (4) experimental tests to determine:

1. Air Temperature Sensor Test
2. Power Consumption of the Trainer
3. Actual COP Test
4. Pressure and Temperature Test

Experiment 1: Air Temperature Sensor Test

The air temperature sensors that would be bough might not be well calibrated to read accurate air temperature. This parameter is important to the trainer's ability to provide accurate data as actual COP would be computed and is a part of the learning outcomes that an individual would get after using the trainer.

Table 2 would show the temperature read on the indoor air temperature. Three trials would be conducted to see the difference on the read of the air temperature sensor compared to the set thermostat temperature. The purpose of this test would be to test the accuracy of the purchased sensor and if the results are not accurate, to provide a temperature tolerance that would solve the issue on inaccuracy.

Trials	Air Temperature Read from the Sensor (°C)	Thermostat Set Temperature (°C)	Difference in temperature (°C)
1			
2			
3			

Table 2. Sample Data Sheet for the Temperature Difference between Temperature Sensor and Thermostat

Experiment 2: Power Consumption of the Trainer

The trainer would be turned on and the researchers would set the trainer's thermostat to 16°C. Three fan modes would be subjected to these test to check which fan mode would be the slowest to fastest cooling time and also which would consume the least to greatest electric power. Each fan mode would have specific time interval before setting the next fan mode, this ensures that the test would be made in a specific indoor temperature. The researchers would use the formula below to compute for electrical power in watts,

$W = V \times A$

Where:

W = Electric power, watts

V = Voltage, volts

A = Current, Ampere

Table 3 would show the power consumption of the trainer. The trainer would be set to 16°C that would cool a 4,995 cu in. enclosure. The experiment would be conducted at a specific time to ensure steady ambient temperature. The result of this test would conclude to which fan mode would be the slowest to fastest in reaching the desired set temperature and which fan mode would consume the least to greatest power consumption in kWh.

Fan Mode	Cooling Time (seconds)	Indoor Air Temperature Before Cooling (°C)	AC Current (A)	AC Voltage (V)	Electric Power (W)	Power Consumption	
						Watts	kWh
1							
2							
3							

Table 3. Sample Data Sheet Power Consumption of the Trainer

Experiment 3. Actual COP Test

The researchers would conduct three trial test for obtaining the desired actual COP of the system in different ambient air temperature. Cooling time would also be measured. The researchers would use Table 5 to choose the fan mode that would run the fastest cooling time. The formula below would be used compute for the actual COP.

The formula for Actual COP in cooling is,

$$COP = \frac{T_c}{T_h - T_c}$$

Where:

T_c = Cold temperature

T_h = Hot temperature

Table 4 would show the COP of the system in different time intervals. Cooling time would also be measured. Three trials would mean different ambient temperature. Indoor temperature would reach 16°C as the researchers would set thermostat temperature to 16°C. The result of this test would conclude ambient temperature the system would be more efficient.

Trials	Cooling Time, min	Ambient Temperature of the Room, ℃	Indoor Temperature of the Room, ℃	Coefficient of Performance
1^{st}				
2^{nd}				
3^{rd}				

Table 4. Sample Data Sheet for Actual COP of the System in a Specific Time Set

Experiment 4: Pressure and Temperature Test

Using the manifold gauge, the researchers would read Freon R-22 pressure at stage 1 (high side) and stage 4 (low side). Temperature reading would be conducted using a temperature sensor. Three trial test would be conducted in this test.

Table 5 would show the temperature and pressure reading of stage 1 and stage 4 of the system. Gathered values from the measuring instruments would be compared to the Freon R22 P-T Chart. The P-T chart would show actual temperature to pressure equivalents. Results of this test would conclude that the measuring instruments are showing close to accurate data to say that is calibrated.

Trials	Temperature		Pressure	
	at Low Side	at High Side	at Low Side	at High Side
1st				
2nd				
3rd				

Table 5. Sample Data Sheet for P-T of Freon R22

The P-T chart was used by the researchers to test the precision of pressure and temperature in the given refrigerant for the data accuracy of the trainer. This P-T chart can be used to determine whether or not a system is working properly. Walker (2013) stated that there are only three places where the P-T relationship can be guaranteed: the evaporator, condenser, and receiver (if the system has one), all of which contain a saturated mixture of refrigerant liquid and vapor. The P-T chart works by reading the pressure or temperature at any of the three system points and then locating the corresponding saturation temperature or pressure in the chart. This would indicate the type of condition present at this point; anything above saturation is classified as superheated vapor, and anything below is classified as subcooled liquid. The P-T chart would be used as a value check in this experiment if the measured temperature and pressure in the trainer matched what was in the chart. The experts' knowledge of operating and testing safety procedures was used by the researchers during the experiment. The laboratory manual would include information on troubleshooting and testing of air conditioning component systems for the safety of future users.

Evaluation Rating

To determine the user satisfaction rating on the air-conditioning trainer, the researchers conducted a survey using a survey questionnaire distributed to qualified respondents. A total of 40 respondents from mechanical engineering students of Bicol University would take the survey to evaluate satisfaction under the study. The researchers would create a survey questionnaire that would include parameters and indicators for assessing satisfaction in terms of functionality, mobility, and safety.

The trainer would be demonstrated to the respondents after the researchers fabricated the prototype. Following the demonstration, the respondents would answer the survey questionnaire. After the respondents are done answering the questionnaire, the researchers would collect the questionnaires from respondents. The researchers would compute for the weighted mean for each parameter using statistical tools to perform data analysis and interpretation of the answer. The instrument used in this study was based on a five-point Likert scale and included the following indicators:

Rating Scale	Interpretation
5	Very Satisfied
4	Satisfied
3	Neither Satisfied or Dissatisfied
2	Dissatisfied
1	Very Dissatisfied

Table 6. Sample Likert Scale Range and Interpretation

Parameters	**Rating Scale**				
Functionality	**5**	**4**	**3**	**2**	**1**
How would you rate the quality of the components used in the trainer?					
How would you rate the operation of the trainer?					
How satisfied are you with the overall design of the trainer?					
How would you rate the ease of use of the trainer?					
Safety	**5**	**4**	**3**	**2**	**1**
User Manual					
Warning Labels					
Structural integrity of the table					
Wire protection					
Mobility	**5**	**4**	**3**	**2**	**1**
Caster Wheel Break					
Caster Wheel Size					
Caster Wheel Condition					
Maneuverability					

Table 7. Survey Questionnaire

Statistical Tool and Analysis

The results obtained from the respondents would be analyzed using statistical tools. In this study, the weighted mean was used as a statistical tool to analyze and interpret data on the device's satisfactory rating. Descriptive statistics such as frequency count, weight, and total number of respondents are considered. The weighted mean would be calculated in this study using the following formula:

Formula:

$$\bar{x} = \frac{\sum fx}{n}$$

Where:

$\bar{x}$ = weighted mean

f = frequencies to the given

x = weights

n = total number of respondents

End Notes

Dowsett, B. (2023, March 30). Understanding the Main Types of R&D. Retrieved from https://www.taxcloud.ie/blog/2023/understanding-the-main-types-of-rd#:~:text=There%20are%20typically%20three%20different,Applied%20Research%20and%20Development%20Research.

Mulyana, A. (2016, August 22). Definition, Purpose and Steps of Research and Development. Retrieved from https://ainamulyana.blogspot.com/2016/08/definition-purpose-and-steps-of.html

CHAPTER 4

PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

This chapter includes the presentation of the findings, analysis and interpretation of the data gathered to satisfy the statement of the problem stated in the Chapter 1 of this paper wherein, its main objective was to determine whether the Prototype Air Conditioning Trainer can perform accordingly with respect to its design and function. The researchers adhere to the research procedure stated in the Chapter 3 of this paper in order to decide with the design of the device and the data gathering tools to be used.

Design of the Prototype Air Conditioning Trainer

The design of the Prototype Air Conditioning Trainer was based on the following: wiring layout, piping layout, evaporator enclosure design and the trainer's table. The wiring layout contains the detailed wiring connections of all the electronic components of the prototype air conditioning trainer. The wiring layout is composed of the AC unit's wiring system, circuit breaker, and the multi-function digital meter. The piping layout comprises all the plumbing materials and piping connection present in the trainer, it shows the flow of refrigerant from the compressor to the condenser, from the condenser to the evaporator, and goes back to the compressor for the full cycle. The piping system is composed of the AC unit's piping system, access valves and the gauge manifold. The evaporator enclosure design is made for the purpose of supply air temperature and humidity readings that is important in studying air conditioning systems. The enclosure is made of phenolic board in specific sizes screwed together to form a wall and a hinge installed on the cover to provide interior access of the enclosure. The table design is to hold/rest the trainer in place where it will sit safely and steadily. The table is made of a steel structure that is angle bars welded together, a base and a board made of phenolic board.

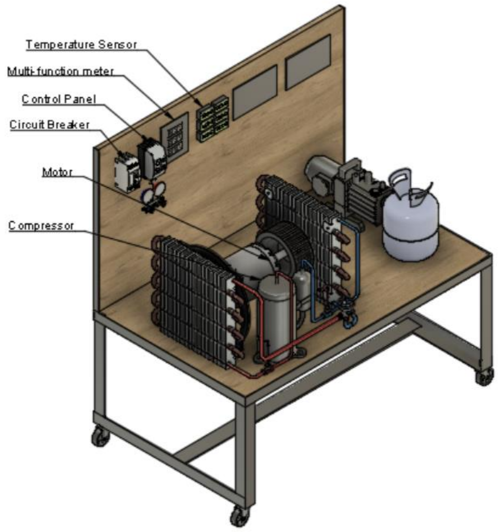


Figure 23. Wiring System Set-up

Figure 23 shows the wiring system of the trainer. The wiring system is consisted of the following accessories: circuit breaker, multi-function meter, control panel, motor and the compressor. The circuit breaker is connected to both the multi-function meter and control panel. The 15A circuit breaker will protect the trainer from overloading or experience short circuit that would damage or destroy parts of the trainer. The multi-function meter reads AC Current, AC Voltage, Frequency, Electric Power, Electric Energy, and Power Factor of the system. The set-up for the air conditioning trainer. A circuit breaker was applied to prevent the system from overloading, the multi-function meter and control panel is connected to the breaker. The multi-function meter reads the electrical parameters of the trainer, the multi-function meter is connected to the capacitor of the control panel. The control panel provides control over the thermostat, power, and fan of the trainer. Once the power is turned on and thermostat temperature is set, the motor will start to run making both the blower and fan spin and the compressor will start compressing the refrigerant.

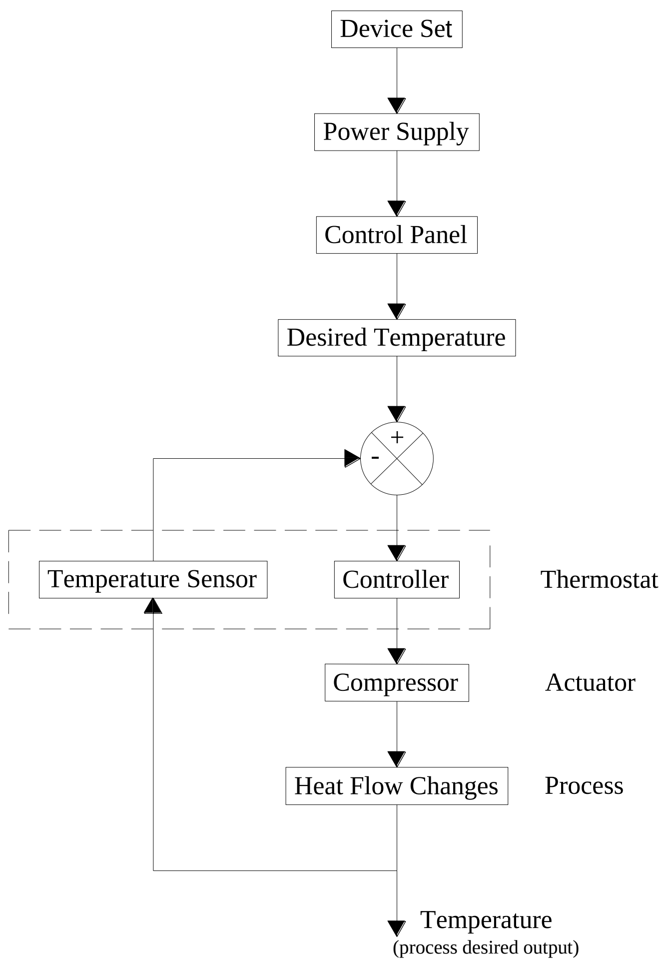


Figure 24. Operational Procedure

Figure 24 depicts the air-conditioning trainer's operational procedure in a block diagram. The device should be prepared and ready to use. Given that it is already put in place, the power supply will be connected to the outlet to provide alternating current (AC) electricity to the system. The control panel will then run and display the reading in the digital meter for the trainer's electric data, which included amperes, voltage, and watts, as well as the reading in the control panel for the temperature set for cooling.

The desired cooling temperature is entered manually or via the remote control (the controller), and the temperature sensor detects the temperature in the enclosure. When the thermostat sense a temperature below set temperature, the compressor will run. The thermostat is made up of this controller and the temperature sensor.

After being controlled by the controller, the compressor now serves as the actuator. This compressor is the system's heart, pumping refrigerant throughout the entire system. The compressor is in charge of moving the refrigerant between the evaporator and condenser coils and ensuring that it changes from gas to liquid as needed.

The heat flow changes from indoors to outdoors during the process. The heat from the indoor air is extracted and sent outside by the air conditioners. The heat is removed from the interior, and the air is cooled.

As the trainer, ensure that the temperature in the closed area is exactly what the user specified as the desired temperature. This will activate the temperature sensor, after which the compressor will turn off and only the fan will run to cool the room to the set cooling temperature.

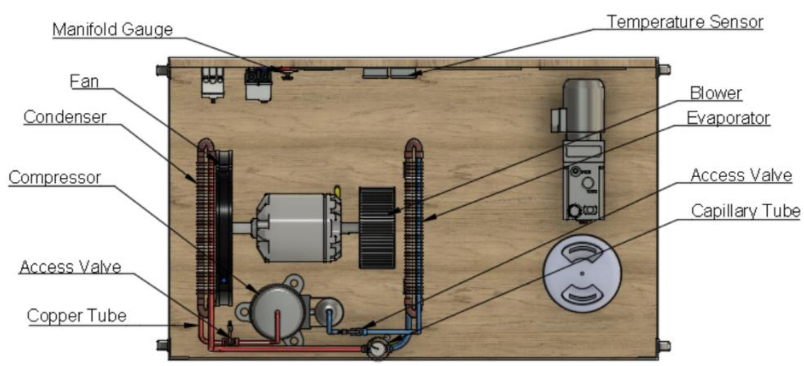


Figure 25. Piping System Set-up

Figure 25 shows the piping system set-up of the air conditioning trainer. The piping system of the air conditioning trainer is similar from the air conditioning unit with the addition of a gauge manifold and access valves connected on the low side and high side pressure of the system. The design of the piping system is based on the refrigeration cycle. Materials used in the piping system were ¼ in. diameter copper tube, (2) access valves, gauge manifold, (2) digital temperature and humidity sensor, and (4) digital temperature sensor. According to the cycle, the refrigeration cycle starts from the compressor and ends to the evaporator. Stage 1 (Compressor). The Compressor pumps high pressure and high temperature gas into the condenser, the temperature sensor then reads temperature. An access valve connect the high side pressure gauge to the system where measures pressure in stage 1. Stage 2 (Condenser). Condenser is both air cooled and water cooled, as the condensation begins, air heats up and the refrigerant cools down then it turns into liquid. A temperature and humidity sensor is connected to the fins of the condenser where it reads the temperature of warm air out. Also, a temperature sensor is attached to the end of the stage 2 to obtain temperature readings. Stage 3 (Expansion Valve). Liquid refrigerant goes into the expansion valve where it expands and gets cold. A temperature sensor is attached to the inlet of the evaporator to read temperature in stage 3. Stage 4 (Evaporator). Blower sucks ambient air onto the evaporator coils, air cools down and refrigerant turn into vapor then it goes back into the compressor. A temperature and humidity sensor is connected to the room to read temperature and humidity of the supply air. An access valve again is connected to the low side pressure gauge along with a temperature sensor and is located at the inlet of the accumulator.

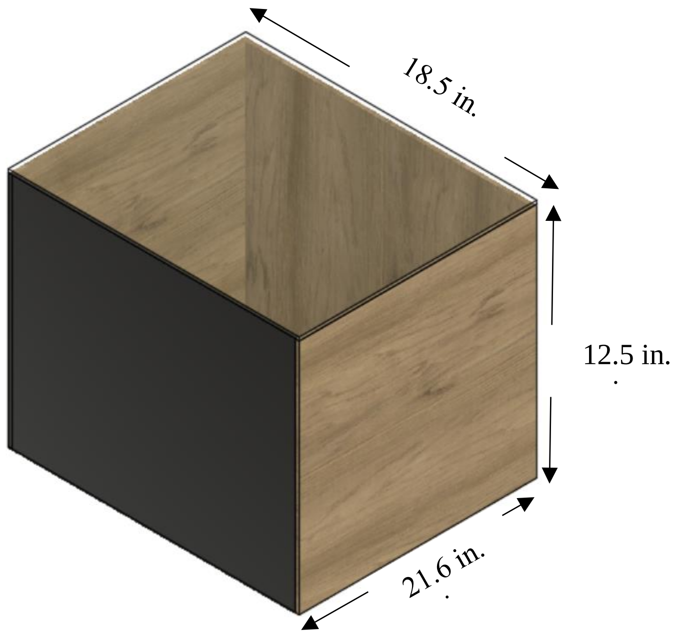


Figure 26. Evaporator Enclosure Design

Figure 26 shows the enclosure design for the evaporator as well as its dimensions. The enclosure's purpose is to hold supply air for temperature and humidity reading. The floor area of the room is 400 sq. in with a volume of 4,995 cu. in. The enclosure walls, cover, and base is made of 3/4 in. thick phenolic board as it is a good insulator. A hinge was installed on the top of the enclosure to provide access for installation and maintenance.

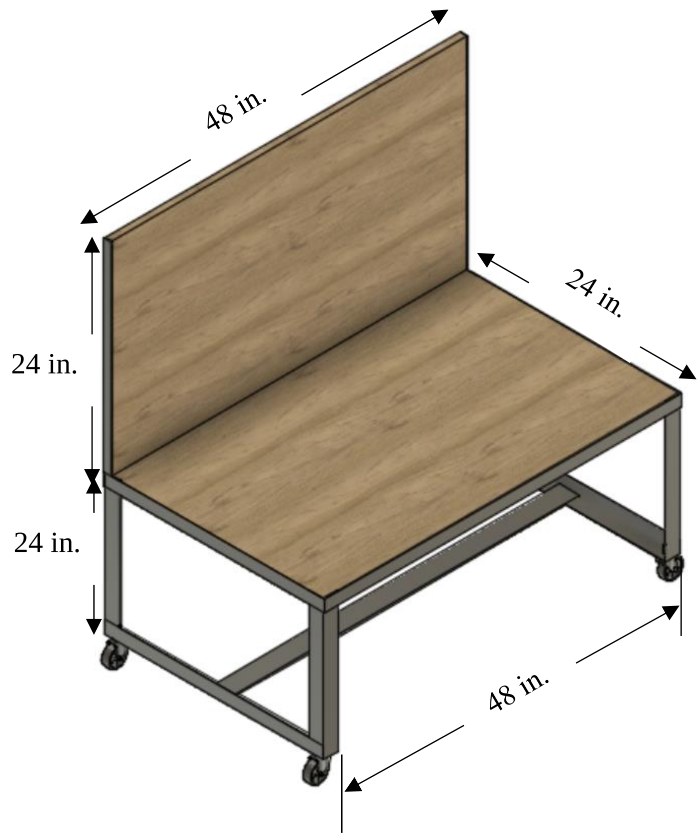
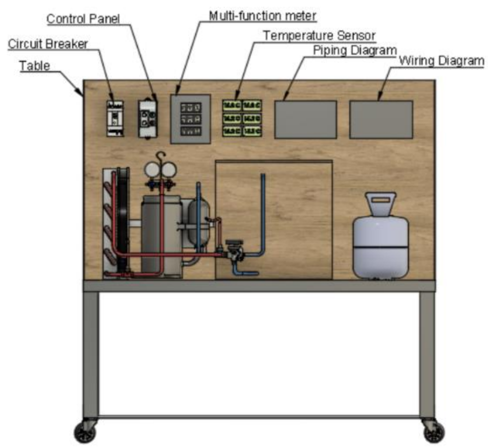
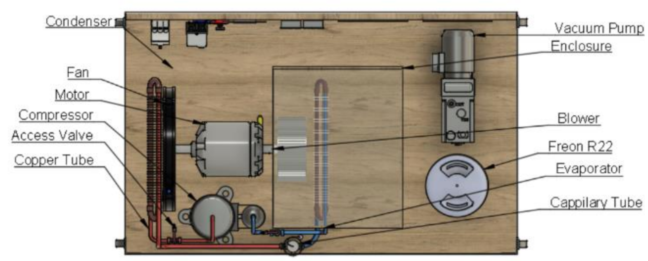


Figure 27. Table Design

Figure 27 shows design and the dimension of the table. The purpose of the base is to hold the trainer in place in a safe and steady manner as well as making trainee comfortable using it. The table's base is made of 2 ft. x 4 ft. phenolic board as well as the mounting board for the wiring system's accessories and schematic diagrams of the trainer. The steel structure of the base is made of pieces of 1 in. wide x ¼ in. thick angle bar welded together. (4) 2 in. diameter caster wheels are attached to each legs of the structure to provide mobility. The trainer rests in this base design to provide safety and stability to the trainer and also to provide comfort for trainees to use.





(a) (b)

Figure 28. Prototype Air Conditioning Trainer Full Set-up

Figure 28(a) and Figure 28(b) shows the Prototype Air Conditioning Trainer Full Set- up. It consisted of a piping system, wiring system, evaporator enclosure and table for the components to rest.

Fabrication of the Prototype Air Conditioning Trainer

The wiring system of the trainer is composed of the air conditioning units wiring system with the addition of the 15A circuit breaker and AC 40-300V 100 A digital meter for AC input. The piping system of the trainer were made of the air conditioning units piping system with a brass gauge manifold connected to both ends of the compressor (2) digital temperature and humidity sensor were attached to the fins of the condenser and to the enclosure room and (4) digital temperature sensor were attached to each stages of the AC cycle. The evaporator's enclosure walls were made of phenolic board. The trainer base were made from phenolic board and angle bar, (4) 2 in. diameter caster wheel were installed to mobilize the trainer.

Wiring System. Proper placement and installation of the electrical components were based upon the design of the lay-out. Skill in using power tools were required for installing the different components of the trainer.

Figure 29(a) shows the installation of the circuit breaker and digital meter. A rail bracket was installed through the use of an impact driver that drill a screw on the rail bracket for the circuit breaker and digital meter to be wall mounted.

(a)

(b)

Figure 29. Mounting of the circuit breaker and digital meter

Figure 30 shows the connecting of the AC 40-300V 100 A digital meter to the 15A circuit breaker for it to have access on power. Cable raceways were present to protect and organize wires. An outlet was connected to the circuit breaker, the outlet was provided in preparation when the vacuum pump is in use.

Figure 30. Connecting the digital meter to the circuit breaker

After the installation of the circuit breaker and digital meter, the control panel was prepared to be mounted to wall. A power tool was used to screw the control panel in place.

Figure 31 shows the mounting of the control panel to the wall. The control panel was mounted using a power tool that drills a screw to the in between of the board and the mount. Then, the control panel was connected to the digital meter for the digital meter to obtain readings. Also, the control panel was connected to the circuit breaker for it to have access on power.

Figure 31. Connecting of the control panel to the circuit breaker and digital meter

After the control panel was connected to the circuit breaker and the digital meter, it was tested to see if the components were working by turning the power on.

Figure 32 shows the electrical components reacting to electricity. The digital meter obtained readings when the power was on and the control panel was set to a specific temperature.

Figure 32. Testing the electrical components

Piping System. The piping system of the trainer was a combination of the AC units piping system with an addition of access valves on the inlet of the accumulator and outlet of the compressor.

Figure 33(a) shows the creation of access holes at the inlet and the outlet of compressor using an acetylene torch to melt a hole in the copper tube for the access valves to connect with. Figure 33(b) shows that the access valves were welded to join them together with the piping system of the unit. The access valve’s purpose was to provide the gauge manifold a connection to the piping system.

(a) (b)

Figure 33. Installation of the access valves

After installing the access valves, Figure 34 shows that the gauge manifold was connected to the access valve for the reading of low and high side pressure of the system.

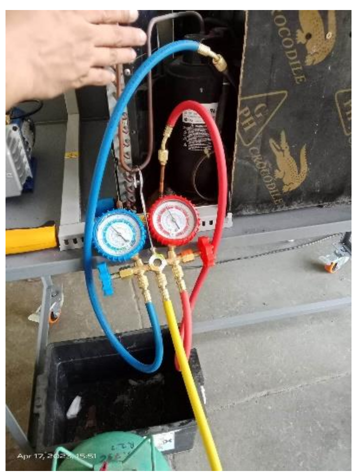


Figure 34. Installation of the manifold gauge

Evaporator's Enclosure. Based on the design made for the enclosure, the enclosure has floor area of 400 sq in. and a volume of 4,995 cu. in. Phenolic board was prepared to be cut into specific measures for the enclosure. Making the enclosure requires skills on cutting and also the use of a power tool to screw the board in place.

Figure 35 shows the cutting of the phenolic board. The board was cut by using a power saw. The phenolic board was cut to (1) 12.5 in. x 18.6 in. phenolic board, (2) 12.5 in. x 21.6 in. phenolic board, and (2) 18.5 in. x 21.6 in. phenolic board to create walls, covers and base of the enclosure.

Figure 35. Cutting of the phenolic board for walls, covers and base

As walls and cover for the enclosure was prepared, the building of the enclosure was next. Based on the design made for the enclosure, the walls, cover, and base were to be put in place.

Figure 36 shows the installation of the walls, covers, and base. An impact driver was used to install screws on the edges of the board to put the boards together.

Figure 36. Drilling screws at the edges of the wood

After the walls have been installed, the cover was put into place. For the cover of the enclosure, a hinge was installed to make the top cover to have the ability to be closed and opened. It was installed to provide user access to the interior of the enclosure.

Figure 37. Installation of a hinge for the top cover

After installing hinges, on the edges of the top cover and the wall. The enclosure was finished and was installed to the evaporator as it is its enclosure.

Figure 38. Evaporator enclosure

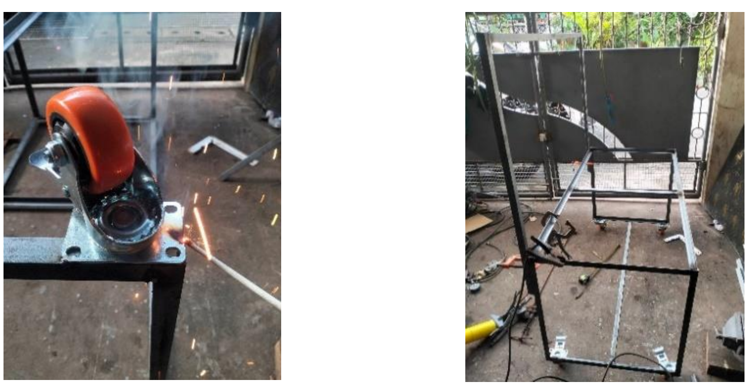
Trainer's table. The trainer's table was designed to hold the trainer components in place safely and steadily. The steel structure was made of welded 1in. wide x ¼ in. thick angle bars. The trainer's base and board was made of 2 ft. x 4 ft. phenolic board. (4) 2 in. diameter caster wheels were installed each leg of the steel structure.

Figure 39 shows the angle bar cut into specific sizes. (4) 4 ft. long angle bar, (11) 2 ft. long angle was cut off from 3 pieces standard size angle bars that came from a warehouse retail. A metal cut-off saw was used to cut the angle bar. After cutting, clamps were used to hold the angle bar in place in preparation for welding. A welding machine was used to weld the angle bars together to form a structure.

Figure 39. Cutting and welding angle bar

When the structure was finished, (4) caster wheel were prepared for installation to mobilize the structure.

Figure 40(a) shows the installation of the caster wheels on each of the structures legs. A welding machine was used to weld the caster wheels in place. Figure 40(b) shows the finished product of the welded structure and installed wheels.



(a) (b)

Figure 40. Installation of the caster wheels

After finishing the steel structure, the trainer's base and board were in preparation.

Figure 41 shows the cutting of the phenolic board using a power saw into sizes. The phenolic board was cut into (2) 2 ft. x 4 ft. phenolic board for the trainer's base and board.

Figure 41. Cutting of the phenolic board to specific size

After the phenolic board was cut to size, installation of the board to the base of the steel structure was prepared.

Figure 42 shows the installation of the 2 ft. x 4 ft. phenolic board to the structure. An impact driver was used to install the board by drilling a screw between the angle bar and the board.

Figure 42. Installation of the phenolic base and board to the steel structure

The next step was painting the trainer base with gray paint to protect the base and the board from termites and the steel structure from corroding.

Figure 43 shows the trainer's base was painted with gray paint. Paint was applied all throughout the steel structure, the base, and the board.

Figure 43. Painting of the table

Prototype Air Conditioning Trainer

As the parts were fabricated, the parts were set-up together to form the trainer. The AC unit was placed on the table and the wiring system were placed wall mounted on the board. The enclosure was placed on the evaporator and the table carries all the parts together to form the trainer. Figure 44 shows the actual set-up of the trainer.

Figure 44. Prototype Air Conditioning Trainer

Data Presentation and Analysis

Air Temperature Sensor Test

The trainer's indoor air temperature sensor was put to a test to see if there was inaccuracy on the reading. Three trials having three different set thermostat temperature. For the first trial was set to 16°C, second was 18°C, and third was 20°C. The reading reads up until the compressors stops running.

Trials	Air Temperature Read from the Sensor (°C)	Thermostat Set Temperature (°C)	Difference in temperature (°C)
1	19.2	16	3.2
2	19.8	18	1.8
3	20.8	20	0.8

Table 8. Temperature Difference between Temperature Sensor and Thermostat

Table 8 results showed that from the first trial, the temperature difference was 3.2°C. For the second trial, the difference was 1.8°C. For the last trial, the difference was 0.8. The results of the test gave different differences. The researchers conclude that the air temperature sensors must be calibrated by a technician or to use the differences as temperature tolerance for air temperature sensor used for each set of thermostat temperature.

Power Consumption of the Trainer

Different Fan Modes was used to cool the 4,995 cu in. enclosure to a room temperature of 16°C. A timer was used to measure the cooling time of each fan mode. Same indoor air temperature before cooling was used. At the end of each trial, numerical data from the multi-function meter and digital sensors was recorded.

Fan Mode	Cooling Time (seconds)	Indoor Air Temperature Before Cooling (°C)	AC Current (A)	AC Voltage (V)	Electric Power (W)	Power Consumption	
						Watts	kWh
1	80	34.4	1.98	234.8	464.9	37,192	$10.3311\ x\ 10^{-3}$
2	73	34.4	1.99	234.9	467.4	34,120.2	$9.4778\ x\ 10^{-3}$
3	67	34.4	2.00	234.9	469.8	31,476.6	$8.7435\ x\ 10^{-3}$

Table 10. Power Consumption of the Trainer

Table 10 shows the power consumption of each fan mode to a set indoor temperature to cool. Fan Mode 1 took 80 seconds to cool to enclosure to 16°C, Fan Mode 2 took 73 seconds and Fan Mode 3 took 67 seconds to cool to enclosure. This proves that Fan Mode 3 has the fastest wind speed as wind speed is a factor in cooling as it draw heat away from an object making Fan Mode 1 having the slowest wind speed. For the power consumption, Fan Mode 1 consumed 0.0103 kWh, Fan Mode 2 consumed $9.4778\ x\ 10^{-3}$ and Fan Mode 3 consumed$8.7435\ x\ 10^{-3}$. It concludes that the Fan Mode 3 having the fastest wind speed and cooling time consumed the least electric power. Increased wind speed decreases the work of the compressor and decreased compressor work means decreased power consumption.

Actual Coefficient of Performance Test

Three trials was conducted in three separate time interval to get a specific ambient air temperature. Fan Mode 3 was used as it has the fastest cooling time and the least power consumption that is fit for this efficiency test. Thermostat was set to 16°C and a timer was used to measure to cooling time in each trial. Before and after numerical data from the digital sensors was recorded.

Trials	Cooling Time, sec	Ambient Temperature of the Room, ℃	Indoor Temperature of the Room After Cooling, ℃	Coefficient of Performance
1st	58.04 sec	28.9	16	1.24
2nd	59 sec	31	16	1.07
3rd	55.6 sec	24.4	16	1.90

Table 11. Actual COP

The test was conducted on April 16, 2023. The first trial began at 9:00 a.m. in the morning with an ambient temperature of 28.9 °C. The second trial began at 12:00 p.m. in the afternoon having an ambient temperature of 31°C. Lastly, the final trial began at 5:00 p.m. in the evening having an ambient temperature of 31°C. Table 11 shows that Actual COP of the Trainer was highest around 5:00 PM in the evening with 1.90 COP and lowest at noon with 1.07 COP. According to the data collected, the ambient temperature of the room influenced the cooling time. It concludes that the air conditioning is more energy efficient and effective at cooling the enclosure at lower ambient temperatures.

Pressure and Temperature Test

The trainer was set-up for three trial test to check the accuracy of the digital temperature sensor and the manifold gauge in reading parameters. The trainer was turned on, Fan Mode 3 was set and thermostat temperature was set to 16°C. Different indoor temperatures before cooling was used for each trial. Recording of numerical data from the manifold gauge and temperature sensors was obtained after the room temperature reached 16°C. After recording, the researchers compared obtained data to an actual P-T Chart of Freon R22 to test the accuracy of the measuring instruments.

Trials	Indoor Air Temperature Before Cooling	Temperature (°C)		Pressure (psig)	
		at Low Side	at High Side	at Low Side	at High Side
1st	33.1°C	13.1	43.4	53	200
2nd	31.4°C	15.7	47.4	55	207
3rd	30°C	19.5	45	55	207

Table 12. Pressure and Temperature at Low Side and High Side

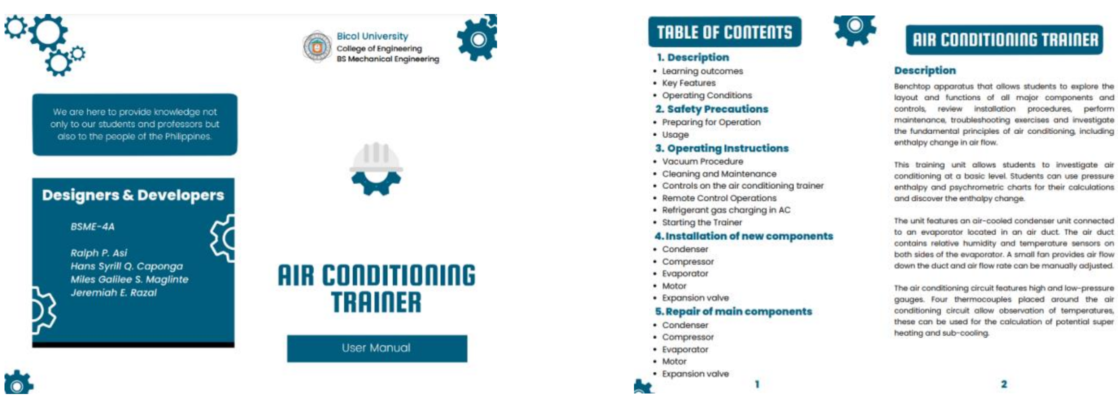
Table 12 shows the temperature and pressure reading data from the low and high sides the system. For pressure having 53 psig, its temperature equivalent from the P-T chart was 11.7°C. For 55 psig, 12.8°C. For 200 psig, 38.7°C and for 207, 39.8°C. The obtained data's were not accurate but shows close to accurate data. The researchers infer that there may have been heat losses around the system that greatly affects the temperature reading. The researchers believe that to obtain accurate temperature reading of the low side and high side, the sensors must be inside the copper tubes to avoid heat losses.

Format of the User Manual

The manuals for the trainer were the user's manual. The user's manual was for the operation, installation, maintenance, repair and safety precautions of the trainer.

For the user's manual, the manual contains the following: description of the trainer, safety precautions, operating instructions, installation of new components, and repair of main components. The user manual contains all the information that a user needs in order to operate the trainer.

Figure 45(a) shows the front and back page of the user manual. Front cover shows the title of the manual and the back contains the motto of the group as well as the names of the designers and developers of the prototype air conditioning trainer. Figure 45(b) shows the table of contents of the user manual, these are information needed by the user to operate and maintain the prototype air conditioning trainer.



(a) (b)

Figure 45

Format of the user manual

Client Satisfaction

The AC trainer was made for the students of Bicol University who are studying refrigeration cycle and their opinion about the prototype air conditioning trainer is significant to the study. This section presents the clientele satisfaction evaluation conducted for the prototype. The evaluation parameters were Functionality, Mobility, and Safety.Comments and suggestions were solicited from the clients for the improvement of the system.

Mechanical Engineering students of Bicol University were chosen as respondents for the evaluation of the design and development of a prototype air conditioning trainer for laboratory instruction. There were a total of 40 respondents that took the clientele satisfaction survey. The researchers provided the respondents survey form on which the parameters stated. The air conditioning trainer is evaluated according to the Likert scale rates indicated below and the data were statistically treated using weighted mean.

Scale	Range	Interpretation
5	4.50-5.00	Very Satisfied
4	3.50-4.49	Satisfied
3	2.50-3.49	Neither Satisfied or Dissatisfied
2	1.50-2.49	Dissatisfied
1	1.00-1.49	Very Dissatisfied

Table 13. Likert Scale Range and Interpretation

Functionality

The academic impact and functionality of the design and development of a prototype air conditioning trainer for laboratory instruction are discussed in this section. A demonstration was performed in order to show the functionality of each component and give it the credit it deserves. Weighted Mean was used to get the mean of parameters under functionality and then, the researchers computed for the overall average to obtain the performance rating for functionality. According to the tabulation in Table 14, which describes the results in this aspect of the prototype, Students are very satisfied with the quality of the components used, satisfied by the operation procedure of the trainer, very satisfied by the overall design of the trainer, and very satisfied of how easy to use the trainer. Students were satisfied by the functionality of the trainer.

Functionality	Mean	Interpretation
How would you rate the quality of the components used in the trainer?	4.1	Satisfied
How would you rate the operation of the trainer?	4.175	Satisfied
How satisfied are you with the overall design of the trainer?	4.8	Very Satisfied
How would you rate the ease of use of the trainer?	4.875	Very Satisfied
Average Mean	4.4875	Satisfied

Table 14. Mean Responses in Terms of Functionality

Safety

The user manual was presented to the respondents by showing them the contents of the manual specially the safety precautions that is needed to be considered when using the trainer and also after using the trainer. Warning labels were placed to where the hazard is present. The table structure were also shown and checked for breaks in the wood and in the steel. Lastly, wire protection were applied by using cable raceways. Table 15 shows the rating of the respondent in terms of the safety use of the trainer. Results shows that the respondents were satisfied to the user manuals format and content, satisfied by the warning labels placed on hazards, satisfied by the quality and strenght of the table as it carries the trainer's components and very satisfied with the wire protection installed on wires.

Table 15 shows the ratings of parameters unders safety. Students were satisfed by the format and content of the manual, satisfied by the warning labels placed around hazards, very satisfied by the structural integrity of the table, and very satisfied by the wire protection installed. Students were very satisfied by the safety use of the trainer.

Parameter	Mean	Interpretation
User Manual	4.225	Satisfied
Warning Labels	4.425	Satisfied
Structural integrity of the table	4.55	Very Satisfied
Wire protection	4.8	Very Satisfied
Average Mean	4.50	Very Satisfied

Table 15. Mean Responses in Terms of Safety

Mobility

The researchers showed the respondents how to release the locks on the wheel and how to move it properly and steadily. Caster wheel specification were also stated by the researchers and explained the reason why they chose the caster wheels installed. Respondents was given a chance to test the mobility by moving the trainer and inspecting the caster wheels installed. Table 16 shows the results for the parameters under mobility. The respondents were very satisfied by the lock installed on the caster wheels, satisfied by the caster wheel size, very satisfied by the caster wheel condition and very satisfied by the maneuverability of the trainer. Students were very satisfied by the mobility of the trainer.

Parameter	Mean	Interpretation
Caster Wheel Lock	4.8	Very Satisfied
Caster Wheel Size	4	Satisfied
Caster Wheel Condition	4.775	Very Satisfied
Maneuverability	4.725	Very Satisfied
Average Mean	4.575	Very Satisfied

Table 16. Mean Responses in Terms of Mobility

For the overall performance of the prototype air conditioning trainer, the researchers computed for the average of the three parameters. Table 17 shows the average and interpretation of the trainer. The trainer's overall performance obtained a very satisfied rating from the respondents.

Parameter	Mean	Interpretation
Functionality	4.4875	Satisfied
Safety	4.50	Very Satisfied
Mobility	4.575	Very Satisfied
Average Mean	4.521	Very Satisfied

Chapter 5

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the data and findings from the previous chapter. Likewise, it presents the conclusions drawn and the recommendation for future researchers.

Summary

The researchers carried out a developmental research study with the goal of designing, developing, testing, and determining the satisfaction level of the air conditioning trainer for laboratory instructions. This concept arose from the department's current problem as well as a review of existing designs and studies of the mechanism.

This study successfully developed a trainer prototype using the ADDIE experimental method under Research and Development. (R&D). The design was created using a CAD software, and the prototype was built according to the plan but some measuring instruments (i.e. air temperature sensor and manifold gauge) have shown inaccuracy on obtaining data, however, it showed close to accurate data and is enough to understand refrigeration cycle. For the fabrication procedure, the researchers found a difficulty of finding a fabricator that can fabricate the trainer. It took 1month to find a suitable fabricator that can realize the design for the trainer. Even though the trainer was cheaper than the commercial air conditioning trainer, the researchers had stumbled a lot of challenges that came from the design, fabrication, and finance. However, all the hard work and expenses paid were worth it as the respondents were satisfied by the trainer's functionality, safety, and mobility. For users to have the ability to operate, maintain, repair, and install components of the trainer.

Findings

This study found relevant results about the prototype air conditioning trainer. The following results and findings are presented according to the problems explored in this study.

1. The prototype air conditioning trainer was designed consisting of four important parts. The wiring system, the piping system, the evaporator enclosure and the table. The wiring system was designed to connect the circuit breaker, multi-function meter, and the control panel together forming a network of connections for the distribution of electrical energy from the power supply. The piping system consists of the basic components of the refrigerant cycle, the compressor, condenser, expansion valve and evaporator. An access valve was installed at the low side and the high side of the system for the manifold gauge to connect to for charging of refrigerant, vacuum process and pressure reading. The enclosure was designed to hold cold air for temperature reading. The table was designed to carry the trainer components and give the trainer a capability to be transported easily.

2. The prototype air conditioning trainer was fabricated using materials found in a local warehouse and online shops. Skills of using power tools, cutting, jointing, fitting, and arithmetic skills were used to fabricate each and every part of the trainer to ensure safety, functionality, and mobility of the trainer. During the testing of the trainer, the researchers found out that the size of the enclosure affects the time to cool a room. Therefore, the smaller the room, the faster it is to cool the room as well as how fast it for a room to get hot. The trainer have a higher actual COP, faster cooling time, and least power consumption when

ambient temperature and indoor temperature is at its lowest. When different fan modes were set, Fan Mode 3 achieved the highest cooling. This concludes that the Fan Mode 3 has the highest fan speed producing faster wind speeds. The higher the fan mode, the faster the cooling time of an object.

3. The format of the user manual were based from the operation procedure of the trainer while the maintenance, installation, repair, and safety precautions are based from the internet. Vacuum procedure was based from the knowledge of the researchers as the researchers have experience on the vacuum procedure. The charging of refrigerant was also based from the experience of the researchers. When the trainer was cleared of the refrigerant Freon R22 because of the installation of access valves, the researchers had a first-hand experience of charging the refrigerant into the piping system.

4. The trainer was demonstrated to the chosen 40 respondents. After the demonstration, respondents answered a survey questionnaire intended to rate the functionality, safety, and mobility of the trainer. For the functionality, it gathered a satisfied rating from the respondents. For safety, it gathered a very satisfied rating from the students. And for mobility, it gathered a very satisfied rating from the respondents. For the overall performance rating, the trainer gathered a very satisfied rating from respondents.

Conclusions

Based on the findings of the study, the following conclusions are derived.

1. The design of the wiring system, piping system, enclosure and table of prototype air conditioning trainer were sufficient to make the trainer functional in providing students experience and information they need to understand and learn refrigeration cycle.

2. Fabrication using local warehouse materials and materials found in online shops was sufficient in making the prototype air conditioning trainer. High skills on air conditioning servicing to create the piping system and wiring system of the trainer, and craftsmanship is necessary to create the trainer enclosure and high integrity table.

3. Format used for the user manual was sufficient in providing students information about air conditioning servicing and refrigeration cycle.

4. The performance evaluation through clientele satisfaction survey proved that the prototype air conditioning trainer is performing sufficiently and achieve a very satisfied rating from the respondents.

Recommendations

Based on the data collected from the survey participants and the findings and conclusions presented, the following recommendations have been made for recommendation and are hereby forwarded.

1. The air conditioning trainer is a prototype that can be expanded in a more digital and programmable manner, with some unknown values automatically stated and used to check the data provided by the student. Since the production of Freon R22 has been stopped because of environmental issues, the researchers suggest to use a recovery machine to change the refrigerant used in the system

2. Provision for a bigger and funded research study may adopt this prototype. Collaborate with government and non-government organizations to seek research funding to develop a more technologically

advanced and productive trainer. Temperature sensors on each stages are recommended to be installed inside the copper tubes to accurately measure the temperature of the refrigerant.

3. Detailed and more informative format of user manual that would give out additional information about the trainer's use. Also print using a coated paper to provide protection and class to the manual.

4. Start a study about the effect of the prototype air conditioning trainer to an individual's learning process and test the performance of the prototype air conditioning using technology, engineering, and science.

5. Further the following are recommended"

a. For high accuracy reading, use high quality measuring instruments.
b. For higher thermal insulating enclosure, use Styrofoam or any material that would hold hot and cold temperature well.
c. Use high pressure tolerance low side pressure gauge or rather high quality gauge manifold to service the trainer sufficiently and obtain high accuracy pressure reading.
d. Use anemometer to measure wind speed accurately

APPENDICES

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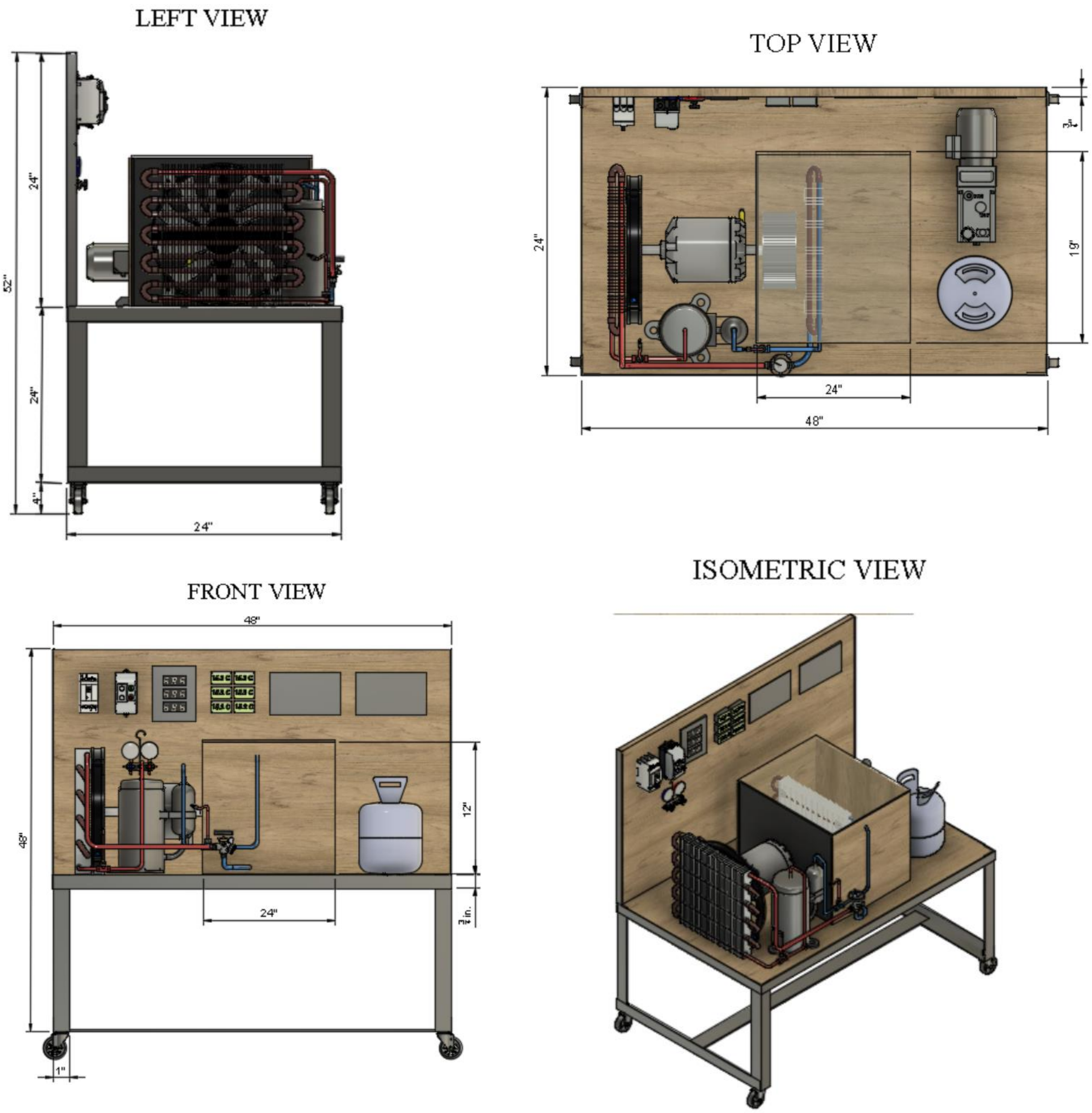
Legazpi City, Albay

APPENDIX A

DESIGN OF THE PROTOTYPE TRAINER



Orthographic and Isometric View of the Prototype Air Conditioning Trainer

APPENDIX B

USER MANUAL FORMAT

This can cause the evaporator to freeze over, or frost to form or come from the AC vents. Either symptom is a sign that the system is getting too much refrigerant, which will actually hinder its efficiency and performance.

To avoid this, lessen the amount of refrigerant used.

3.) AC compressor constantly running

A constantly running compressor is another symptom of a possible problem with the AC expansion valve.

If the AC expansion valve fails or sticks open, it will cause the compressor to pump refrigerant through the AC system, even when it may be undesirable for it to do so. This will put an additional strain on the compressor and associated AC components, making them more susceptible to premature failure.

The AC expansion valve and orifice tube are important components to the proper operation of the AC system and any issues with them can lead to AC system problems and malfunctions.

If you suspect that your expansion valve or orifice tube may be having an issue, have the AC trainer's air conditioning inspected by a professor or a professional technician.

WARNING

1. Do not use the power cord near flammable gas or combustibles such as gasoline, benzene, thinner, etc.
2. Do not place the power cord near a heater for it may cause fire and electric shock.
3. Do not disassemble or modify products for it may cause failure and electric shock.
4. Plug in the power plug properly.
5. Do not operate or stop the unit by inserting or pulling out the power plug.
6. Do not damage or use an unspecified power cord.
7. Do not modify cord length.
8. Do not share the outlet with other appliances.
9. Always plug into grounded outlet.
10. Unplug the trainer if strange sounds, odors, or smoke come out from it.
11. Do not use the socket if it is loose or damaged.
12. Do not operate with wet hands or damp environment.
13. Do not allow water to run through electric parts.
14. Leave the room closed while the trainer is running.

APPENDIX D

INSTRUMENTS USED IN DATA GATHERING

Digital air temperature and humidity sensor

Gauge manifold

APPENDIX D (CONTINUATION)

Din-rail Multi-Function Meter

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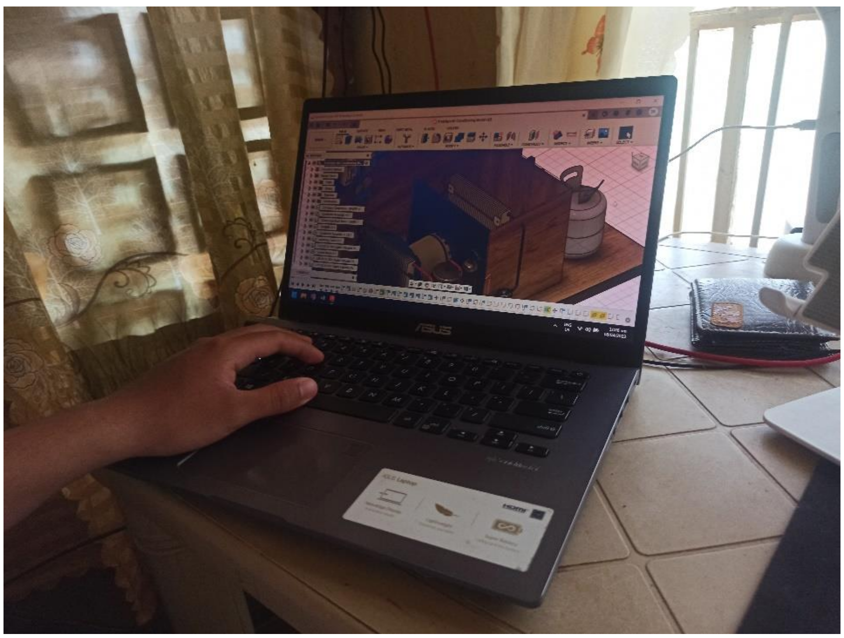
Legazpi City, Albay

APPENDIX E

DOCUMENTATION OF PROCESSES



Drafting the plan for the prototype design

APPENDIX F

TRAINER'S SET-UP AND COMPONENTS

APPENDIX E

BILL OF MATERIALS

Materials	**Quantity**	**Amount**	**Total Amount**
Secondhand LG LAO60RC Window-Type Air Conditioning Trainer	1	₱4,500.00	₱4,500.00
0.25 HP Rotary Vane Vacuum Pump	1	₱2,299.00	₱2,299.00
Brass Manifold Gauge Set with Hose	1	₱499.00	₱499.00
Digital Temperature and Humidity Sensor	6	₱76.12	₱456.72
Din-rail Digital AC Monitor	1	₱680.94	₱680.94
10A Circuit Breaker	1		
Phenolic Board	1		
Angle Bar	3		
2 in. diameter Caster Wheel	4		
Welding Rod	2 kilo		
Access Valve	2		
Copper Tube	1		
Glass Window	1		
Styrofoam			
Freon R-22	2 kilo		
Diagrams			

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Legazpi City, Albay

ENGR. AGERICO U. LLOVIDO, PME, RMP
Mechanical Engineering Department
Bicol University

Dear Sir:

You are hereby requested to act as the adviser of **RALPH P. ASI**, **HANS SYRILL Q. CAPONGA**, **MILES GALILEE S. MAGLINTE and JEREMIAH E. RAZAL** for their Project Study entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"**.

As such, you are to do the following duties and functions:

1. To guide the students in the conduct of the research work within, and if so required, outside of the Bicol University.
2. To assist in monitoring the student's work from the proposal stage to the data gathering until presentation of the research output.
3. To ensure that the suggestions/ recommendations of the Project Study Evaluation Panel are judiciously adhered to.
4. To require the advisee to:
    a. Submit the initial/final copies of the manuscript one week before the scheduled defense.
    b. Comply with other requirements:
        i. Certification from an editor and statistician, if required by the evaluators.
        ii. Submission of all bound copies of revised and final manuscript two weeks before the final examination and academic council meeting.
5. To be available during consultation schedule agreed upon,
6. To serve as a recorder during the Research Study Evaluation. .

Please be guided accordingly.

ENGR. AMELIA B. GONZALES
Dean, College of Engineering

Conforme:

ENGR. AGERICO U. LLOVIDO, PME, RMP
Research Study Adviser

Republic of the Philippines
Bicol University
COLLEGE OF ENGINEERING
MECHANCICAL ENGINEERING DEPARTMENT
Legazpi City, Albay

ENGR. JOSEPH DEL VILLAR
Mechanical Engineering Department
Bicol University

Dear Sir,

You are hereby requested to form the committee to evaluate the project study of **RALPH P. ASI**, **HANS SYRILL Q. CAPONGA**, **MILES GALILEE S. MAGLINTE and JEREMIAH E. RAZAL** for their Project Study entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"**.

As project study evaluator, such you are tasked to do the following:

1. Appraise the validity and acceptability of the project study work in terms of its scholarly quality, corrections of the facts and claims contained therein, and completeness as to its basic components,
2. Make sure that all suggestions have been incorporated,
3. Evaluate the project study report based on the adopted criteria and
4. Be present during the oral defense.

Please be guided accordingly.

ENGR. AMELIA B. GONZALES
Dean, College of Engineering

Conforme:

ENGR. JOSEPH DEL VILLAR
Research Study Evaluator

Republic of the Philippines
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MECHANCICAL ENGINEERING DEPARTMENT
Legazpi City, Albay

ENGR. NICO O. ASPRA, ME, RMP
Mechanical Engineering Department
Bicol University

Dear Sir,

You are hereby requested to form the committee to evaluate the project study of **RALPH P. ASI**, **HANS SYRILL Q. CAPONGA**, **MILES GALILEE S. MAGLINTE and JEREMIAH E. RAZAL** for their Project Study entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"**.

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2. Make sure that all suggestions have been incorporated,
3. Evaluate the project study report based on the adopted criteria and
4. Be present during the oral defense.

Please be guided accordingly.

ENGR. AMELIA B. GONZALES
Dean, College of Engineering

Conforme:

ENGR. NICO O. ASPRA, ME, RMP
Research Study Evaluator

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Legazpi City, Albay

ENGR. MARY JOY M. ORTIZ
Mechanical Engineering Department
Bicol University

Dear Ma'am,

You are hereby requested to form the committee to evaluate the project study of **RALPH P. ASI**, **HANS SYRILL Q. CAPONGA**, **MILES GALILEE S. MAGLINTE and JEREMIAH E. RAZAL** for their Project Study entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"**.

As project study evaluator, such you are tasked to do the following:

1. Appraise the validity and acceptability of the project study work in terms of its scholarly quality, corrections of the facts and claims contained therein, and completeness as to its basic components,
2. Make sure that all suggestions have been incorporated,
3. Evaluate the project study report based on the adopted criteria and
4. Be present during the oral defense.

Please be guided accordingly.

ENGR. AMELIA B. GONZALES
Dean, College of Engineering

Conforme:

ENGR. MARY JOY M. ORTIZ
Research Study Evaluator

Republic of the Philippines
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Legazpi City, Albay

MAY 04, 2022

Office of the Dean:

Engr. Joseph Del Villar	Chairman
Engr. Nico O. Aspra	Member
Engr. Mary Joy M. Ortiz	Member

Dear Engr. Joseph Del Villar,

Kindly form the panel to evaluate the project study of **RALPH P. ASI**, **HANS SYRILL Q. CAPONGA**, **MILES GALILEE S. MAGLINTE and JEREMIAH E. RAZAL** entitled **"DESIGN AND DEVELOPMENT OF A PROTOTYPE AIR CONDITIONING TRAINER FOR LABORATORY INSTRUCTIONS"**.

As thesis evaluators, you must thoroughly assess the research proposal in terms of the parts/basic components of the thesis and make sure that all suggestions were judiciously incorporated.

The defense is scheduled on May 07, 2022 through pre-recorded video presentation of the study.

Please be guided accordingly.

ENGR. AMELIA B. GONZALES, Ph.D.
Dean, College of Engineering