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Design and Development of Refrigeration and Air Conditioning Instructional Trainer

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***Abstract*-The study aims to infuse advanced educational technology in classroom instruction or training on refrigeration and air conditioning. Specifically, the focus of the study includes designing, developing, fabricating, and evaluating the instructional trainer. Through simulations, end-users experiences the actual function of the refrigeration and air conditioning system that could help enhance students learning capabilities and skills in basic troubleshooting on both electrical and the mechanical system. This trainer was evaluated by twenty-five (25) respondents composed of two (2) faculty and twenty-three (23) students to determine its level of quality in terms of functionality, reliability, portability, aesthetics, economy, safety, and academic impact using a descriptive survey questionnaire. Based on the result of the study, the trainer's functionality, reliability, portability, safety, and academic impact are Excellent while the aesthetics and the economy are Very Good. This implies that the trainer serves its purpose in providing comprehensive teaching-learning capabilities to equip the users with thorough knowledge and skills. It is recommended for further research studies to use Programmable Logic Controller (PLC) in monitoring and in detecting the pressure and temperature of the refrigeration system; to inject more faults in the trainer to enhance the troubleshooting skills of the students, and to mount a whiteboard for lecture purposes at the back of the trainer.**

***Keywords*-refrigeration, air conditioning, instructional trainer, technology education, simulation**

I.INTRODUCTION

Refrigeration relates to the cooling of air or liquids, thus providing lower temperatures to preserve food, cool beverages, make ice, and for many other applications. Air conditioning includes space cooling, heating, humidification, dehumidification, air filtration, and ventilation to condition the air and improve indoor air quality [1]. Also, air conditioning systems are vital in ensuring the comfort of people at home and in the workplace, and refrigeration systems are essential to the storage and preservation of food resources [2]. According to Trott and Welch [3], refrigeration is the process of removing heat, and the practical application is to produce or maintain temperatures below the ambient. Refrigeration systems refer to the different physical components that make up the total refrigeration unit [4].

The different stages in the refrigeration cycle are undergone in these physical systems. These systems consist of an evaporator, a condenser, a compressor, and an expansion valve.Since today's refrigeration and air conditioning systems are using new technology after the discovery that chlorofluorocarbon (CFC) refrigerants such as R-11 and R-12 were harmful to the environment, it is also very challenging to prepare students in the classroom to meet the demands in the real world. Students need to be equipped to become skillful technicians. They need an instructional trainer that uses the latest technology which conforms the Montreal Protocol to further their knowledge in troubleshooting, servicing, repairing, and maintaining refrigeration and air conditioning system.

In this aspect, the researcher designed a refrigeration instructional trainer made up of brand new refrigeration components to teach refrigeration principles and practices on complete operational systems using standard procedures and equipment. All the components are assembled into a complete refrigeration system.

The mechanical and electrical parts are also connected to make the trainer functional. This training unit is designed for schools that taught refrigeration and air conditioning as part of an appliance training course since it simulates most of the equipment and electrical circuitry used in both domestic and commercial refrigeration and air conditioning. This research aims to develop a Refrigeration and Air Conditioning Instructional Trainer through simulations wherein end-users will experience the actual function of the system that could enhance their learning capabilities in basic troubleshooting of the electrical and the mechanical system. Thus, this study spells out the following specific objectives:

- To design an instructional trainer;
- To develop and fabricate an instructional trainer; and

- To evaluate the instructional trainer in terms of functionality, reliability, portability, aesthetics, economy, safety, and academic impact.

The output of this study will be beneficial to all learning institutions that offer refrigeration and air conditioning as part of the appliance training course. Specifically, it is beneficial to the Refrigeration and Air Conditioning Technology Department of MSU-Maigo School of Arts and Trades, where the researcher is connected, in improving the quality of instructions. It is also necessary and timely to have this trainer in the department considering the increase of students enrolled in Refrigeration and Air Conditioning Technology and for them to be equipped with the latest technology. Specifically,

- The results of this study can provide the end users – the faculty and the students a comprehensive teaching-learning procedure that gives ease in grasping the actual mechanism and flow of the refrigeration cycle; thus equipping the end-users with thorough knowledge and experience.
- This study can boost their morale of the administration with the influx of students enrolling in Refrigeration and Air Conditioning Technology through word-of-mouth that graduates have gained expertise and become successful in their field.
- This can become an effective instructional tool for all learning institutions that offered refrigeration and air conditioning technology.
- This can be beneficial to the community as well as the country as it helps develop strong and multi-skilled individuals equipped with sufficient knowledge and expertise in refrigeration technology.

II. METHODOLOGY

1. Design Consideration

The design of the Refrigeration and Air Conditioning Instructional Trainer represents a typical refrigerant circuit consisting of a hermetic compressor, a condenser, an evaporator, and an expansion element. This instructional trainer sets out the fundamentals and provides a step-by-step guide through the experiments. Figure 2.1 below shows the perspective view of the trainer with its dimensions.

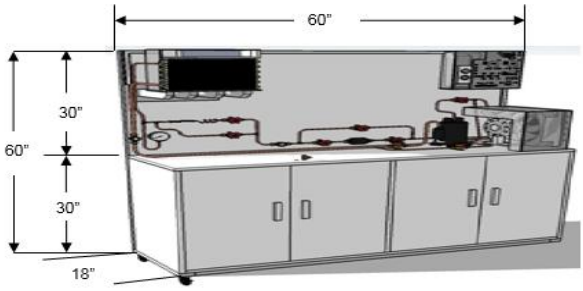

Figure 1 Prototype Design.

The first law of thermodynamics applies the conservation of energy principle to systems where heat transfer and doing work are the methods of transferring energy into and out of the system. The first law of thermodynamics states that the change in internal energy of a system ΔU equals the net heat transfer into the system Q, plus the net work done on the system W. In equation form, the first law of thermodynamics is,

$$\Delta U = Q + W$$

Here ΔU is the change in internal energy U of the system. Q is the net heat transferred into the system—that is, Q is the sum of all heat transfer into and out of the system. W is the net work done on the system.So positive heat Q adds energy to the system and positive work W adds energy to the system. This is why the first law takes the form it does, ΔU = Q + W. It simply says that adding to the internal energy by heating a system, or doing work on the system [5].

When the second law of thermodynamics applied to the refrigeration cycle, it is important to know that conventional refrigerators operate following the principles of the mechanical steam compression cycle [6].

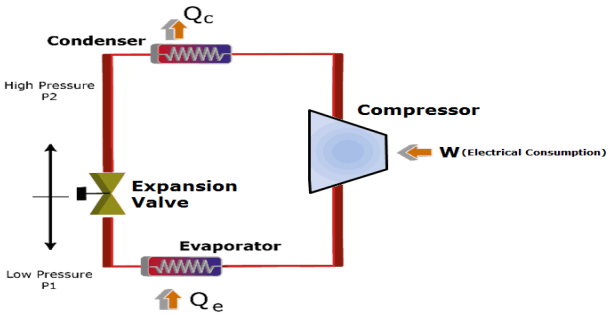

Figure 2 Vapor Compression Refrigeration Cycle.

Figure 2 shows the p-h diagram of a complete ideal vapour compression refrigeration system. Various calculations are done based on this system using different refrigerants. COP of vapour compression refrigeration system is a very important criterion for performance analysis. It represents the refrigeration effect per unit compressor work [6].

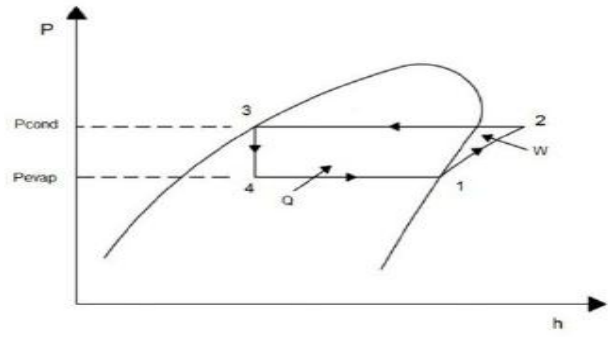

Figure 3 Ideal Vapour Compression Refrigeration Cycle in P-H Diagram.

First, remember that this cycle is based on the process of changing the physical state of the refrigerant fluid (from liquid to gas and vice versa). These substances condense (become liquid) at high pressures and evaporate (become gases) at low pressures. The cold in cooling systems happens due to the change of state of this liquid refrigerant fluid to gas.This process depends on the work done by the compressor which uses mechanical energy to compress the refrigerant fluid from the evaporator in the gas phase. With this compression, the pressure, and temperature of the refrigerant fluid increase.

$$W = h_2 – h_1$$

W = Work of Compression
When it enters the condenser, the refrigerant transfers the heat to the environment, causing its temperature to decrease and condensation occurs, which is the process of phase change from gas to liquid.

$$Qc = h_2 – h_3$$

Qc = Heat rejected in the Condenser
After that, the refrigerant fluid passes through the control element – capillary tube or expansion valve – which, by narrowing the passage, slows its speed on the evaporator, causing its pressure to decrease.

Constant Enthalpy

$$h_3 = h_4$$

The refrigerant fluid arrives on the liquid state and under low pressure to the evaporator, during which it is changing phase again, from liquid to gas. During the change phase, it absorbs the heat present in the conditioned items in the refrigerator case and returns to the compressor, restarting the refrigeration cycle [7].

$$Qe = h_1 – h_4$$

Qe = Refrigerating Effect or Cooling effect of the Evaporator

2. Project Development

2.1 Metal Frame

As shown in Figure, the metal frame is designed for mounting the refrigeration and air conditioning system which includes the electrical controls, components, and all wiring installations. The frame is fitted with roller casters to be easily moved around inside the classroom or shop area. The construction procedures are as follows:

- Make a project plan.
- Prepare the tools needed.
- Gather all the supplies and materials needed.
- Measure the rectangular tube to the desired length as specified in the plan.
- Cut the metal with the use of the hacksaw.
- Drill or bore holes for the mounting and installation of materials and accessories.
- Join the metal with the use of electric arc welding machine.
- Smoothen the welded surface using a portable electric grinder.
- Paint the frame.

Figure 4 Metal Frame.

2.2. Panel Board

The panel board shown in Figure 2.4 is fitted in the Formica board and frame. It is where the power generation can be monitored and the generated power can be distributed. The procedures involved are as follows:

- Make a plan for a panel board.
- Prepare the tools needed.
- Measure the plastic acrylic to the desired length as specified in the plan.
- Cut the plastic acrylic with the use of the cutter.
- Drill or bore holes for the mounting and installation on the panel board.
- Join the plastic acrylic with the use of a fastener.
- Smoothen the rough surface with fine sandpaper.

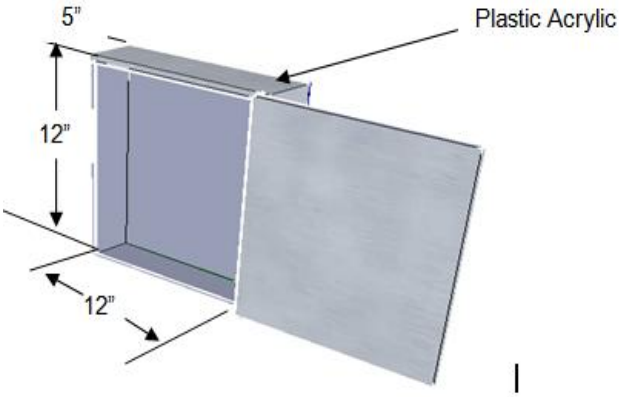

Figure 5 Panel Board.

3. Evaluation

The evaluation sheet is used to validate the Refrigeration and Air Conditioning Instructional Trainer. It consists of

5 criteria namely: Functionality, Reliability, Portability, Aesthetics, Economy, Safety, and Academic Impact. Each statement contains a single thought or idea which describes the trainer under the said criterion.

3.1. Research Instrument

The study uses the descriptive survey to ascertain the level of quality of the Refrigeration and Air Conditioning Instructional Trainer. Table 2 below presents the interpretation of the mean range. It also uses the 5-Point Likert Scale which is an ordinal level of measurement.

Table 2. Interpretation of the Mean Range and Weight

Mean Range	Weight
4.50 - 5.00	5
3.50 - 4.49	4
2.50 - 3.49	3
1.50 - 2.49	2
1.00 - 1.49	1

3.1.1. Respondents of the Study

The respondents of the study are randomly selected comprising twenty-three (23) students of the Department of Electro-Mechanical Technology directly involved in the Refrigeration and Thermodynamics subjects and two (2) faculty members of the Department of Automotive Technology of Mindanao University of Science and Technology (MUST).

3.2. Data Gathering Procedure

In gathering the data, the researcher distributes the survey questionnaire. Before answering the questionnaire, the researcher conducts a demonstration in operating the trainer then the respondents evaluate it according to the parameters stipulated in the questionnaire.

3.2.1. Quantitative Analysis

The researcher employs the mean to describe the level of quality of the Refrigeration and Air Conditioning Instructional Trainer.
Formula:

$$\bar{x} = \frac{(x_1 f_1 + x_{2f_2} + x_{3f_3})}{n}$$

$\bar{x}\}$ = Mean
X = Number of Responses
f = Class Marks Midpoint
n = Total Number of Respondents

III. RESULT AND DISCUSSION

The figures shown below are the design and the completed refrigeration and air conditioning instructional trainer. The trainer shows the evaporator coil enclosed with transparent plastic acrylic for easy viewing of the low-pressure gauge at the left side of the evaporator coil. The dual pressure control is installed at the top portion of the compressor for safety during critical running suction pressure and head pressure of the system. The compressor together with the copper tubing, hand valves, filter drier, sight glasses, low and high-pressure gauges allow the users to simulate and to inject mechanical faults in the refrigeration system.

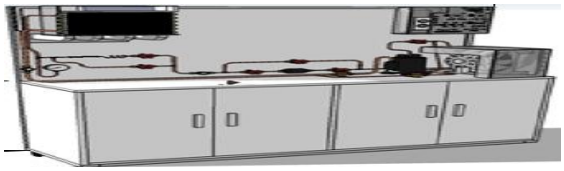

Figure 6 Prototype Design.

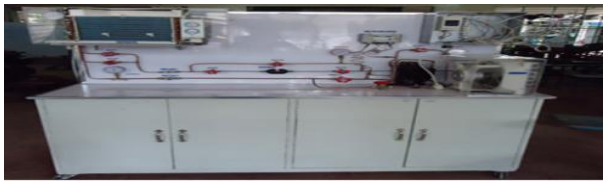

Figure 7 Completed Refrigeration and Air Conditioning Instructional Trainer.

Results of the data gathered indicated implications based on the mean value of each statement that corresponds to the given evaluation parameters are interpreted, analyzed, and discussed.
The discussions cover on:

- The effectiveness of the refrigeration and air conditioning instructional trainer in terms of functionality, reliability, portability, aesthetics, economy, safety, and academic impact;
- how the refrigeration and air conditioning instructional trainer applications affect the learning skills of the students; and
- How the students' knowledge and skills are assessed in the use of the instructional trainer for laboratory activities.

Table 2 below presents the overall mean of the respondent's evaluation of the refrigeration and air conditioning instructional trainer.

Table 2 Overall Mean

Evaluation Parameter	Mean	Qualitative Description
Functionality	4.6	Excellent
Reliability	4.5	Excellent
Portability	4.5	Excellent
Aesthetics	4.4	Very Good
Economy	4.4	Very Good
Safety	4.5	Excellent
Academic Impact	4.6	Excellent

Overall Mean 4.5

The overall mean of 4.5 rated as excellent is indicative that the objectives of the study are attained and are recommended for utilization.

IV. CONCLUSIONS

With the results of this study, the refrigeration and air conditioning instructional trainer serves its purpose in providing comprehensive teaching-learning capabilities to equip the users with thorough knowledge and skills. The trainer functions according to the design specifications with the capability to inject faults wherein users can simulate and troubleshoot the system. Further, the trainer is reliable since all the mechanical components and the electrical controls functioned accordingly.

The trainer is also portable because of its stable foundation with roller casters for easy transportation. Its aesthetics is presentable wherein components are properly mounted, labeled, neatly installed, and accessible to users. This instructional trainer is affordable and reasonable. It employs safety precautions to avoid risk to the users. Much more, it is the best equipment to enhance the learning capabilities of the students and other users to further their knowledge and skills as it gives life-long retention.

4.1. Recommendations

Though the level of quality of the Refrigeration and Air Conditioning Instructional Trainer is remarkable, the researcher recommended the following for further research:

- Use Programmable Logic Controller (PLC) monitoring and in detecting the pressure and temperature of the refrigeration system;
- Introduce more faults in the trainer to enhance the troubleshooting skills of the students; and
- 3 Mount a whiteboard for lecture purposes at the back of the trainer.

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