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Chilled Water Industrial Air-Conditioning System Simulator

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ABSTRACT-Facilitating learning of industrial technology courses lies on the capability of the instructor to design a curriculum relevant to the needs of the industry. The main purpose of this study was to design, assemble, and assess the performance of the Chilled Water Industrial Air-Conditioning System Simulator. This study was conducted at Bohol Island State University Main Campus, Tagbilaran City in the second semester of the school year 2017-2018. It was done to create a better understanding for refrigeration and air-conditioning students and electrical technology students on the industrial air-conditioning system and electrical controls operation. The control panel is held outside to allow students to manually perform the installation and troubleshooting of its hard wiring. The study employed the experimental research design in developing the device in the assessment of its performance. The descriptive design was used to determine the acceptability of the simulator in terms of its performance, durability, safeness, convenience and cost. The observation revealed that the device was 100% functional in terms of cooling ability and was 90-100% functional in terms of its functionality. This is an indication that the device is in very good working condition. The level of acceptability of the device had an average weighted mean of 3.74 and was described as "very high". The results proved that the device is suitable to be used as a device for instruction.

Keywords: Chilled Water, Air-Conditioning System, Simulator, Performance, Functionality.

INTRODUCTION

In the field of technical-vocational education in the Philippines where it employs the Competency-Based Training approach in learning, it emphasizes on what the learner can actually do. It focuses on the competency development of the learner as a result of training. Competency involves applying knowledge, skills and attitudes to perform work activities to the standard expected in the workplace. These are gained through life experiences, formal education, apprenticeship, on-the-job trainings, among others (National TVET Trainers Academy, 2012).

The use of mock-ups and simulators is one way of achieving the ideal industry-like environment. Cognitive Load Theory suggests that an effective instructional material facilitates learning by directing cognitive resources towards activities that are relevant to the schema acquisition (Plass, 2010). An instructional device that requires trainees to direct cognitive resources towards activities other than schema acquisition may be inferior. Learning media is everything that is used to channel messages and can stimulate thoughts, feelings, attention, and willingness to learn so that it can encourage the occurrence of a deliberate, purposeful, and controlled learning process (Miarso, 2009). Simulation is an imitation of the operation of real-world processes or systems over time (Banks & Nelson, 2004). Real objects or model objects that are very similar to real objects will provide a very important stimulus for students in learning tasks that involve psychomotor skills. The simulator is included in the context of M-learning with a new concept and contains content that is easy to use, and does not involve the location where the learner does it (Triatmaja & Khairudin, 2018). Simulation of industrial multi-processes control as a medium or means of practice has good performance in the use of learning in class (Sukir, 2010).

Chilled Water Air-Conditioning System Simulator is an instructional device that would help improve the teaching techniques of instructors. This device can be used to deliver quality education to students of Refrigeration and Air-Conditioning Technology. This device is designed under the motivation to address the inadequacy of learning tools that

students use in learning the industrial applications of air-conditioning. This can be used to assist the teachers in imparting lessons. This may be an effective tool to transmit information and ideas to the learners. The Chilled Water Air-Conditioning System Simulator was fabricated for the development of skills of the students and technicians in the installation and troubleshooting of electrical wiring of an industrial air-conditioning system. This lies in the conjunction with the Stimulus Condition which stressed, that in learning the more frequently a stimulus and a response are associated with each other, the more likely the particular response will follow the stimulus (Domjan, 2014).

The instructional device consisted mainly of a chilled water compartment, a cooling tower and an air-handling unit for the distribution of cold air inside the conditioned space, and a control panel for the students to perform the wiring installation. The chiller, which is used to produce cold water, is composed of a compressor, a water-cooled condenser, a capillary tube, an evaporator, a water pump and a specified amount of distilled water as secondary medium of heat transfer. Distilled water is utilized to make sure that cooling coils are less exposed to corrosion.

According to Wang (2001), this type of air-conditioning system operates under the principle of using chilled water as a secondary refrigerant. The primary refrigerant is the one present in the vapor compression system in the chiller which is, in the present case, R-22 or the monochlorotrifluoromethane. Water is cooled in the chiller until it reaches the temperature of 7^0C to 5^0C. This chilled water is then pumped to the air-handling unit which is also composed of a fin-static coils and a fan used to blow cold air inside the conditioned space at a maximum cooling temperature of 18^0C. This time, heat from the room is absorbed by the water inside the fin-static coils producing a condensate in the coils which is collected by a condensate pan below the cooling coils and disseminated outside through a drain pipe. The heat-carrying water, usually having a temperature ranging from 13^0C to 15^0C, goes back to the chilled-water compartment where it is, once again, re-cooled. This is in correspondence to the Second Law of Thermodynamics which states that heat always transfers from an area of higher temperature to that of the lower temperature (Althouse, et.al, 2014).

The creation of the Chilled Water Industrial Air-Conditioning System Simulator gives Refrigeration and Air-Conditioning technology instructors and trainers the edge to easily demonstrate the parts and functions of an industrial air-conditioning system. Moreover, they can conduct simulation of installation and troubleshooting with the use of this device. The hands-on application of students with this technology allows them to better understand the operation of this system. This way, students are well-prepared by the time they will graduate from the learning institution.

MATERIALS AND METHOD/S

The experimental and descriptive research design were used in conducting the study. The device was assembled and tested for its performance such as the cooling ability of its low and high fans selections in the different temperature setting in the thermostat. The observation was in accordance with the observation guide. After the experiment, questionnaires were distributed to thirty (30) respondents to assess its acceptability in terms of performance, durability, safeness, convenience and cost. The study was conducted at Bohol Island State University Main Campus, Tagbilaran City. This institution was chosen by the researcher since it is equipped with the facilities needed for designing and assembling the simulator.

The researcher utilized the purposive sampling method in choosing thirty (30) respondents composed of five (5) mechanical engineers, two (2) refrigeration and air-conditioning technology instructors, three (3) electrical technology instructors, ten (10) experts in the industrial air-conditioning applications from different industrial and commercial establishments and servicing shops in Tagbilaran City and ten (10) electrical technology experts from different industrial and commercial establishments in Tagbilaran City. They were chosen as respondents since they have the technical knowledge of the actual operation of chillers. They answered the observation guide to

validate the performance level and assessed the acceptability of the simulator.

RESULTS AND DISCUSSION

This presents the findings, analysis and interpretation and holistic project design of the study. Data were gathered, collated and tabulated in accordance with the specified statistical treatment. The construction of the Chilled Water Industrial Air-Conditioning System Simulator was based accordingly to its specified design. This design was the basis of the assembly of the device.

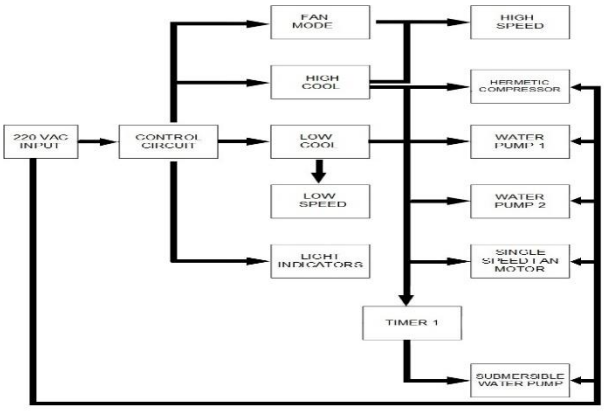

Figure 1. Block Diagram of the Chilled Water Industrial Air-Conditioning
System Simulator

Figure 2. Perspective View of the Chilled Water Industrial Air-Conditioning
System Simulator

Cooling Ability of the Chilled Water Industrial Air-Conditioning System Simulator

Table 1

Thermostat Setting/Expected Air temperature	Time	Ambient Air Temperature (^{0}C)	Low Cool		High Cool	
			Air Temperature (^{0}C)	Description	Air Temperature (^{0}C)	Description
1 25.5-26.5^{0}C	Morning 7:00-12:00nn	29.62	26.1	100% achieved	26.2	100% achieved
	Afternoon 12:00nn-5:00pm	31.40	26.1	100% achieved	26.2	100% achieved
	Evening 5:00pm-10:00pm	28.58	26.1	100% achieved	26.1	100% achieved
2 23.5-24.5^{0}C	Morning 7:00-12:00nn	29.90	23.9	100% achieved	24.0	100% achieved
	Afternoon	31.34	23.9	100% achieved	24.0	100% achieved

	12:00nn-5:00pm					
	Evening 5:00pm-10:00pm	28.68	23.9	100% achieved	24.1	100% achieved
3 21.5-22.5^{0}C	Morning 7:00-12:00nn	29.84	22.0	100% achieved	22.1	100% achieved
	Afternoon 12:00nn-5:00pm	31.32	22.0	100% achieved	22.1	100% achieved
	Evening 5:00pm-10:00pm	28.48	22.0	100% achieved	22.1	100% achieved
4 19.5-20.5^{0}C	Morning 7:00-12:00nn	29.62	20.2	100% achieved	20.2	100% achieved
	Afternoon 12:00nn-5:00pm	31.26	20.2	100% achieved	20.2	100% achieved
	Evening 5:00pm-10:00pm	28.64	20.2	100% achieved	20.2	100% achieved
5 17.5-18.5^{0}C	Morning 7:00-12:00nn	29.70	18.0	100% achieved	18.1	100% achieved
	Afternoon 12:00nn-5:00pm	31.30	18.0	100% achieved	18.1	100% achieved
	Evening 5:00pm-10:00pm	28.48	18.0	100% achieved	18.0	100% achieved

Table 1 shows the performance of the Chilled Water Industrial Air-Conditioning System Simulator in terms of cooling ability in the different times of the day, in the different thermostat setting both in low cool and high cool. The thermostat used was a manual type and cut-off temperature were based upon manufacturer's specifications.

During the observation, the device was let to operate in a close room with an area of 10 square meters. The device was tested in the morning, in the afternoon and in the evening where it shows that it has achieved 100% of the desired temperature in every thermostat setting.

Functionality Level of the Chilled Water Industrial Air-Conditioning System Simulator

Table 2

Item	Component	Function	Trial	Operation	Description
1	Compressor	Discharges refrigerant at 220 psi at the high-pressure side	1	Discharged refrigerant at 275 psi at the high-pressure side	100% Functional
			2	Discharged refrigerant at 280 psi at the high-pressure side	100% Functional

			3	Discharged refrigerant at 285 psi at the high-pressure side	100% Functional
		Draws refrigerant at 60 psi at the low-pressure side	1	Drawn refrigerant at 66 psi at the low-pressure side	100% Functional
			2	Drawn refrigerant at 68 psi at the low-pressure side	100% Functional
			3	Drawn refrigerant at 64 psi at the low-pressure side	100% Functional
2	Water Pump	Pumps water at 34.0 liters/minute	1	Pumped water at 34.0 liters/minute	100% Functional
			2	Pumped water at 34.0 liters/minute	100% Functional
			3	Pumped water at 34.0 liters/minute	100% Functional
3	Submersible Water Pump	Pumps Water at 10.5 liters/minute	1	Pumped Water at 9.5 liters/minute	90% Functional
			2	Pumped Water at 9.5 liters/minute	90% Functional
			3	Pumped Water at 9.5 liters/minute	90% Functional
4	Fan Motor	Low Speed: Rotates at the rate of 800 RPM at 80% efficiency	1	Rotated at the rate of 765 RPM	100% Functional
			2	Rotated at the rate of 760 RPM	100% Functional
			3	Rotated at the rate of 770 RPM	100% Functional
		High Speed: Rotates at the rate of 1800 RPM at 80% efficiency	1	Rotated at the rate of 1725 RPM	100% Functional
			2	Rotated at the rate of 1720 RPM	100% Functional
			3	Rotated at the rate of 1730 RPM	100% Functional
5	Magnetic Contactor	Closes NO contacts and opens NC contacts when energized	1	Closed NO contacts and opens NC contacts when energized	100% Functional
			2	Closed NO contacts and opens NC contacts when energized	100% Functional
			3	Closed NO contacts and opens NC contacts when energized	100% Functional
6	Magnetic Relay	Closes NO contacts and opens NC contacts when energized	1	Closed NO contacts and opens NC contacts when energized	100% Functional
			2	Closed NO contacts and opens NC contacts when energized	100% Functional
			3	Closed NO contacts and opens NC contacts when energized	100% Functional
7	Timer Relay	Delays the turning on operation of the	1	Delayed the turning on operation of the submersible water pump by 15 minutes	100% Functional

		submersible water pump by 15 minutes	2	Delayed the turning on operation of the submersible water pump by 15 minutes	100% Functional
			3	Delayed the turning on operation of the submersible water pump by 15 minutes	100% Functional

Table 2 shows the performance of the Chilled Water Industrial Air-Conditioning System Simulator in terms of functionality. Major components of the device were tested for actual operation then compared with the desired operations. It was found out that the major components of the device were 90-100% functional.

Acceptability of the Chilled Water Industrial Air-Conditioning System Simulator

Table 3

Acceptability	WM	Description	Rank
3.1 Performance			3
1. Air is cooled according to desired temperature setting in different times of the day.	3.80	VH	
2. Air temperature is maintained at constant temperature setting in different times of the day.	3.77	VH	
3. All components are functional.	3.73	VH	
Average	3.77	VH	
3.2 Durability			4
1. The simulator can stand through vibrations.	3.73	VH	
2. Simulator framing is made of steel square tube to hold the weight of the device.	3.67	VH	
3. Longevity of its electrical and mechanical components.	3.67	VH	
Average	3.69	VH	
3.3 Safety			2
1. Circuit breaker is used as over-current and short circuit protection for the simulator.	3.90	VH	
2. Electrical components are grounded	3.57	VH	
3. Electrical components are properly rated according to specified voltage and current.	3.73	VH	
4. Terminal connections and joints have adequate mechanical and electrical supports.	3.87	VH	
5. Conductors are all insulated.	3.90	VH	
Average	3.79	VH	
3.4 Convenience			1
1. Ports and terminals are accessible	3.83	VH	
2. Secondary refrigerant/water is readily available.	3.90	VH	
3. Troubleshooting of the different refrigerant circuit components is accessible.	3.90	VH	
Average	3.88	VH	
3.5 Cost			5
1. The Chilled-Water Industrial Air-Conditioning System Simulator has a total cost of Php67,680.20.	3.57	VH	

Average	3.57	VH	
Average WM	3.74	VH	

To sum up, the average rating of the Chilled Water Industrial Air-Conditioning System Simulator in terms of convenience ranked highest with a rating of 3.88 and was interpreted as "very high". It implies that the device was easy to use and requires less effort to operate and troubleshoot since ports and terminals are accessible. Another thing is that water, as the secondary refrigerant used, is very readily available especially here in our country.

Cost was described as "very high" and was ranked the lowest. Chilled Water Industrial Air-Conditioning System Simulator was expensive because the materials used were guaranteed to have quality to provide better performance during operation. Selecting the suitable material for a specific application is always considered in constructing instructional tools for imparting knowledge to students (Dym, et. al., 2004). Despite of this, the cost of assembling the device is much lesser compared to very huge equipment present in the industry which costs millions.

The overall weighted mean of the Chilled Water Industrial Air-Conditioning System Simulator was 3.74 which was described as "very high". The respondents assessed the device to be very highly acceptable to be used for instruction in refrigeration and air-conditioning technology.

The results of the study revealed the following findings:

On the Performance Level of the Chilled Water Industrial Air-Conditioning System Simulator in terms of Cooling Ability and Functionality

The Chilled Water Industrial Air-Conditioning System Simulator was able to 100% achieve the desired air temperature according to the different settings of the thermostat in the different times of the day, in both the low cool and high cool selection. Its components were also working according to the specifications and were rated as 90-100% functional.

The Acceptability Level of the Chilled Water Industrial Air-Conditioning System Simulator

The Chilled Water Industrial Air-Conditioning System Simulator was found to be highly acceptable in the aspects of performance, durability, safety, convenience and cost with a total average weighted mean of 3.74 and described as "Very High". Cost was ranked lowest with an average weighted mean of 3.57. Although it was ranked as the lowest, it was described as "Very High" by respondents.

CONCLUSION AND RECOMMENDATION

Based on the study's findings, the following conclusions were drawn:

The Chilled Water Industrial Air-Conditioning System Simulator was functional in terms of its performance as an equipment. It was able to cool air according to desired operation and its components functioned according to specifications. The device was rated "Very High" in all aspects. The device was acceptable as an instructional device.

It is recommended for shop instructors to introduce the Chilled Water Industrial Air-Conditioning System Simulator for BS Industrial Technology major in Refrigeration and Air-Conditioning Technology and BS Electrical Technology programs to assist the learning of students. It will be used particularly in curriculum related with industrial air-conditioning system.

School administrators are also encouraged to have their instructors construct instructional devices that replicate the actual functions of machines and equipment present in the industry.

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