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# Design and Construction of a Cold Production Simulator System: Chiller

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*system;*

**Abstract**

The design and construction of a cold production system from the ice water submitted by a mechanical direct expansion system contributing to the development of knowledge in the area of air conditioning were carried out. Among the technical design parameters, a direct expansion system with cooling capacity of 9000 BTU/Hrs, R134 refrigerant gas to a turbine for the work of the Fan Coil of ½ Hp of force 220 V was selected, as was the fan motor of the cooling tower as fundamental means for heat transfer. The recirculation pumping system is carried out by pumps of 0.37 kW of power and a maximum flow of 40 l/min. For both the evaporator sump (cold) and the condenser sump (hot). The work stage is given in two independent circuits, the Fan Coil system is connected to the evaporator sump and the cooling tower, in turn, is connected to the condensation system for proper operation and achieve condensation temperatures of 35 ° C and in case of having water requirements in the cold sump, the tower is connected by means of an electromagnetic valve for its supply.



**Contents**



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## 1 Introduction

Refrigeration and air conditioning are fundamental processes in industrial and service production, as continuous technological progress makes understanding essential and properly operate these systems, as well as the optimization of the different equipment used in the manufacture and assembly of these cold collection systems. The chillers are used both for the implementation of cold water pumping systems, and for the improvement of productive processes in which the cooling of certain machinery is required for its correct operation, as well as in the implementation of air conditioning in different workspaces such as offices, offices, buildings, shopping centers, hospitals, among others. The chilled water cooling system is one of several systems that allow air conditioning a certain environment, as this type of equipment is widely used in the industrial sector. These water management systems for each area, open and close the flow of water through specific areas keeping the air in the rooms at the desired temperature. It is important to highlight that, within the air conditioning systems or air conditioning systems, chilled water chillers (chiller systems) are one of the most used today for large cooling capacities; being these water-cooled equipment those that present greater efficiency than those cooled by air, because the temperatures reached for the condensation of the refrigerant, are lower when the water is used than when the air is used.

By definition chiller comes from the English word "chill" meaning frost, therefore, a chiller is general industrial chiller equipment of water, antifreeze or any type of brine that is common in the food treaty. The main objective of the chiller equipment is the exchange of heat in a certain process with which heat is extracted from a fluid, the heat energy gained returns to the cooling unit and thus reduces its temperature by repeating the circulation process (Copeland, 2010).

The chiller is a team that serves to cool water, it is also known as a generator of ice water. Chiller in the English language, it translates as refrigerator, fridge or fridge. Water Chiller is a more appropriate term for a water cooler. A chiller, like any refrigeration equipment, is composed of a compressor, condenser, expansion device and evaporator. Variations in these components give rise to different types of water coolers. For example, depending on the type of compressor used, chillers can be classified as scroll chillers, screw chillers, centrifugal chillers and reciprocating chillers (Ruelas, 2017; Castillo *et al.,* 2016).

According to (Castro & Mendoza, 2015) the chiller is a mechanism used regularly in the industry to produce cold water in industrial processes is the Chiller (water cooler), whose principle of operation is to extract the heat of the water used in a certain process in order to reduce its temperature to also reduce the temperature of the product to be obtained. In other processes, the water returns to the Chiller to be cooled again since it is not in direct contact with the product. In the case of concrete, water is used for mixing and is part contained in the final product. The chiller is basically a heat exchanger, consisting of a compressor, condenser, evaporator, expansion valve and coolant, as well as a pump for the delivery of water from its container to the chiller through pipes. It also usually has an automated electronic control board. Depending on the type of condenser, we find them as chillers with air-cooled condensers or water-cooled condenser. The function of the condenser is to transform the refrigerant in a gaseous state to the liquid state and thus reject the heat that is intended to be extracted from the system. The condenser is a heat exchanger where on the one hand the hot gas enters at high pressure and liquid flows to the expansion device (Ruelas, 2017).

The chiller uses two types of refrigerants, the main one is the one that uses the condensing unit to lower its temperature through mechanical compression, this thermal energy is transmitted to a secondary refrigerant through the heat exchanger. The energy assigned requires that the properties of these secondary refrigerants reach temperatures well below the freezing point of water, using mixtures based on glycol and other different salts. Calcium chloride dissolved in water better known as brine is one of the most commonly used secondary refrigerants in the industry due to its low cost and forms of presentation, it has different chemical and physical properties due to the change of concentrated solution in water. This makes these brines adapt very easily to different types of processes. Among the important components of the chiller refrigeration system are the hermetic compressor, plate evaporator, expansion valve, refrigerant charge and refrigerant charge effect on the evaporator (Macas & Toainga, 2015; Farfán *et al.,* 2019).

The cooling process is confused by most people with the term cooling when it is nothing more than a heat transfer process. The cooling consists of lowering the temperature of a certain enclosure or chamber below that of the environment and keeping it at that temperature, for this it is necessary to extract heat from said enclosure continuously or at least intermittently in a closed cycle (Ashrae, 2010). In refrigeration equipment the heat transfer is carried out through fluids known as refrigerants, the heat passes from a hot body to a cold body by the contribution of mechanical work or heat from the outside. Steam compression cooling is a case of mechanical work input and has become the most widely used method today for equipment that does not need to deliver more capacity (Tecumseh, 2002).

The cooling effect is understood as the amount of heat that a refrigerant is able to absorb while flowing in the evaporator as a liquid and ending up as steam. We can refer to the fact that liquids have a good cooling effect due to their high latent heat of vaporization, therefore it can be said that it is only the difference in heat due to the phase change when passing through the evaporator. When the refrigerant in liquid state approaches the valve its temperature is generally always higher than the vaporization temperature of the refrigerant inside the evaporator coil, from the same we can deduce that the cooling effect is usually less than the heat of vaporization (Macas & Toainga, 2015).

The process of changing the liquid-vapor phase is a well-known phenomenon that exemplifies the basic principles of thermophysical and transport that motivate the mechanisms of the condensation and vaporization processes (Carey & Sandberg, 2007), cited by (Zafar-Hayat *et al.,* 2019). Phase change procedures in porous materials exhibit a wide range of thermodynamic configurations. These procedures are commonly influenced by three factors (i) through the orientation of the heating and cooling of the surfaces, (ii) through the micro and macro scale geometry of a porous material and (iii) by interactions with convective procedures and conductive In nearby regions. The problems of mobile limit value in porous media are of practical importance in the storage of thermal energy, freezing of biological tissues, cooling of electronic equipment for food processing (Masur *et al.,* 1989; Mortensen *et al.,* 1989) cited by (Zafar-Hayat *et al.,* 2019).

In a centrifugal cooler, the evaporator is generally a full liquid evaporator. To keep the liquid level of the evaporator constant, it is usually equipped with a floating ball valve, which controls the flow of the refrigerant according to the liquid level of the evaporator. The evaporator liquid level is considered constant. Applying energy conservation, the amount of heat lost to the chilled water is equal to the amount of heat transferred from the side of the chilled water to the side of the coolant (Hao & Wang, 2014).

As is well known, the heating, ventilation and air conditioning (HVAC) system play an important role in modern life. It is essential in large buildings such as hotels, workshops, hospitals, etc. In terms of energy consumption, the energy consumed in HVAC The system represents more than 50% of the total energy of the building. The HVAC system runs under maximum load, however, in most cases, the actual load in the operating time is less than the full load. Obviously, these conditions cause a large sum of waste. Consequently, to save energy, the efficiency of the HVAC system needs to be improved. A typical HVAC system consists of an indoor air circuit, cold water circuit, coolant circuit, condenser water circuit, and outdoor air circuit. Researchers focused on different components, some in the cold water circuit, and some in the condenser water loop. To control the entire system, it is necessary to identify the HVAC models. Among the five procedures mentioned above, two water circuits and the refrigerant circuit are the most important, because the energy consumption of the three parts explains an overwhelming proportion of total energy use. The primary energy consumers of the water circuits and the refrigerant circuit are respective pumps and coolers (Yukui Zhang1 *et al.,* 2010).

The objective of this study is to design and build a cold production simulator system, known as Chiller to be used in the technical-technological training of the electromechanical students of the Paulo Emilio Macías Higher Technological Institute.

## 2 Materials and Methods

The investigation was carried out in the city of Portoviejo, province of Manabí, Republic of Ecuador, position 341 ° N, 170 ft high, 1 atm atmospheric pressure; in the facilities of the Paulo Emilio Macías Higher Technological Institute, with an experimental design based on several test tests at a variable rate interval, applied to an air conditioning system that aims to reach temperatures from 29 ° C to 18 ° C. To achieve this objective, the following materials were selected, detailed in Table 1, below:

Table 1
Materials and equipment for the preparation of the freezing system

| Description | Quantity |
|---|---|
| Angle 50x3mm2x1 / 8 | 4 |
| Iron galv.1220x2440x0.70mm 1/32 | 5 |
| Iron galv.1220x2440x0.40mm | 5 |
| Water drain 60x60x30mm | 2 |
| Water drain of 1.18x1.15x15mm | 1 |
| System of direct expansion capacity 9000 BTU / h | 1 |
| Water pump 0.5hp | 1 |
| Contactors of 9 Amp. of 220V | 3 |
| Plastigama tube ½ | 4 |
| Pedrollo manometer of 150 psiCutting | 2 |
| Tee of ½ | 10 |
| Bushin 1x1 / 2 ” | 5 |
| Extension of 5 m | 1 |
| Disc 4 ½” x 1/16”. | 2 |
| charging valve 2¼ | |
| Broca w / metal1/8 | 4 |
| Cable #12 m | 10 |
| Broca w / metal = | 5 |
| Elbow 1 / 2x90plastigama (90 °) | 10 |
| Teflon | 10 |
| Insulation tape. | 2 |
| Radiator | 1 |
| Fan | 1 |
| Copperm | 10 |
| pipeRefrigerant gas r22 | 2 |
| Propane gas | 2 |
| Silver welding rod | 2 |
| Silicone | 2 |
| Turbine 0.5 hp | 1 |

Source: Authors System

Description:
Figure (1) below shows the design made for the construction of the Chiller cooling system.

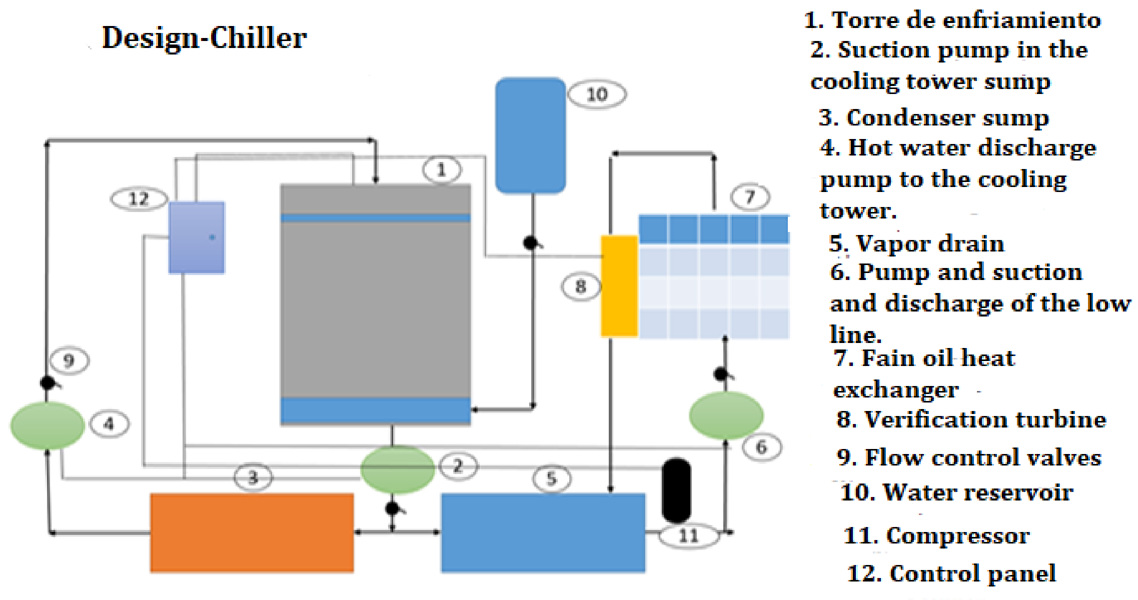


Figure 1. Design of the chiller

The simulation module-chiller is a simulation device with didactic application in the area of air conditioning, reaching a temperature of 18 ° C with internal dimensions of 2 $m^3$ of volume where all the units of functioning. In figures (2) and (3) you can see these operating units in the Chiller.

Figure 2. Chiller operating units

Figure 3. Chiller operating units

*Direct mechanical expansion unit:* This equipment has a capacity of 9000 BTU / h[1], with its equivalences of 2267 Kcal / hr, 2,636 Kw / Hr, 2636 W / hr, 2267 frig / Hr, 9450 KJ / Hr; intended for the exchange of heat in the high and low sinks, its operation will be carried out with the R22 refrigerant gas at a volume of 600 gr.

*Pumping Systems:* It has 3 water pumps, 2 for the high circuit and 1 for the low one; its characteristics Maximum flow rate Qmax: 40 l / min., power P: 0.37 Kw, voltage V: 115-230, Frequency: 60 Hz.

*Fluid level controllers:* The level controls will allow us to guarantee the water level in a range of preset variations. There are some differences in the conception of level controls, depending on whether they are: channels; Treatment plants; Water storage tanks or a reservoir, for our equipment there will be a control device in the reserve sump, low and high circuit sinks, as well as in the cooling tower sump.

*Sensors:* A sensor is a device capable of detecting physical or chemical quantities, called instrumentation variables, and transforming them into electrical variables. The instrumentation variables applied in the system will be temperature, pressure, volume; located in the sinks of the tower, the high and low circuit for the detection of temperatures and thus control the cold production processes.

*Condensing Unit:* The function of the condenser is to transform the compressed refrigerant gas inside the compressor into a refrigerant liquid. Inside the condenser, the refrigerant gas loses the heat that is absorbed during the evaporation process from the space to cool, as well as delivers the heat absorbed during its circulation through the return line to the compressor and the heat absorbed during the compression phenomenon inside the compressor.

*Evaporator Unit:* An evaporator is a heat exchanger used in refrigerant systems, where energy is exchanged ends from a medium whose objective is to transfer heat to the refrigerant, that is to say, that the refrigerant absorbs heat from the medium to evaporate.

*Cold handling unit:* It is composed of a radiator type panel reaching up to 3°C, with a turbine for heat absorption and delivery to the environment with a temperature of 18°C.

*Cooling Tower:* This unit It has the design of current Induced Draft to the flow of water to the collection sump where there will be an exchange of temperature with respect to the interaction between the condensation sump and the tower obtaining the reduction of 60°C to 35°C optimum temperatures to guarantee the Condensation process will also provide the water supply for both the high and low circuit, if necessary. Structurally, we have worked with Galvanized Sheet materials manufactured under ASTM A653G40 standard of 1.4 mm thick, its dimensions are 1220 mm wide by 2440 mm long[2] and iron angles 3.2 mm thick[3] as a support chassis for both camera and of mechanical equipment and electrical and electronic connections; also the structure will be joined by bolts of 1¨x 3/16 steel.

*Mechanical connection system:* PVC plastic pipes of ½ inch inside diameter, elbows at 90 ° T couplings, covered with an insulating material such as polystyrene were used in the connection pipes with a heat transfer coefficient K = 0.032 W / (mK ) at 0.044 W / (mK).

*Automatic control and control unit:* An order is issued to perform automatic chiller control.

*Verification processes:* The test procedure was carried out in the industrial conditioning systems laboratory workshop of the Paulo Emilio Macías Higher Technological Institute, in 15 measurements at a variable interval of 5 hours, for 5 days. As a measuring instrument, several temperature meters (Zhang & Faghri, 1996) were used, with the following characteristics.

[1] British Thermal Unit onTime
[2] Kubiec-Conduitmore than a steel (Metalworking and Locksmith)
[3] Acindar Grupo Arcelor Mittal-Pefiles, bars and planks

Table 2
Specifications instrumentation

| Description | features Technical |
|---|---|
| Infrared Thermometer<br>temperature gauge<br>and liquid<br>meter Room temperature<br>and humidity | *PM6530C Peak Meter*<br>*range -50 ° a800 ° C*<br>TA288 Stainless steel probe<br>Range: 50 ° C and 300 ° C<br>Peak Meter MS6508<br>Range: -20 to 60 ° C<br>Accuracy: +/- 0.5 ° C<br>RH: 0 to 100%, accuracy 2.0% |

Source: Authors

## 3 Results and Discussions

After the experimentation phase, the technical operation data were obtained of the chiller system with parameters in each work unit, in the cooling tower unit temperatures of 45°C inlet and 23.4°C of output were achieved, the condensing unit ranges between 45°C and 35°C, The cold unit is at a temperature of 8°C and an air temperature of 18°C and a humidity of 65% was obtained in the Cold Handling Unit.

Table 3
Parameters of energy costs system chiller-cooling tower

| Unit | Consumption (KW / h) | Time Operating (h) | Consumption operating (KW / h) |
|---|---|---|---|
| System operation circuit low: | | | 0.66 |
| Compressor | 0.66 | 0.5 | 0.33 |
| Pump Low circuit | 0.33 | 1.00 | 0.33 |
| High circuit operating system: High circuit | | | 0.41 |
| pump | 1.21 | 0.25 | 0.30 |
| Cooling tower fan | 0.44 | 0.25 | 0.11 |
| Control panel circuits: Control | | | |
| board | 0.22 | 1 | 0.20 |
| Total system consumption (KW / h) | | | 1.27 |
| Cost per consumption ($ 0.12-KW / h) | | | $ 0.15 |
| Consumption for 16h / 30 operating days | | | $ 73.15 |

Source: Authors

Table 4
Technical data of operation of the chiller-cooling tower system

| # | Description | Value obtained |
|---|---|---|
| 1 | The water inlet temperature of the condenser to the cooling tower | 58.86 ºC |
| 2 | Water outlet temperature in the evaporator unit | 6.74 ºC |
| 3 | Water cooling tower to the condenser | 23.74 ºC |
| 4 | inlet temperature from the Fan Co temperature il | 18.07 ºC |
| 5 | Refrigerant discharge pressure R22 | 250 PSI |
| 6 | Refrigerant suction pressure R22 | 50 PSI |
| 7 | Voltage | 220 V |

| | | |
|---|---|---|
| 8 | Consumption | 1.27KW / h |
| 9 | Cooling capacity | 9,000 BTU / h |

Source: Authors

The importance of a system as mentioned is that it has the ability to cool large areas such as shopping centers, hospitals, buildings among others with great efficiency, due to its control electronically, providing water at the desired temperature with more precision, and can lower the temperature to the water in Comparison with other equipment such as cooling towers. Because it is a generally closed circuit, water becomes less contaminated and its replacement is less, that is, there is not much evaporation loss. The installation is relatively small and the chiller generally has a large amount of pressure, temperature, flow, voltage, current sensors, which makes it very useful in terms of detecting problems in the system.

In the study of (Ruelas, 2017), the replacement of the aluminum-aluminum condenser to aluminum-copper condenser was carried out to avoid the loss of refrigerant gas, since the new material used for the manufacture of the condenser is more resistant to corrosion and moisture.

In this investigation, the chiller was manufactured with materials other than the usual ones, having functional results in relation to the variables studied, that is, the designed system is contributing to the process of technical-technological training of students of the electromechanical career of the Instituto Superior Tecnológica Paulo Emilio Macías of the city of Portoviejo.

## 4 Conclusion

The chiller cooling system, designed and built to provide practical training in superior technology, in electromechanics within the subject of refrigeration systems is an experiential example, that the use of recycled materials for the generation of equipment Like the chiller, it provides a useful source for obtaining positive data and results in certain areas that require maintaining a cooling temperature, in which a conventional system is not recommended. The built system is functional from the academic-technical-technological point of view, however, to take it to industrial scales, materials that are commercialized in the market for these purposes are required.

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