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Design of 40 URT Heat Pump for the Vertical Aquarium Energy Management System

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Abstract

In this paper, the vertical aquarium is designed for the new energy management system is called as a vertical aquarium energy management system (VAEMS). This energy management system is the first time in the world. In the future, this energy will be played a vital role not only to save energy, also eco-friendly to the world. Generally, many thermal power plants are wasting the hot water and send to the sea. So that, the thermal power plant could be used in their process and after that will be wasted. This water can be used for the vertical aquarium at the temperature range of 21^0c - 30^0c, but this temperature is maintained for the vertical aquarium so that, we specially designed a 40 URT heat pump. The main concept of 40 URT is to reduce the maintenance and electricity cost. The 40 URT heat pump made with specially designed like tube typed evaporator, semi screw compressor, plated type condenser and expansion valve. The main concept of 40 URT heat pump inlet temperatures is 15^0c and outlet temperature is 65^0c used to less electricity. In this, the heat pump totally monitoring with sensors. The experimental results of the heat pump have been satisfied for the design of the aquarium.

Keywords*: Vertical aquarium, energy, hot water, ICT VAEMS, 40 URT Heat pump, Heat management monitoring system*

1. Introduction

In this paper, the vertical aquarium is designed for the new energy management system. The energy management system also operated with a computer system which is designed specifically for the automated control and monitoring of those electromechanical facilities in a building which yield significant energy consumption such as heating, ventilation, and lighting installations. The scope may span from a single building to a group of buildings such as university campuses, office buildings, retail stores networks or industries. Most of these energy management systems also provide facilities for the reading of electricity, gas and water meters. The energy can be managed in Building energy management system (BEMS), now a day, the world needs to seek the renewable green energy which does not harmful to the environment. But this energy management system is new to the world; this energy management system is called as a vertical aquarium energy management system (VAEMS). This system is new to utilize the wasting thermal energy. In this process, many thermal power plants are wasting the hot water and sending to the sea water. So that, the thermal power plant could be used in their process and after that will be wasted [1].

In this energy management system, heat pump system is playing a vital role to design this system. Heat pump systems are energy-efficient devices and it provides heat water for the vertical aquarium. Commonly used heat sources and sinks are sea water, lake water, river water, ground water, earth, rock and waste water. Ambient air is free and widely available, and it is the most common heat source for heat pumps. However, the capacity and performance of air-source heat pumps decrease rapidly with decreasing ambient temperature during the heating season, and with increasing ambient temperature during the cooling season [2]. Especially in the continental climates during winter season, heat pumps cannot provide the necessary heating needed for the system requirements because of the low atmospheric air temperature and hence they may become idle during the heating season. In order to overcome this problem, heat pumps can also be used efficiently in colder climates by using some warmer waste heat source instead of the atmospheric ambient one.

For example, the average wasted warm water temperature to the vertical aquarium. Some of these implementations are about improving the quality of the waste heat at low temperatures by way of using a heat pump since heat pump can provide heating and cooling energy in much greater amount than their consumed energy. Also, hot water for usage in various utility needs can be produced by a heat pump. The amount of energy consumption for obtaining hot water in commercial buildings can be lower than that for heating, ventilation, and illumination, whereas it can be much more important in places providing service facilities such as [3] [4]. As known, the condensing temperature of a heat pump is about 65°C. Therefore, since the 1950's many researchers have conducted a lot of theoretical and experimental studies regarding the mechanics, thermodynamics analysis, cooling fluids (*i.e.* refrigerants), control systems, and economics of the hot water producing of the heat pumps systems [5] [6].

In this paper, how to use the waste hot water from the thermal power plants and pump into the vertical aquarium. This waste water can be stored into the buffer tank. The buffer tank maintains this temperature cannot be constant so that heat exchangers used to maintain the required temperature and this heat water send to balancing tank. In between heat exchanger and balancing tank installed inverter pump. This entire aquarium can be monitored using the sensors.

2. Design of Energy Management System for ICT VAEMS

The new energy management system was designed for the ICT vertical aquarium. The vertical aquarium mainly consists of Heat pump. The Heat pump mainly consists of condenser, compressor, expansion valve and evaporator as shown in Figure 1. A heat pump is a device that provides heat energy from a source of heat to a destination called a "heat sink". Heat pumps are designed to move thermal energy opposite to the direction of spontaneous heat flow by absorbing heat from a cold space and releasing it to a warmer one. A heat pump uses some amount of external power to accomplish the work of transferring energy from the heat source to the heat sink. A mainly heat pump is used to keep warm water in the vertical aquarium, in this heat pump used to reduce the cost and electricity. We are maintain 40 USRT means less electricity use and give the more quantity of hot water discharge. The condenser and the evaporator consist of heat exchangers, which are special tubes placed in contact with service fluids (which may be water or air) in which the refrigerant flows.

In the condensation the refrigerant flowing from the compressor passes from a gaseous to a liquid state, giving off heat to the outside. The model of the condenser is tubular type and the weight is 920 kg. The input temperature of the condenser is 28℃ and the output temperature is 65℃. The temperature source of the heat exchanger is 25℃.

In the Expansion: passing through the expansion valve, the liquid refrigerant cools and is partially transformed into vapor. The type of expansion valve is R-134a.

Evaporation: the refrigerant absorbs heat and evaporates completely. In this, we are using brazed plate type evaporator. The water circulation capacity of the evaporator is 63.20 LPM (liters per minutes) and the inflow and outflow of pipe dimensions are 50A.

Compression: the refrigerant, in a gaseous state and at low pressure, coming from the evaporator, is taken to a high pressure; during compression, it is heated, absorbing a certain amount of heat. The compressor model is the semi-enclosed screw. The capacity of control is 0~100% and court refrigerating capacity of this compressor is 13.19 RT. The Design specifications of Heat pump as shown in table.1.

2.1. The Energy Conversion Modeling of the Heat Pump Unit [7] [8]

In the entire heat pump system is considered a constant mass flow of refrigerant. The energy of refrigerant entering into an evaporator is:

$$Q_{eu} = q_{ref}.s_{eu}.T_{eu}(W) \tag{1}$$

The heat flow received from the environment through the evaporator can be expressed as :

$$Q_{evop} = q_{air}.c_a.(T_1 - T_2)(W) \tag{2}$$

Thermal power delivered by the compressor into a refrigerant

$$Q_{comp} = q_{ref}.(s - s_{evap}).(T_c - T_{evap})(W) \tag{3}$$

The energy input of refrigerant into the expansion valve

$$Q_{cond} = q_{ref}.s_{co}.T_{co}(W) \tag{4}$$

Subsequently, it can be expressed, that the heat flux input to the storage tank is reduced of the efficiency of the heat exchanger, which is around 70 - 80%.

The Equation (4) is used for the calculation as simplification because the s_{ev} and T_{ev} are not known. It presumes $Q_{cond} = Q_{evap}$

$$Q_{HP} = \left(\frac{Q_{\exp} + Q_{evap} + Q_{comp} - Q_{cond}}{q_{ref}\,\frac{S_{co} - S_c}{2}}.c.q_s \right).Q_z(W) \tag{5}$$

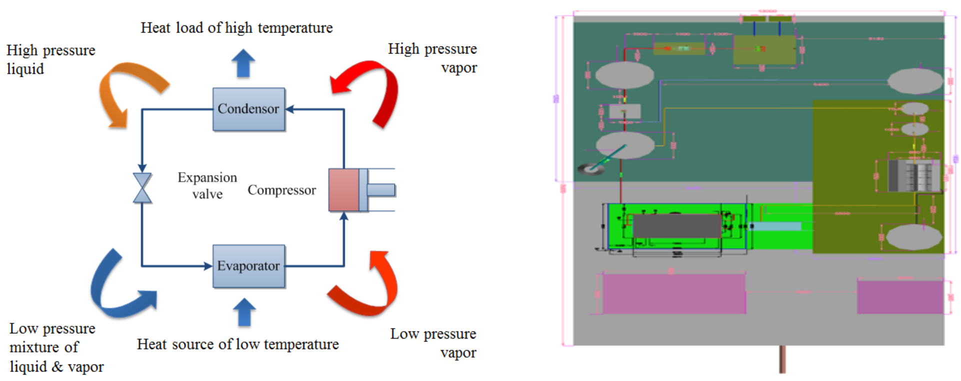
The calculation of mass flow of hot water into the accumulation tank is determined:

$$q_s = \left(\frac{q_{ref}.\frac{S_{co} - S_c}{2}}{c} \right)(kg.s^{-1}) \tag{6}$$

The coefficient of performance (COP) is related to the heating mode and it is determined from the energy output of the heat pump and the electrical energy.

$$COP = \frac{Q_{HP}}{W_c} = \frac{Q_{HP}}{\frac{Q_c}{\eta_c}} \tag{7}$$

where q_{ref}, q_{air} mass flow of refrigerant, air entering into an evaporator $kg.s^{-1}, q_s$ mass flow of water input to the accumulation tank $(kg.s^{-1}), s_{ev}, s_c,$ entropy of refrigerant behind the expansion valve, the compressor $(Jkg^{-1}.k^{-1}), s_{evap}, s_{co},$ entropy of refrigerant behind the evaporator, the condenser $(Jkg^{-1}.k^{-1}), T_{ev}, T_{evap},$ temperature of refrigerant behind the expansion valve, the evaporator (K), $T_e, T_{co},$ temperature of refrigerant behind the compressor, the condenser (K), $T_1, T_2,$ input and output temperatures of the air (K), $c_a, c,$ specific heat capacity of air, of water $(Jkg^{-1}.k^{-1}), W_c$ work done in compressor and η_c the efficiency of the compressor (%).

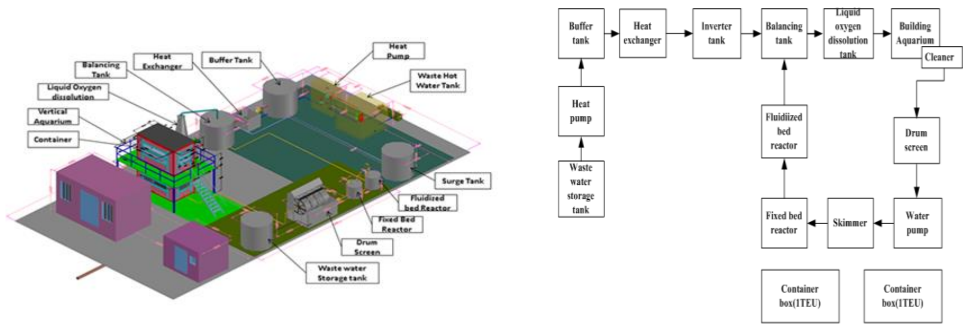


(a) (b)

Figure 1. (A) Block Diagram of Heat Pump (B) Layout of the Heat Pump

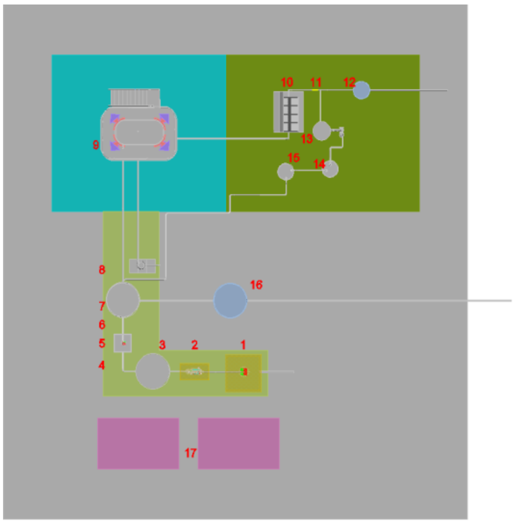
2.2. Design of Heat Pump for ICT VAEMS

This project initiated to ICT (Information of creative technology), ICT is the dealing best projects like city development and encouraging the creative thinking plans and support to fund too many projects. In this, the 40 URT heat pumps made with specially designed like tube typed evaporator, semi screw compressor, plated type condenser and expansion valve. An application of heat pump as shown in Figure 2(a). The target consists of mainly Heat management system, vertical aquarium, RAS plant and monitoring system. The heat management system consists of the waste water storage tank, Heat pump, buffer tank, circulated pump, heat exchanger, inverter pump, balance tank, liquid oxygen dissolution tank and RAS plant consist Drum screen, water pump, Drain out waste water tank, skimmer, fixed bed reactor, and ground water tank. The layout of the heat pump as shown in Figure 2(b). The top view of the vertical aquarium as shown in Figure 3. The water is taking from the waste water storage tank and send to the Heat pump. The Heat pump heats the water and sends to the buffer tank. Here, the buffer tank act likes a reservoir because when the water level down or no hot water at that time, this water can be used. The Heat exchanger can transform the heat from one form to another form like hot to cold or cold to hot vice versa. The



(a) (b)

Figure 2. (a) Application Target of Heat Pump (b) Application Targeted Heat Pump Layout



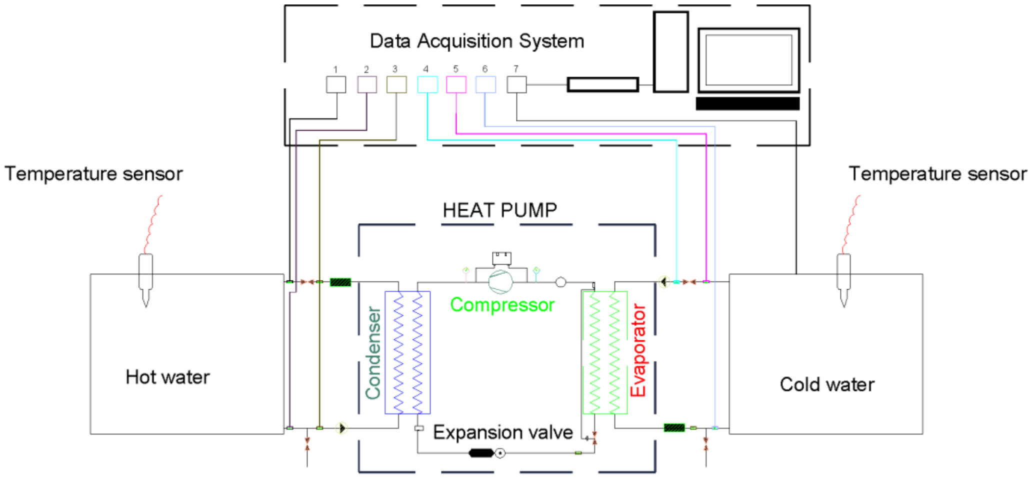
1.Waste water storage tank
2.Heat pump
3.Buffer tank
4.Circulated pump
5.Heat exchanger
6.Inverter pump
7.Balance tank
8.Liquid oxygen dissolution tank
9.Vertical aquarium
10.Drum screen
11.Water pump
12.Drain out waste water tank
13.Skimmer
14.Fixed bed reactor
15.Fluidized bed reactor
16.Ground water tank
17.Monitoring system

Figure 3. The Top View of the Vertical Aquarium

inverter pump can get hot water from the heat pump and whatever heat the water has. It keeps the constant temperature. The balancing tank balances the water after getting from RAS plant and inverted pump. This balancing water will be mixed with oxygen water tank to keep the certain level of oxygen in the water. The main concept of the building aquarium is to reduce the occupation of the more space. In this vertical aquarium, the aquariums are build one over another as shown in Figure 2 (a). This vertical aquarium has another advantage is operated with automation and totally controlled with sensors. The main concept of the building aquarium is reducing the space and controls the labor cost. This vertical aquarium can be monitored remotely. The cleaner is used to clean the aquariums and it is connected to the bottom of the aquarium with pipelines, the cleaner is collecting the dust from the aquarium and send to outside. The drum screen is connected to the lower tank of outflow of the aquarium. It is collecting the water from the aquarium and removes the unwanted dust like fish feed (waste), ammonia from grills and feces. The circulated water pump takes the water from the Drum screen and sends to the skimmer. The skimmer, fixed bed reactor, and fluidized bed reactors are kind of purifiers to purify the water. The two container boxes are used to monitoring and fish food storage.

2.3. Design of Heat Pump Monitoring Using Sensors

The schematic diagram of the water-water heat pump designed in this study for the aim of waste heat recovery is illustrated in Figure 4. The main components of the heat pump system are the compressor, condenser, evaporator, and expansion valve.



1 Temperature of hot water (i.e transport water) from condenser
2 Temperature of hot water (i.e transport water) to condenser
3 Flow meter (measuring water flow from hot water tank)
4 Flow meter (measuring water flow to cold water tank)
5 Temperature of cold water from cold water tank to evaporator
6 Temperature of cold water from evaporator to cold water tank
7 Temperature of cold water

Figure 4. The Schematic Diagram of Experimental Rig of the Heat Pump System

The operation principle of the system is as follows: in an ideal vapor-compression refrigeration cycle, the refrigerant enters the compressor as saturated vapor and is compressed isentropically to the condenser pressure. In fact, the refrigerant is slightly superheated at the compressor inlet to ensure that the refrigerant is completely vaporized when it enters the compressor [9]. The temperature of the refrigerant increases during this isentropic compression process to well above the temperature of the hot water (that is heat storage tank). The refrigerant then enters the condenser as superheated vapor and leaves it as a saturated liquid because of heat rejection to the circulating water. The temperature of the refrigerant at this situation is still above the temperature of the surrounding water.

The rejected heat is conveyed to the storage tank as heat energy by means of the circulation pump. The refrigerant is sub-cooled somewhat before it enters the throttling valve so that the refrigerant, in this case, enters the evaporator with a lower enthalpy and thus it can absorb more heat from the waste water source. The saturated liquid refrigerant is throttled to the evaporator pressure by passing it through an expansion valve. The refrigerant temperature drops below the waste water temperature during this process. The refrigerant enters the evaporator as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the heat source. The refrigerant leaves the evaporator as saturated vapor and reenters the compressor to complete the cycle. The evaporator and condenser of the heat pump are plate type heat exchangers and An external compensated thermostatic valve was also used in the system. The refrigerant used in the system was R134a (CH2FCF3—tetrafluoromethane) that does not harm the environment. Two separate 190 L capacity storage tanks insulated with 50 mm cotton wool material having a thermal conductivity of 0.035 W/mK were used as heat sink and source. Two transport water circuits that have three different circulation pump flow rates from the evaporator to the storage tank (*i.e.* heat source) and from the condenser to the storage tank (*i.e.* heat sink) were used. There are two insulated hot water tanks with a capacity of 10. A liquid retainer to prevent the return of the liquid refrigerant to the compressor, a prostate to protect the compressor, a sight glass to observe the physical conditions of the cooling fluid at the condenser exit and two manometers at the inlet and outlet lines of the compressor to measure the pressures were used in the system. The waste heat source temperature in the water tank was kept almost constant by using three electrical heaters. The operation of the heaters was controlled by means of a proportional–integral–derivative (PID) temperature controller. Temperature measurement sensors were attached to the water inlet and outlet lines of the waste heat tank. Heat output capacity of the condenser (*i.e* transferred heat rate to the hot water tank) was determined from the temperature and flow rate measurements of the hot water. Water temperature differences between the inlet and outlet of the condenser and evaporator were measured using K-type thermocouples inserted into the water line circuits. Volumetric flow rates of the water flowing through the system were measured with two turbine flow meters (Sika-VTH model) with an accuracy of $\pm 10^{-3}$, one at the outlet of the evaporator and the other one at the outlet of the condenser in the waste and hot water circuits [10]. The Specifications of monitoring sensors as shown in Table 1. It explains about the sensors for a heat pump. Heat pump mainly consists four components like condenser, evaporator, compressor and expansion valve. Each component has some specific sensors to monitor their parameters. The condenser has temperature, discharge and pressure sensors. The temperature sensor measures the heat load of high temperature. The discharge sensor is also called as a level sensor. The flow of water will be sensed and keeps the constant flow level of water. The pressure sensor is placed in between compressor and expansion valve. It senses required pressure to maintain at the output of condenser and input to the condenser. The expansion valve has an only pressure sensor. The inlet of the expansion valve has high-pressure liquid from the condenser and outlet of the condenser has a low-pressure mixture of liquid and vapor. So that, the pressure sensor keeps the required pressure. The evaporator has temperature, discharge and pressure sensor. The inlet of the evaporator is a low-pressure mixture of liquid and vapor and outlet of the evaporator is low-pressure vapor. Here, the pressure sensor controls the heating and cooling of the pressure to maintain the required pressure. The temperature sensor controls the low-level temperature from the heat source and discharge sensor maintains the constant flow of water. The inlet of the compressor is low-pressure vapor and outlet of the compressor is high-pressure vapor. The temperature sensor controls the heating and cooling of refrigerant. The discharge sensor controls the flow.

Table 1. Specifications of Monitoring Sensors for Heat Pump

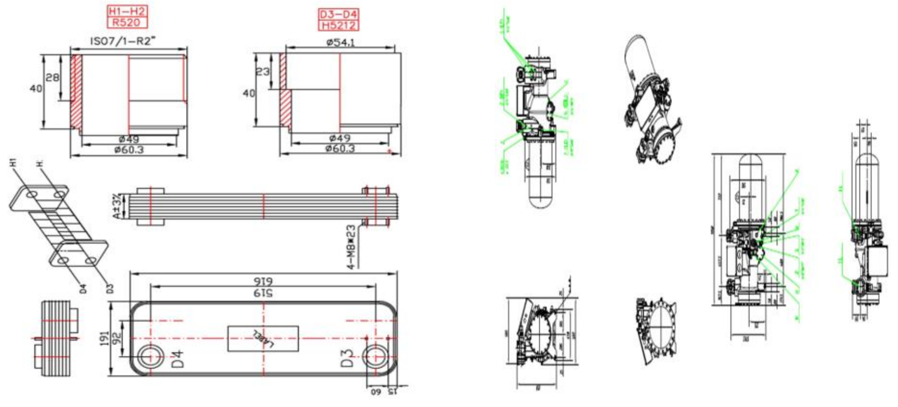
Equipment	Sensor	Name	Position	Physical data
Condenser	Temperature	K103FW R-T(NTC10KΩ)	Load	$(-40\sim120)^0$ c
	Discharge	Series VMM 40	Load	(1.5~45.2) m^3/s
	Pressure	ASK3000	Inhale Discharge	(1~1000) hpa
Evaporator	Temperature	K103FWR-T	Source	$(-40\sim120)^0$ c
	Discharge	SeriesVMM100	Source	(7~282.7) m^3/s
	Pressure	ASK3000	Inhale Discharge	(1~1000) hpa
Compressor	Temperature	K103FWR-T	Inhale Discharge	(-40~120) hpa
	Discharge	ASK3000	Inhale Discharge	(1~1000) hpa
Expansion Valve	Pressure	ASK3000	Inhale Discharge	(1~1000) hpa
Power		LD3410DR-120	-	(19.7~78.9) kwh

Table 2. Specifications of Monitoring Sensors for Vertical Aquarium

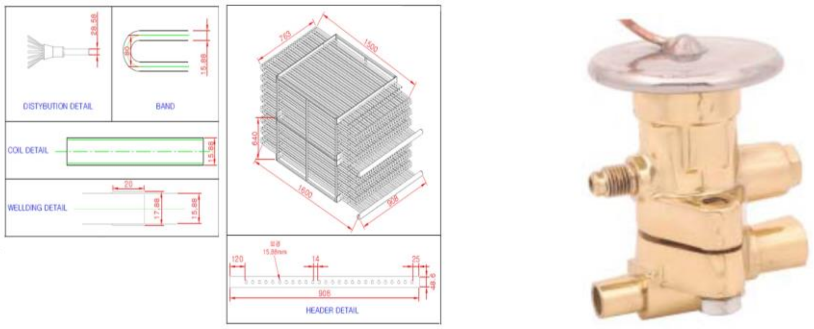
S. No	Vertical Aquarium Sensors		
	Equipment	***Sensor Name***	***Position***
1	Vertical Aquarium	Temperature	In flow
			Outflow
		Ph	Ph of water
		DO	DO in water

The monitoring of vertical aquarium sensors as shown in Table 2. In this Table, temperature, ph, and DO sensors are used to the vertical aquarium for monitoring. The temperature sensor used to control the inflow temperature and outflow temperature of water. The ph sensor used to control the ph of water and DO sensor used to maintain the required level of oxygen dissolved in the water.

3. Experimental Results



(a) (b)



(c) (d)

Figure 5. Manufacturing of Heat pump (a) Evaporator (b) Compressor (c) Condenser (d) Expansion Valve

Figure 6. The Experimental Results of Heat Pump

The manufacturing of Heat pump consists of the evaporator; compressor, condenser and expansion valve are designed for 40URT Heat pump as shown in Figure 4. The designed particular dimensions of the evaporator are shown in Figure 5(a). The refrigerant absorbs heat and evaporates completely. The designed particular dimensions of the compressor are shown in Figure 5(b). The 40 URT Heat pump is used for the vertical aquarium. The heat pump changes the temperature of the hot water and it maintains the thermal equilibriums. The 40 URT heat pump is essential to maintain the required temperature to keep the water warm. The designed particular dimensions of the condenser are shown in Figure 5(c).

Table 3. Experimental Results of Heat Pump

S.No	**Experimental Results**	
	PARAMETER	***VALUE***
1	Temperature	65^{o}c
2	Circular Difference Pump	15^{o}c
3	Water Capacity	6.48 ton
4	Heating performance	112.32kW
5	Capacity (Quantity of heat *120%)	40USRT

Table 4. Experimental Design of Heat Pump

Elements			**IWK-12D-46**
Performance	Heating performance	Kw	163.14
		Kcal/h	140,300
		USRT	46.4
	Power Consumption	Kw (heating)	48
Power Source			Φ3*380V*60Hz
Layout dimensions	Length	mm	1,700
	Height	mm	1,720
	Width	mm	850
Compressor			Semi-Enclosed Screw
	Startup Method		Y-Δ Startup
	Capacity Control	%	0~100%
	Count refrigerating Capacity	RT	13.19
Refrigerant	Type		R-134a
	Control		Expansion Valve
Heat Exchange(Load)	Circular Water Capacity	LPM	
	Pipe Dimension (In/Out)	A	
Heat Exchange (Source)			(STS 316L)
Weight	Kg		
Condition	Heating		

The design of the experimental heat pump set up as shown in Figure 6. The first level of the performance of the heat pump has been tested and the performance of the heat pump has satisfied. The experimental data of the heat pump as shown in Table 3. In the table, the performance of heating is 163.14 kW and burns 140,300 kcal/h.The power consumption of the heat pump is 48 kW. The power source connected to the heat pump is 3-phase, 380v, and 60Hz. The dimensions of the heat pump are length 1700 mm, width 850 mm and height 1720 mm. The temperature of the heat pump is 65and the capacity of the water is 6.48 tons. The quantity of heat is 92,200 kcal/h and the heating performance of the heat pump is 112.32 kW as shown in Table 4. The capacity of 40 URT heat pump has been satisfied. The temperature can be measured in degree celsius, the pressure can be measured in the hpa, the water discharge can be measured in m3/s and power consumption of the heat pump is kWh.

4. Conclusion

In the conclusion, the vertical aquarium was designed for the new energy management system through 40 URT heat pump. Generally, many thermal power plants are wasting the hot water and send to the sea. So that, the thermal power plant could be used in their process and after that will be wasted. In this, the hot water could be utilized for the vertical aquarium. The 40 URT heat pump is specially designed with tube typed evaporator, semi screw compressor, plated type condenser and expansion valve to accomplish the required criteria for the vertical aquarium. In this, the heat pump totally monitored with sensors. The experimental results of the heat pump have been satisfied for the design of the aquarium.

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