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RESEARCH ARTICLE

REALIZATION OF HEAT PUMP FOR RECYCLE ENERGY MANAGEMENT SYSTEM USING WASTED HOT WATER

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ABSTRACT

The present work is about the design and installation of the heat pump and vertical aquarium energy management system (VAEMS). This design is new invention to the world. The main concept of this project is to recycle the waste hot water produced from the power plants. This hot water after processing is filled in the vertical aquarium for aquaculture. The vertical aquarium means building the aquariums one over the other to reduce the space occupation. The processing of hot water is to maintain constant thermal equilibrium temperature of water in the aquarium that is suitable for fish living, which is possible by this design. This warm water is continuously supplied by the 48 URT heat pump according to the need. This design is eco-friendly,easily available, reduces maintenance and electricity cost. The design of aquarium is done based on experimental results of the heat pump. The dimensions of heat pump is 1700mmx850mmx1720mm (i.e length 1700 mm, width 850 mm and height 1720 mm) is installed on site. It can be operated with automation (PID) and controlled by sensors. The performance of and heat pump is evaluated experimentally by the monitoring system.

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INTRODUCTION

This energy management system is new to the world; it is called as vertical aquarium energy management system (VAEMS). In this paper, the vertical aquarium is designed for improving the aquaculture even at freezing temperature of surroundings. Especially in the cold countries it is challenging task to protect the fish at a freezing temperature to improve the aquaculture by maintains the constant temperature of warm water inside the vertical aquarium. It can be achieved by the thermal energy management system. Thermal energy management system is a solution to utilize various energy systems more effectively without harming the environment. The heat engines in the power plants, produces largest proportions of low temperature of heat called waste heat that rejects to the sink. Heat engines require cooling. In power plants the cool water is circulated for condensing process. Due to the heat exchanger temperature of this cool water gradually increases and becomes hot. This hot water is directly discharges in to the seas or oceans. It results in the death and decay of sea animals and plants causes thermal pollution. In the present project this waste hot water is recycled instead of increasing thermal pollution. This hot water is transported by means of thermal energy storage tanks by using PCM (paraffin wax) as a medium, recycled and used for the aquaculture in the vertical aquarium. This system is new to utilize the waste thermal energy to improve the aquaculture. In this process, many thermal power plants are wasting the hot water and discharging into the sea. So that, the thermal power plant could be used in their process and after that will be wasted (Ali Kahraman *et al*., 2009).Thus, this design consists of heat pump and other equipment as shown in Fig 2. That helps in circulating the waste warm water to vertical aquarium. Another important factor in building the vertical aquarium is space saving. The present scenario to build any equipment or infrastructure is based on the space saving according to the current needs. By keeping this context in mind, the vertical aquarium is designed, to save the space by placing the aquarium one over the other instead of side-by side like general construction. And the installation was also done as shown in the Fig 7. In this energy management system, heat pump system plays a vital role to design the system. Heat pump systems are energy-efficient devices and it provides hot water for 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 summer season and with increasing

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ambient temperature during the cooling season (Çengel *et al*., 2006). Especially in the continental climates during winter or cold season, heat pumps cannot provide the necessary heat needed for the system requirements because of the low atmospheric air temperature and hence they may become idle during the summer season. In order to overcome this problem, heat pumps can also be used efficiently in colder climates by using some warm 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 using a heat pump, since heat pumps 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 (Janicek, F) (Jiri Pitron). As we knew, 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 (Kim *et al*., 2004) (Kokkinides *et al*., 2002). In this paper, it is clearly shown that how to use the waste warm water and pump to the vertical aquarium. This waste warm water from power carrying by using heat transportation system and this water stored in to storage tank, this storage tank is connected to heat pump, and another side of the heat pump is connected to buffer tank. The buffer tank maintains this temperature cannot be constant so that heat exchangers used to maintain the required temperature and this hot water send to balancing tank. In between heat exchanger and balancing tank installed inverter pump. This entire aquarium can be monitored by the sensors.

Design of energy management using heat pump

The new energy management system is designed for the ICT vertical aquarium. The heat pump is a device that draws heat energy from a source of heat and transfer it to a destination called a "heat sink”, this process is based on the Carnot cyclic process. The vertical aquarium mainly consists of Heat pump that includes condenser, compressor, expansion valve and evaporator as shown in the Fig 1. In the condensation the refrigerant flowing from the compressor passes from a gaseous to liquid state, by rejecting heat to the sink. The model of the condenser is tubular type and the weight is 920 kg. The refrigerant absorbs heat and evaporates completely. The design specification of the compressor is shown in the Fig 6. In the Expansion: passing through the expansion valve, the liquid refrigerant cools and is partially transformed into vapour. 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 50mm. 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 the Table1.The Energy Conversion Modeling of the Heat Pump Unit (Kokkinides *et al*., 2002; Mastny *et al*., 2011). The heat pump uses some amount of external power to accomplish the work of transferring energy from the heat source to the heat sink. Mainly heat pump is used to maintain the warm water in the vertical aquarium and it helps in reduce the cost of electricity. We maintain 48 URT means consumes less electricity and gives the more quantity of hot water discharge. The condenser and the evaporator consist of heat exchangers that are special tubes placed in contact with service fluids (which are water) in which the refrigerant flows. (Luo *et al*., 2005)

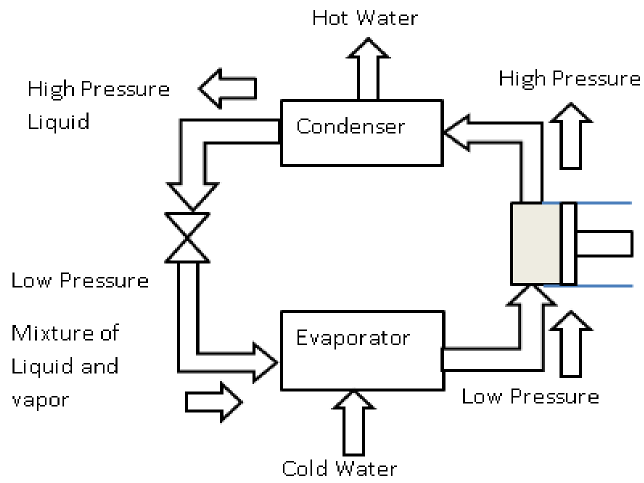

Fig. 1. The Heat Pump

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

$$Q_{evop} = q_{air} . c_a . (T_1 - T_2)(W) \quad (1)$$

Thermal power delivered by the compressor into a refrigerant

$$Q_{comp} = q_{ref} . (s - s_{evap}) . (T_c - T_{evap})(W) \quad (2)$$

The energy input of refrigerant into the expansion valve

$$Q_{cond} = q_{ref} . s_{co} . T_{co}(W) \quad (3)$$

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 $Q_{cond} = Q_{evap}$

$$Q_{HP} = \left(\frac{Q_{exp} + Q_{evap} + Q_{comp} - Q_{cond}}{q_{ref} \frac{S_{co} - S_c}{2}} . c . q_s \right) . Q_z (W) \quad (4)$$

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

$$q_s = \left(\frac{q_{ref} \cdot \frac{S_{co} - S_c}{2}}{c} \right) \left(kg.s^{-1} \right) \quad (5)$$

Table 1. 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
	Length	mm	1,700
Lay out dimensions	Height	mm	1,720
	Width	mm	850
Compressor			Semi-Enclosed Screw
	Startup Method		Y-△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		

Table 2. Specifications of monitoring sensors for heat pump

Equipment	Sensor	Name	Position	Physical data
Condenser	Temperature	K103FWR-T(NTC10KΩ)	Load	(-40~120)^{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	(-40~120)^{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

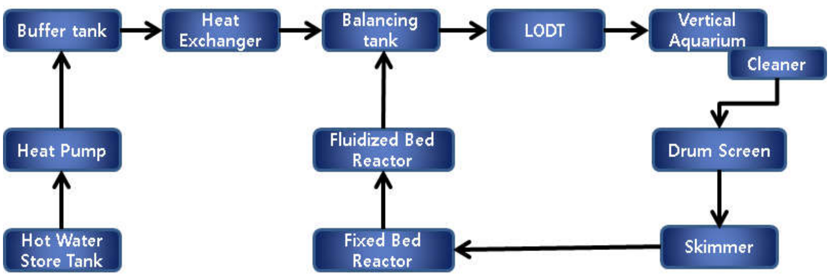

Fig 2. Application targeted heat pump layout

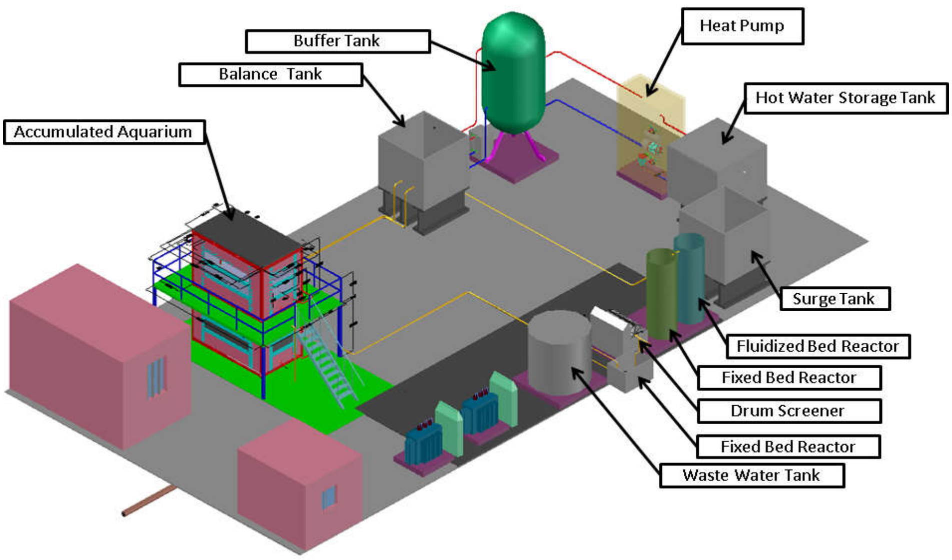

Fig. 3. Schematic diagram of vertical aquarium plant for energy management

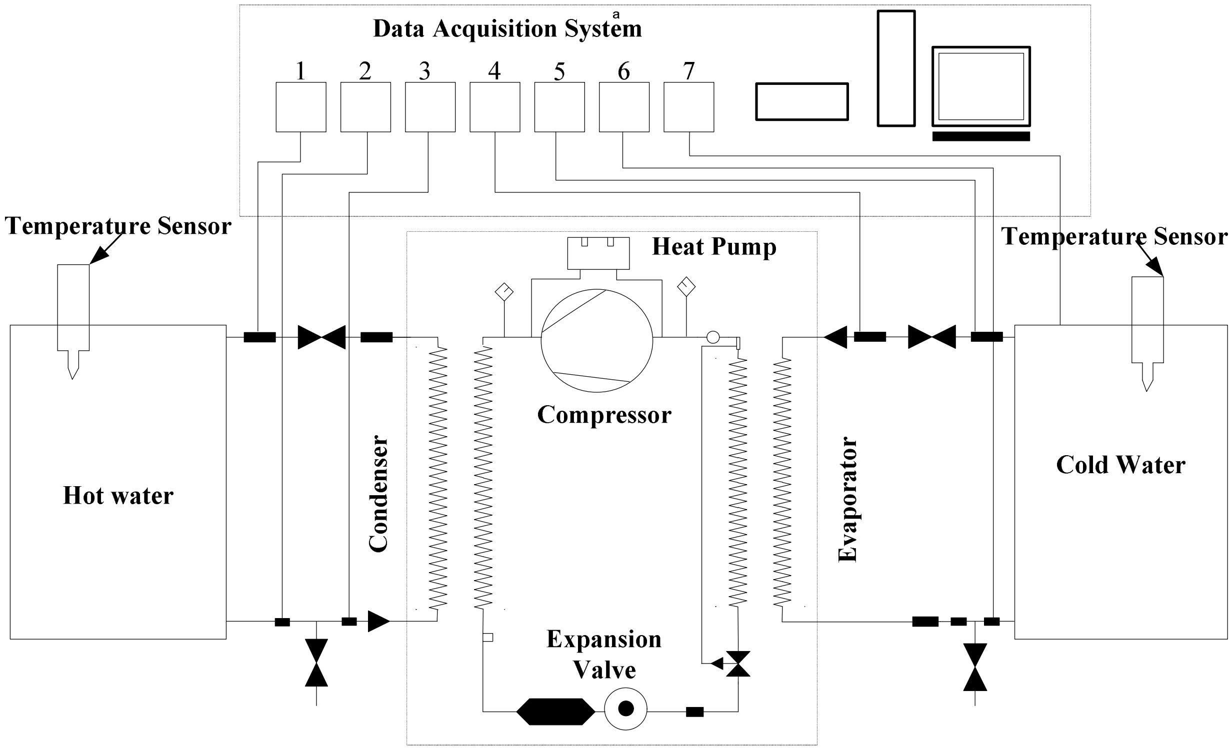

Fig. 4. Heat pump monitoring system

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.

$$COP = \frac{Q_{HP}}{W_c} = \frac{Q_{HP}}{\frac{Q_c}{\eta_c}} \quad (6)$$

where q_{ref}, q_{air} mass flow of refrigerant, air entering into an evaporator $kg.s^{-1}$, q_s mass flow rate 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 (%).

Design of energy management system and processing of waste warm water to vertical aquarium

The heat management system is designed especially for fish in the aquarium. The water temperature is major criteria in the environment of fish. Hence proper care is to be taken for maintaining the suitable temperature for the fish in aquarium. Hot water for usage in various utilities can be produced by heat pump. The condensing temperature of heat pump is 50°c and the temperature of water for domestic purpose is 45°c (Mason *et al*., 1997). The development of heat pump system with domestic hot water can reduce the thermal pollution according to (Zhang *et al*., 2007; Neksa *et al*., 1998). The heat management system consists of waste water storage tank, Heat pump, buffer tank, circulated pump, heat Exchanger, inverter pump, balance tank, liquid oxygen dissolution tank, and RAS plant consists of drum screen, water pump, drain out waste water tank, skimmer and fixed bed reactor. The layout of the heat pump as shows in the Fig 2, and Fig 3. Two transport water tanks with three different circulation flow rates from evaporator to storage tank (heat source) and from condenser to storage tank (heat sink) were used, The waste water from the power plants are transported by heat delivery system using PCM to the vertical aquarium. Vertical Aquarium system mainly consists of hot water storage tank, heat pump, buffer tank, balancing tank, surge tank, RAS and aquarium tank as shown in Fig 3.The working process is as follows: the waste hot water with constant temperature of 30-35°c, from the power plants is collected into the hot water storage tank. This warm water is pumped to the heat pump to heat the water up to 60~65°c and this water is collected in the reservoir called buffer tank. Buffer tank will supply warm water whenever needed. The temperature in the aquarium is maintained constant thermal equilibrium temperature at 25°c to 29°c, for the comfort condition of fish living in the aquarium. Hence this hot water sent to the balancing tank where the hot water is mixed with the cold water, which is supplied from the surge tank, to maintain the constant temperature of 25-29°c in the aquarium. This vertical warm water is pumped to the aquarium tanks as in Fig 3. And installation is show in Fig 7.The cleaner is used to clean the aquariums and it is connected at the bottom of the aquarium tanks with pipelines, and it collects the dust from the aquarium and drain out to waste water tank. RAS system is mainly consists of the drum screen, fixed bed reactor and fluidized reactor, water collecting form aquarium tanks to drum screen the drum screen is nothing but a physical filter it is removing the sludge and dust molecules like fish feed, fish pee from the water, and also same times collecting the excessive flow water from the aquarium tank and send out this water. (Marek Miara *et al*., 2010; Sanjeevchandra, 2016)

Table 3. Specifications of monitoring sensors for vertical aquarium

Vertical aquarium Sensors		
Equipment	Sensor Name	Position
Vertical Aquarium	Temperature	In flow Out flow
	Ph	Ph of water
	DO	DO in water

Table 4. Heat Pump Specification Unit

S.No	**Specifications**	
	Expression	*Position*
1	Input and Output temperature	Condensor, Evaporator and Compressor
2	Difference Temperature	Condenser and compressor
3	Refrigerant Pressure	Condenser, Evaporator, Compressor and Expansion valve
4	Water Discharge	Condenser and Compressor
5	Power Consumption	Heat pump

Table 5. Experimental results of heat pump

S.No	Experimental Results	
	Parameter	*Value*
1	Temperature	65°c
2	Circular Difference Pump	15°c
3	Water Capacity	6.48ton
4	Heating performance	112.32kW
5	Quantity of heat	48USRT
6	Power consumption	14.99 kwh

After sometime there is gradual decrease in the temperature of warm water filled in the vertical aquarium, hence again this cold water which is purified by RAS, is pumped to the balancing tank for maintaining the constant temperature of 25-29°c.This entireprocess is cyclic. (Yunus *et al*., 2015)

Design of heat pump monitoring system using sensors

The vertical aquarium and heat pump are monitor remotely and controlled by the sensors hence the design of heat pump monitoring system by using sensors is arranged as shown Fig. 4. (Kyoo Jae *et al*., 2016) The schematic diagram of the waste-water heat pump designed in this study for the aim of waste heat recovery is illustrated in Fig. 3. The main components of the heat pump system are compressor, condenser, evaporator and expansion valve. The operation principle of the system is as follows: in an ideal vapour-compression refrigera-tion cycle, the refrigerant enters the compressor as saturated vapour and is compressed is entropically 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 (Obüyükalaca *et al*., 2003). The temperature of the refrigerant increases during this isentropic compression process to well above the temperature of the hot water (i.e. heat storage tank).The refrigerant then enters the condenser as superheated vapour and leaves 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 completely evaporates by absorbing heat from the heat source. The refrigerant leaves the evaporator as saturated vapour and re-enters 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 A liquid retainer to prevent the return of the liquid refrigerant to the compressor, a presorted 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 attached to the 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) is 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 one at the outlet of the evaporator and the other one at the outlet of the condenser in the waste and hot water circuits (Zhang *et al*., 2007). The Specifications of monitoring sensors as shown in the Table 2, and it explains about the sensors for 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. Condenser has temperature, discharge and pressure sensors. The temperature sensor measures the heat load of high temperature. The discharge sensor is also called as level sensor. The flow of water will be sent and keeps the constant flow level of water. 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 only pressure sensor. The discharge sensor controls the flow. The monitoring of vertical aquarium sensors as shown in the Table 3.

The inlet of the expansion valve has high pressure liquid from the condenser and outlet of the condenser has 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 evaporator is low pressure mixture of liquid and vapour and outlet of evaporator is low pressure vapour. Here, the pressure sensor controls the heating and cooling of the pressure to maintain the required pressure. The temperature sensor control 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 vapour and outlet of the compressor is high pressure vapour. The temperature sensor controls the heating and cooling of temperature as shown in the table 4. 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, as well as measure the temperature of water. These sensors measure in flow and out flow of the water.

EXPERIMENTAL RESULTS

The main components of Heat pump consists of evaporator, compressor, condenser and expansion valve are designed for 48URT Heat pump as shown in the Fig 5. The designed particular dimensions of the evaporator is shown in the Fig 5(a). The refrigerant absorbs heat and evaporates completely. The designed particular dimensions of the compressor is shown in the Fig 5(b) The heat pump changes the temperature of the hot water and it maintains the thermal equilibriums. The 48 URT heat pump is essential to maintain the required temperature to keep the water warm. The designed particular dimensions of the condenser is shown in the Table 1. The design of the experimental heat pump set up as shown in the Fig.6.

The first levelperformance of the heat pump hastested and the performance of the heat pump was satisfied. The experimental data of the heat pump as shown in the Table 5. In this 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, and the dimensions of the heat pump is 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 the table 3. The capacity of 48 URT heat pump has been satisfied. The heat pump specification parameter units as shown in the table 5. 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 powerconsumption of the heat pump is kwh as shown in the Table 5.

(a) (b) (c) (d)

Fig. 5. Componentsin heat pump (a) Evaporator (b) Compressor (c) Condenser (d) Expansion Valve

Fig. 6. The Experimental setup of Heat Pump and Monitoring Control System

Fig. 7. Vertical Aquarium and Overall system of VEAMS Installation on site

Fig. 8. Results of Heat pump by monitoring system

Fig. 9. Results of Heat pump by monitoring system

The Fig 9 shows the experimental results of 48URT heat pump. The COP of the heat pump is calculated as the ratio of output thermal energy to input electrical power consumption. The temperatures at expansion valves, evaportaor, compressor and condenser were monitored as: The experimental results obtained from the monitoring of heat pump system is as follows, the working fluid, in its vapour state, is pressurized and circulated through the system by a compressor. On the discharge side of the compressor the high temperature of 26.5°c, inflow temperature is 24°c and pressure of 4hpa of the refrigerant is observed, and it is sent to cool in a heat exchanger called condenser, until it condenses into high pressure of 6hpa and moderate temperature liquid of 25°c is observed. The condensed liquid then passes through a pressure lowering device called expansion device and yields the reading of pressure as 3hpa.This low pressure liquid then enters to evaporator, in which fluid absorbs heat from the inflow as 24.5°c and outflow temperature is obtained as 28°c at a pressure of 2.5hpa.The refrigerant then returns to the compressor and cycle is repeated. The power consumption is 14.9kwh to 15 kwh is observed. These temperatures yield the better performance of heatpump. Hence the further work has been carried out by successful installation of the VAEMS on site

Conclusion

The aim of this project is to evaluate the coefficient of performance of heat pump when it is coupled with waste warm water from power plants and to observe how effectively it is recycled for improving the aquaculture. The following conclusions were made by this design of VAEMS:

- Vertical aquarium energy management system is designed and installed on site.
- Experimental results of heat pump at ambient temperatures yields better performance of heat pump.
- Thermal pollution in seas and oceans can be reduced.
- Waste water from the power plants can be recycled for improving the aqua culture.
- This design is mainly done for automatic operation and controlled by sensors.

Vertical aquarium energy management system is successfully install as shown in the Fig7 and we installed sensors in vertical aquarium as shown in the Table 3. The Fig 9 shows the experimental results of 48URT heatpump. The COP of the heat pump is calculated as the ratio of output thermal energy to input electrical power consumption. The temperatures at expansion valves, evaporator, compressor and condenser were monitored and we get experimental results as shown in the table 5 and heat pump monitoring system as shown in the Fig 4 we monitoring condenser, compressor, evaporator and expansion valve respectively inflow out temperatures, pressures and power. We develop the heat pump monitoring system as shown in the Fig 8 for monitoring the temperature level inlet and out of the heat pump is success fully installed. The fundamental requirement for a 48URT heat pump obtained the temperature of heat source and heat sink is very slight different. Furthermore, the report emphasize that achieving a good effectiveness, that is saving energy, is more important than achieving efficiency. Both aims could mainly be influenced in advance during process. When considering the installation of a heat pump, primer step is to analyses the energy saving, importantly connection with vertical aquarium. The ways in which energy could be saved should be thought in advance. We get very good result would be reflected in the installation of 48URT heat pump with temperature is 60~65c as well as lower electrical energy usage. In this way we get very good result. The design and manufacture of 48URT heat pump is field test could show in Fig. 5 and Fig. 6 this heat pump systems operate very good. Further processing, however, 48URT heat pump is very good efficiency. It is a constant of the COP value. In future we can apply this heat pump to the domestic purpose. We proposes this processing the industrial application also.

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