Heating Zuara Desalination Plant Housing Units Using Available Hot Water

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ABSTRACT

Heating systems are used to provide places and people at the right temperature at times of increased cold for comfort, without such heating systems, people have to spend most of their energy and ability in resisting cold winter in the colder areas of the earth. Zuara desalination plant contains three production units of a multi-effect type with a design capacity of $40{,}000\, m^3/day$. The plant has 28 housing units for the staff of the plant. The location of the housing units near the beach gives it an amazing weather in the summer, but in winter it needs heating. Due to the availability of hot water in the desalination plant, it can be used to heat these units. This work studies the extent of hot water produced in the heating of housing units. This could be done by calculating the heating loads of residential buildings and selecting the appropriate types of heating units and the design of the network of pipes; including the calculation of size, type of pipes used, valves and fittings needed for the delivery of hot water to the residential buildings. Furthermore, the appropriate flow rates and pressures of the system and the choice of type, quantity and capacity of the necessary pumps are also demonstrated. The study showed that the total load of heating in residential units reached 360.6 kW. This amount of thermal energy can be supplied when using hot water directly from the water produced at 40°C using a large heating system with high flow rates of hot water. Water flow rates and system size can be reduced by using fan coil units at the same temperature as 40°C.

Keywords: Heating system; hot water; desalination; fan coil.

1 Introduction

In recent years, heating systems gained important developments and concern, especially in cold countries. The development of internal heating systems has enabled humans to live and work in locations far from the warmer areas of the world. Without such heating systems, people have to spend most of their time and energies in resisting very cold climate.

Central heating is one of the best types of heating systems because of its low risk to property and people. It has a low cost of installation and maintenance. It also provides good health conditions throughout the place where it is heated, adding fresh air to the space and longer use than other heating systems. This type of heating system depends on the transfer of heat from the heating source to the thermal radiators inside the building, and is based on a number of systems, including the use of diesel or by pumping hot water, steam or hot air, which is used to transfer heat to the building through a network of pipes connected to heat source.

Water is used as an intermediary transfer fluid for heat transfer as the cheapest and safest media. It is heated in special boilers, and then circulated in a pipe network by circulating pumps. It is then distributed to heat exchangers and radiators; the heat is then transferred to the air of the space. This system is the most common in heating homes, schools, hospitals and hotels. The hot water heating system is characterized by lower installation and operational cost than other systems and provides good health conditions with ease of maintenance.

There are many studies and researches in the field of using hot water in the central heating as per the study carried out by Dietrich Schmidt and others in 2017 [1], the study was about the low temperature distract heating for future energy systems. Results show that the utilisation of lower temperatures reduces losses in pipelines and can increase the overall efficiency of the total energy.

A review of water heating technologies; an application to the South African context, was a study carried out by P.A. Hohnea and others [2]. The purpose of this study is to provide a survey of the most frequently used domestic water heating technologies. It aims to critically analyse and summarize recent advancements made in renewable and non-renewable water heating technologies. Results of this survey identify gaps in existing research. It focuses on a new perspective on the importance of energy efficient hybrid water heating systems and the cost savings they might offer.

M.Köfinger and other [3] presented an article about Low temperature district heating in Austria: Energetic, ecologic and economic comparison of four case studies. The paper describes the development of economically and ecologically optimized concepts for low temperature district heating networks using four representative case studies in Austria. The results of the study show that the availability and economic conditions of low temperature heat sources is a key factor for facilitating Low Temperature District Heating (LTDH) networks. In rural areas, lower heat losses due to lower network temperatures are beneficiary for the LTDH network performance.

Zuara desalination plant contains three production units of a multi-effect type with a design capacity of 40,000m^3/day. The plant includes in addition to the production units many facilities such as workshops, operating control room, and administrative building, as well as 28 housing units 400 meters from the production units, and because of the view of these residential units on the sea makes them suitable for housing in summer, but they need heating in winter. Heating water is produced at a temperature of up to 40°C, which may be considered suitable for the use in heating housing units.

The objective of this study is to study the extent of using hot water produced by Zuara desalination plant in heating the housing units of the plant in order to reduce the electricity consumption in heating by calculating the heating loads and then selecting and designing the appropriate system.

2 Materials and Methods

Figure (1) shows the layout of one of the residential units with the designed comfortable temperature for each room. The average temperature of the water produced by the desalination plant is 40°C. The distance between the hot water source and the residential housing buildings is 400 meters. The data for the residential units including details and type of walls, ceilings, doors, windows, roofs and floors were obtained from the site. The collected data are used in calculating the heating loads. The pumps were selected from KSB manufacturer [4] and the radiators and fan-coil units were selected from KORADO and SCHAKO suppliers, respectively [5, 6].

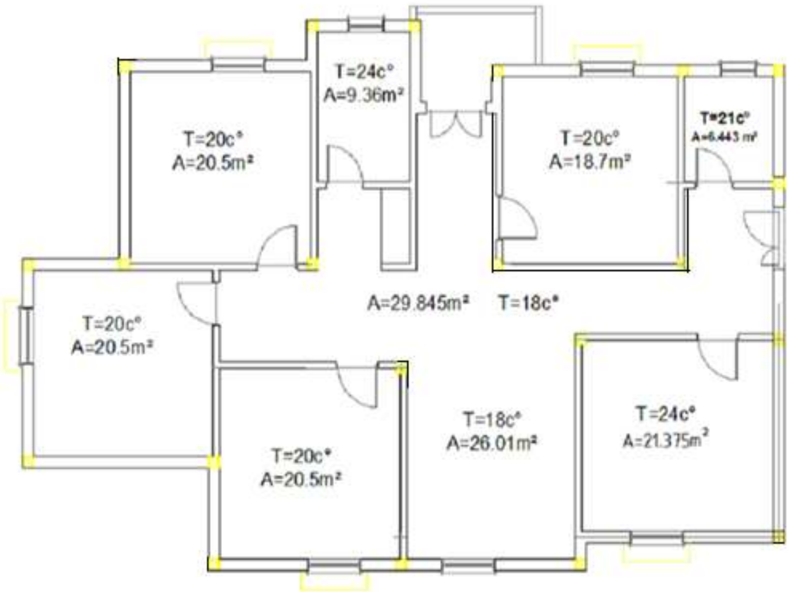

Figure 1: Housing Unit Layout

3. Theory and Calculation

The use of hot water at low temperature for heating greatly reduces the thermal losses to the environment and provides a lower cost of thermal insulation. The only drawback is the need of large water quantity to overcome the building heating loads which should be calculated first to find the system components such as the size, pressure, flow rate, capacity and pump size.

3.1 Heating Loads

The heating loads used to estimate the heat loss from the building to the outdoor environment can be calculated by [7]:

$$Q = U.A(T_{in} - T_{out}) \qquad (1)$$

where:

U: The overall heat transfer coefficient (W/m^2K)

A: Heat transfer area (m^2).

T_{in}: Building inside temperature (°C).

T_{out}:Building outside temperature (°C).

3.2 Required hot water

The amount of hot water required for the heating system can be calculating using:

$$\dot{m_w} = \frac{Q}{Cp(T_{in} - T_{out})} \qquad (2)$$

where:

Q: Total building heat load (kW).

C_p: Specific heat capacity of water (kJ/kg.K).

T_{in}: Inlet hot water temperature to the system (°C).

T_{out}: Outlet hot water temperature from the system (°C)

3.3 Pipeline network design

A pipeline network contains sets of pipes and fittings, many factors should be taken into account if an adequate flow rate is to be achieved without using oversized pipe. The required volume flow rate and the pressure available are very important parameters. Other factors that have to be considered include; pipe diameter, length, type and number of fittings. In this study, PPR pipes (Polypropylene Random Copolymer) were used due to their low friction factor, thermal conductivity and corrosion resistance.

3.3.1 Pipe line diameter

For long gravity flow pipelines, the starting point in selecting the pipe diameter is to determine the smallest pipe that can pass the required flow without friction loss exceeding the available head. The following equation is used to calculate the pipeline size [8]:

$$D = \sqrt{\frac{4.\dot{V}}{\pi.v}} \qquad (3)$$

where :

D: Pipe diameter (m)

$\dot{V}$: Water volumetric flow rate (m^3/s)

v: Water Velocity (m/s)

3.4 Pipeline network head losses

Calculating pressure drop in pipeline network in meter head of water is very important for selecting the right pump to provide the required flow rate. The system total head losses is the sum of major and minor losses and it is calculated by [8]:

$$h_l = f \frac{L}{D} \frac{v^2}{2\,g} \qquad (4)$$

$$h_{lm} = f \frac{L_e}{D} \frac{v^2}{2\,g} = K \frac{v^2}{2\,g} \qquad (5)$$

where:

h_l: Major losses in pipes (m).

f: Friction factor.

L: Pipe length (m).

h_{lm}: Minor losses (m).

$\frac{L_e}{D}$: Equivalent length of equipment.

K: Minor loss coefficient of equipment.

v: Water velocity (m/s)

g: Gravity acceleration (m/s^2)

3.5 Pump size

The pump size must conform to the flow rate, pressure, speed and suction conditions. After the system head is calculated it can be used to evaluate the pump power rating in kW from this formula [8]:

$$P = \frac{\dot{V}\rho g H}{3.6x10^6 \eta} \qquad (6)$$

where:

$\dot{V}$: System total water flow rate (m^3/hr)

ρ: Water density (kg/m^3)

g: Gravity acceleration (m/s^2)

H: System total head (m)

η: Pump mechanical efficiency

4. Results and Discussion

The results were obtained by using the building component details and equations outlined in the previous section. The calculation was conducted using one house only. The house consists of two floors. The presented results include building heating load, suitable number and loads for radiators in each room, pipeline network pressure drops, suitable number and load of Fan Coil Units (FCU) for each room, total pipeline network pressure drop and selected pumps' characteristics. It also presents a comparison between the radiators and fan coil units systems.

4.1 Building heating load

The heating load of the building is determined from equation 1 after calculating the overall heat transfer coefficient by using the building construction details, areas and directions. The details of comfortable temperature design for building spaces are shown in Figure 1 and the outside temperature design is 9 °C.

Table 1 presents the heating loads for one house building. The house is two floors building. The first column shows the heating loads for the first floor rooms. It can be noted that the guest room provides the highest load and bathroom 1 has the lowest load. The heating load of the second floor is presented in the second column. The total load of the second floor is higher than the first floor because of the contact of the roof to the environment while the first floor is insulated from the external environment by the second floor. The third column shows the total house load of $25.756\ kW$. The total residential building load was found out to be $360.6\ kW$.

Table 1: heating load of one house building

Room	Heating Load 1st Floor (kW)	Heating Load 2nd Floor (kW)	Total House Load (kW)
Bathroom 1	0.726	0.887	1.613
Guest room	2.113	2.775	4.888
Bathroom 2	1.25	1.521	2.771
Bedroom 1	0.978	1.444	2.422
Bedroom 2	1.55	2.021	3.571
Bedroom 3	1.322	1.788	3.11
Kitchen	1.194	1.633	2.827
Hall	0.88	1.319	2.199
Corridor	0.894	1.461	2.355
Total Load	***10.907***	***14.849***	***25.756***
Total residential buildings load (kW)			**360.6**

4.2 Radiator system

Heat transfer in radiators depends on radiation and natural convection. To select the suitable radiator for each room, the radiator heating load design should be known and selected from the manufacturer catalogues. For this study the KORADO radiators company has been used. For the available hot water of 40°C, radiator type 40/35 has been selected from the manufacturer catalogue. Number 40/35 designates the inlet and outlet hot water temperatures. the suitable number and load for the radiators is selected based on the room load and the water flow rate calculated by equation 2. Table 2 shows the suitable number and load for radiators in each room in the first and the second floors.

Table 2: Suitable number and loads for radiators in each room.

Room	Design Room Temp. ° C	Room Load (kW)		Correction Factor	Radiator Load (kW)		Water flow rate (kg/s)		Suitable Radiator Load (kW)		No. of Radiators	
		Floor			Floor		Floor		Floor		Floor	
		1st	2nd		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Bathroom 1	21	0.73	0.89	4.62	3.35	4.10	0.16	0.20	3.66	4.16	1	1
Guest room	24	2.11	2.78	5.54	11.7	15.4	0.56	0.73	5.99	5.33	2	3
Bathroom 2	24	1.25	1.52	5.54	6.93	8.43	0.33	0.40	3.66	4.33	2	2
Bedroom 1	20	0.98	1.44	3.93	3.84	5.67	0.18	0.27	3.85	5.99	1	1
Bedroom 2	20	1.55	2.02	3.93	6.09	7.94	0.29	0.38	6.26	4.66	1	2
Bedroom 3	20	1.32	1.79	3.93	5.20	7.03	0.25	0.34	5.33	7.22	1	1
Kitchen	20	1.19	1.63	3.93	4.69	6.42	0.22	0.31	4.78	6.66	1	1
Hall	18	0.88	1.32	3.41	3.00	4.50	0.14	0.21	3.02	4.66	1	1
Corridor	18	0.89	1.46	3.41	3.05	4.98	0.15	0.24	3.36	5.33	1	1
Total							**2.29**	**3.08**	**39.9**	**48.3**	**11**	**13**

From the results presented in Table 2, the hot water flow rate needed for the two floors is 5.37 kg/s. Based on this result, the pressure drop in the pipeline network is calculated using equations (4 and 5) which is used to select the right pump that can provide the mentioned radiators hot water flow rate. The values of the calculated pressure drops in the pipeline network are summarized in Table 3.

Table 3: Pipeline network pressure drops.

Pipeline Path	Major losses (m)	Minor losses (m)	Total Losses (m)
Internal pipes Network	38.13	21.41	59.54
Main pipeline	2.75	2.65	5.40
Total	40.88	24.06	64.94
Building Units Total Losses (m)			**129.88**

4.3 Fan Coil Unit system

Heating with fan coil units provide fast and uniform warm air flow distribution. In this study, the fan coil units were selected from SCHAKO suppliers. To select the adequate unit for each room, the rooms load should be known. Table 4 shows the results of the suitable number and load of Fan Coil Unit (FCU) for each room in the first and second floors. It can be observed that all rooms in the first and second floors require one radiator accept the guest room, due to the high fan coil load, requires two radiators. The total number of radiators needed are nineteen.

Table 4: Suitable number and loads for FCUs for each room.

Room	Design room Temp. (°C)	Room Load (kW)		Air flow rate (kg/s)		Fan coil Load (kW)		Water flow rate (kg/s)		No. of Radiators	
		1st Floor	2nd Floor	1st Floor	2nd Floor	1st Floor	2nd Floor	1st Floor	2nd Floor	1st Floor	2nd Floor
Bathroom 1	21	0.73	0.89	0.18	0.19	2.17	2.31	0.05	0.06	1	1
Guest room	24	2.11	2.78	0.56	0.66	8.5	10.0	0.20	0.24	1	2
Bathroom 2	24	1.25	1.52	0.29	0.35	4.37	5.28	0.11	0.13	1	1
Bedroom 1	20	0.98	1.44	0.19	0.33	2.16	3.65	0.05	0.09	1	1
Bedroom 2	20	1.55	2.02	0.38	0.54	4.25	5.97	0.10	0.14	1	1
Bedroom 3	20	1.32	1.79	0.29	0.39	3.21	4.32	0.08	0.10	1	1
Kitchen	20	1.19	1.63	0.23	0.43	2.57	4.77	0.06	0.11	1	1
Hall	18	0.88	1.32	0.19	0.29	1.74	2.63	0.04	0.06	1	1
Corridor	18	0.89	1.46	0.19	0.33	1.74	2.98	0.04	0.07	1	1
Total								**0.74**	**1.00**	**9**	**10**

From Table 4, the hot water flow rate needed for the two floors is 1.74 kg/s. The pressure drop in the pipeline network is calculated using equations (4 and 5) which is used to select the pump that provides the needed flow rate for the fan coil units. Results of the pressure drop in the pipeline network are summarized in Table5.

Table 5: Total pipeline network pressure drop.

Pipeline Path	Major losses (m)	Minor losses (m)	Total Losses (m)
Internal pipes Network	38.35	21.02	59.37
Main pipeline	5.50	5.30	10.81
Total	43.85	26.32	70.18
Building Units Total Losses (m)			**140.35**

4.4 Pump selection

Depends on the hot water flow rates and pressure drop in sections 4.2 and 4.3, the suitable pumps were selected from KSB manufacturer. Selected pumps' characteristics are illustrated in Table 6.

Table 6: Selected pumps' characteristics

System	Pressure drop (m)	Water flow rate (m^3/hr)	Pump power (kW)	Pump efficiency (%)
Radiators	129.88	136.3	63.75	75
Fan Coil Units	140.35	88.1	44.75	75

4.5 Unit selection

Table 7 shows a comparison between the results of the two proposed systems for covering the buildings heating load that were illustrated in sections 4.2 and 4.3.

Table 7: Comparison between the two proposed systems.

System	Total load (kW)	No. of units	Building load rate (kW)	Load rate (%)
Radiators	1572.2	336	360.6	400
Fan Coil Units	1015.9	266	360.6	300

However, when choosing a radiator system, the heating load value is 4 times the designed heating load, whereas, when choosing a fan coil unit system, the loads of the units are reduced to 3 times of the designed load. The water flow rate and the pump power decreases, but there is an increase for consumption due to the presence of the fans.

5 Conclusions

The use of hot water at low temperatures is suitable for heating residential units because of its safety, low operational cost and low thermal losses. This study showed that the water produced by the desalination plant can be used directly at 40°C using radiators, or heating units of the type of Fan-Coil. The amount of water needed for radiators is larger than that water needed for Fan-Coil units. The use of fan coils reduces the size and capacity of the pump.

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