REPLACEMENT OF GAS BOILEIR BY GEOTHERMAL/AEROTHERMAL VRF-HEATPUMP FOR SWIMMING POOL HEATING IN MOROCCO.

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Abstract - *Faced with the challenges of the rapid increase in energy consumption in Morocco, where more than 95% of energy needs are imported from outside, energy efficiency has become one of the key issues in all areas of activity. In the latter, the energy needs are very varied and the heating systems represent a significant part of the electricity consumption. According to the AMEE [1], Morocco has set itself the goal of achieving energy savings of 15% by 2030, through the implementation of an energy efficiency plan in the various economic sectors. This is particularly the heating systems.*

To respond to this situation, we replaced a gas boiler system with ground source VRF (variable refrigerant flow) heat pump mixed with aerothermal VRF for heating an outdoor swimming pool in Rabat (Morocco). The objective of this article is to analyze the electrical consumption of the new installation and define the real ROI based on two years running of this pilot site.

***Key Words*:** Swimming pool heating, very low enthalpy geothermal energy, VRF, Geothermal, Aerothermal, Electricity consumption, ROI.

1. INTRODUCTION

Morocco is an energy importing country because it has virtually no natural resources to meet its energy needs.

Over the past decade, the country's energy needs have increased significantly. This is mainly due to the industrialization of the country and the good global economic dynamics.

In view of these elements, the exploitation of geothermal resources in Morocco allows the production of thermal energy in a sustainable way for the heating of swimming pools.

2. EXISTING INSTALLATION

Most of the heat used for non-electric heating results from the combustion of hydrocarbons. The combustion of gas mainly emits water vapor and carbon dioxide (CO_2). Thus, Morocco notes a weakness of non-renewable resources.

The system is equipped with two propane gas boilers with an output of 800 kW.

- Annual propane consumption is approximately 81.4 tonnes

- The average price of propane in Morocco during the year of operation is 12.9 MAD / kg

- The price paid for one year is: 1 050 000 MAD (Moroccan dirham)

3. NEW INSTALLATION

A heat pump (VRF) is a thermal machine that uses mechanical energy (compressor pumps) to extract low-temperature heat from an environment and restore it at a higher temperature to make it usable for heating needs.

We have installed a mix system between 30% geothermal heat pump and 70% aerothermal heat pump to guarantee energy performance.

The set temperature is 29 °C

The well is at 22 m, with a temperature of 15°C and a capacity of 20 m3/h

To estimate the calorific power to be installed, a heat balance must be carried out taking into account the most unfavorable external conditions of the year:

Thermal balance during the filling phase in order to deduce the calorific power required during filling P1.

Thermal balance enabling the calorific power required to maintain the temperature of the pool water at 28°C during the operating period P2 to be deduced.

With:

Estimation of the heating capacity during the filling phase:

P1 = Surface losses + Wall heat losses + Water and concrete heating - Solar gains

-Surface losses = Losses by evaporation + losses by convection + losses by radiation

Evaporation loss- source ASHRAE 2019:

When the vapor pressure of the ambient air is lower than the saturated vapor pressure at the surface of the water, evaporation of water occurs.

In the literature, several scientific formulas deduced from experiments make it possible to quantify losses by evaporation.

In this project, I chose to use the formula from the American ASHRAE 2019 [2]:

$$\text{kW } P_{evap} = S_{water}\left(P_w - P_a\right)\left(0,089 + 0,0782 \times V\right) \times 0,5$$

$$\text{kPa } P_a = HR\% \times P_w$$

With:

0.5: is a coefficient linked to the activity in the basin. During the filling phase, there is no swimmer. We then multiply by a coefficient of 0.5, as shown in the following table.

The following activity factors should be applied to the areas of specific features, and not to the entire wetted area:

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Type of Pool	Typical Activity Factor (F_a)
Baseline (pool unoccupied)	0.5
Residential pool	0.5
Condominium	0.65
Therapy	0.65
Hotel	0.8
Public, schools	1.0
Whirlpools, spas	1.0
Wavepools, water slides	1.5 (minimum)

Outside temperature when filling: 10 °C

Desired water temperature (setpoint): 28 °C

Ambient air speed at 1m from the pool surface: V = 1.2 m/s

Pw (saturated vapor pressure): at T = 28 °C, Pw = 3.783 kPa

Pa (saturation pressure): at T = 10 °C and for relative humidity RH = 70%;

$$\text{kPa } P_a = 0,7 \times 1,228 \approx 0,86$$

Swater= 340.12 m2 (Water surface)

$$\text{kW } P_{evap} = 90,89$$

Convection loss:

Convection is one of the thermal heat transfer modes. As the air above the pool moves at any speed, the water molecules also move, causing thermal heat transfer in the event that there is a temperature gradient.

Also, several scientific experiments have been made in this direction, in order to present a formula for quantifying the heat exchange coefficient. The formula used in this study was also taken from the ASHRAE.

$$\text{kW } P_{conv} = S_{water} \cdot h_C\left(T_{water} - T_{amb}\right) \cdot 10^{-3}$$

$$\text{W/m2.K } h_c = 5,7 + 3,8 \times V$$

For a wind speed of V = 1.2 m / s

$$\text{kW } P_{conv} = 62,81$$

Radiation loss:

Everything emits radiation of an electromagnetic nature, whatever its state: solid, liquid or gas. This emission of energy comes at the expense of the body's internal energy.

Water exchanges with the environment by radiative heat transfer.

This radiative exchange is expressed by the following relation:

$$\text{kW } P_{ray} = S_{water} \cdot 5,68 \cdot 10^{-8}\left[\varepsilon_{water}(T_{water} + 273)^4 - \varepsilon_{sky}(T_{amb} + 273)^4\right] \cdot 10^{-3}$$

$$\varepsilon_{sky} = 0,004 \times T_{dew} + 0,8$$

Digital Application:

For Tamb = 10 °C and RH = 70%, T dew = 4.79 °C therefore

$$\varepsilon_{sky} \approx 0,82$$

$$\text{kW } P_{ray} = 49,04$$

Surface losses = 202.74 kW

-Losses through the walls of the basin:

Heat losses represent heat losses through the walls of the basin. They are all the more important when the walls are poorly thermally insulated.

The thermal losses are expressed as follows:

$$\text{kW } Q = U \cdot S\left(T_{water} - \text{T}_{earth}\right) \cdot 10^{-3}$$

Digital Application:

The surface of the concrete walls: 143 m2

Tearth: 15 °C, temperature of the earth in winter.

Twater: 28 °C

U: the transmission coefficient of concrete is around 2.5 W / m2.K, but for safety margin, we take a coefficient of 3.5 W / m2.K

kW $Q = 6,5$

-Water and walls heating:

To reach the set temperature in the basin, it is necessary to raise the temperature of the water and the walls of the concrete basin, from their initial temperatures to the desired temperature.

Water heating:

According to the calorimetry relationship, the capacity required to heat the volume of water in 72 hours is as follows:

kW $$P_{water} = \frac{\rho_w \cdot V_w \cdot C_{P_w}\left(T_{finalwater} - T_{initialwater}\right)}{h \cdot 3600}$$

kW $P_{water} = 197,38$

Heating of the walls:

According to the calorimetry relationship, the capacity required to heat the walls of the basin made especially of concrete for a period of 48 hours is as follows:

kW $$P_{wall} = \frac{\rho_c \cdot V_c \cdot C_{P_c}\left(T_{finalconcrete} - T_{initialconcrete}\right)}{h \cdot 3600}$$

Digital Application:

Concrete volume: S concrete x concrete thickness = 57.2 m3, with concrete thickness = 0.4 m

Concrete Cp: 0.837 KJ / Kg.K

Concrete density = 2500 kg / m3

Initial concrete T (average): 9.5 ° C

T final concrete (average) = ((Hot water temperature + earth temperature) / 2)

kW $$P_{wall} = \frac{2500 \cdot 57,2 \cdot 0,837\left(21,5 - 10\right)}{72 \cdot 3600}$$

kW $P_{wall} = 5,31$

$P_{Heating} = P_{water} + P_{walls}$

$P_{Heating}$ = 202.69 Kw

-Solar gains (in winter) = 0 W

P1 = 411.93kW

Estimation of the heating capacity during the maintenance phase:

P2 = Surface losses + Wall heat losses + Renewed water heater - Solar gains

-Surface losses = Losses by evaporation + losses by convection + losses by radiation

Evaporation loss- source ASHRAE 2019:

As a result of the activity of bathers, evaporation losses tend to increase. It is therefore necessary to take into account the impact of the activity of bathers during this phase.

According to the ASHRAE 2019, for public swimming pools, the equation must be multiplied by the activity factor Fa (Factor Activity): 1

kW $P_{evap} = S_{water}\left(P_w - P_a\right)\left(0,089 + 0,0782 \times V\right) \times 1$

We use the unfavorable climatic conditions:

Outdoor temperature: 4 °C

Desired water temperature (setpoint): 28 °C

Ambient air speed at 1m from the pool surface: V= 1.2 m/s

Pw (saturated vapor pressure at hot water temperature): at T = 28 °C, Pw = 3.783 KPa

Pa (saturation pressure at ambient air temperature): at T = 4 °C and for relative humidity RH = 88%

kW $P_{evap} = 190,73$

Losses by convection:

The unfavorable external conditions being the same; during the temperature maintenance phase, convection losses are calculated as follows:

kW $P_{conv} = 83,75$

Radiation losses:

The unfavorable external conditions being the same; during the temperature maintenance phase, radiation losses are calculated as follows:

kW $P_{ray} = 58,66$

Surface losses = 333.14 kW

-Losses through the walls of the basin: kW $Q = 6,5$

-Water heating renewed:

To preserve the quality and volume of water over the long term, water must be constantly recycled. According to article D1332-6 of the public health code in France, an intake of 30 liters per day and per bather must be respected. This rule is also required in Morocco.

Water renewal rate per day: 30 liters per bather.

Estimated number of people per day: 90 people.

Volume of water to be renewed: Renewal rate x Number of people.

Calculation of the volume of water to be renewed per day:

l Volume of water renewed = Renewal rate x Number of people

l Volume of water renewed = 30 liters x 90

l Volume of water renewed = 2700 liters

m3 Volume of water renewed = 2.7 m3

The capacity required for heating the renewed water:

$$\text{kW } P_{renewed} = \frac{\rho_w \cdot V_{wr} \cdot C_{P_w} \left(T_{finalwater} - T_{initialwater}\right)}{h \cdot 3600}$$

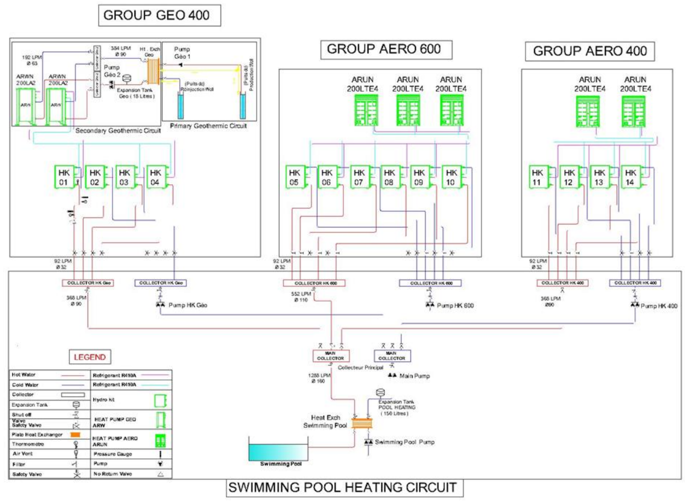
kW $P_{renewed} = 2,35$

-Solar gains (in winter) = 0 W

P2 = 341.99 kW

The capacity needed to heat the pool in 72 hours is P1 = 411.93 kW, while the temperature maintenance capacity is P2 = 341.99 kW. The largest capacity is used to select the equipment to be installed. Therefore, we installed a capacity of P = 441 kW

- Installation diagram:



The entire facility contained:

- 2 geothermal unit to make the exchange with the exchanger through softened water, and with the hydro kits through the refrigerant. The capacity of each outdoor unit is 63 kW.

- 5 aeraulic units to make the heat exchange with air and with the hydro kits through the refrigerant. The calorific power for each group is 63 kW.

- An exchanger to exchange heat between the geothermal groups and the wells.

- 14 hydro kits for the exchange between hot water and refrigerant.

- A submersible pump designed to fetch hot water from a depth where it is impossible to suck it from the surface.

- A circulation pumps to float hot water in the pipes.

- The flow switches make it possible to check the presence of a minimum flow in the installation

- The safety valves for pressure release in case of overheating of the installation.

- The manometers to measure the pressure.

- The thermometers to measure the temperature.

- The automatic air vents that allow the installation to operate in the best conditions. It eliminates air, the presence of which disrupts heat exchange, which causes noise and promotes circuit corrosion

- Expansion tanks to absorb variations in the volume of water due to temperature changes in the installation.

- Anti-vibration sleeves for absorbing the vibration of circuits and pumps.

- Non-return valves to control the direction of circulation.

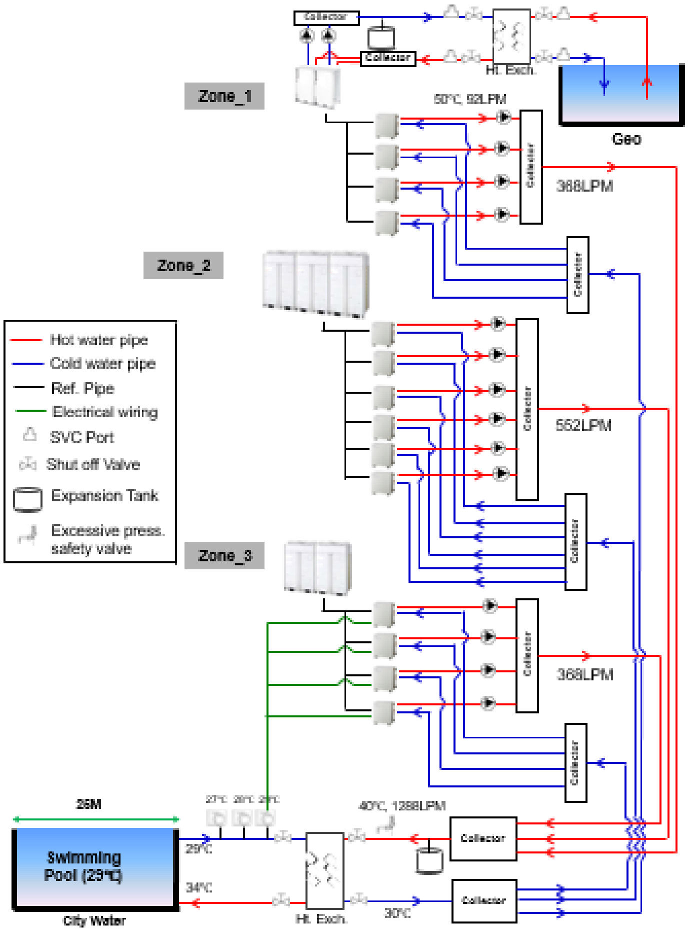
- Balancing valves to control the flow and pressure.

- Drain valves.

- Shut-off valves to isolate the circuit.

- The collectors to accumulate and distribute water.

After studying the system for two years, the diagram below clearly defines additional guidelines to optimize the performance of the entire system.



- 2 Heat exchangers are recommended nearby swimming pool. During maintenance, 2nd heat exchanger can allow the operation.

- We recommend to design heat exchanger near swimming pool based on 40℃ inlet temp. (Originally, inlet temp. was 38℃)

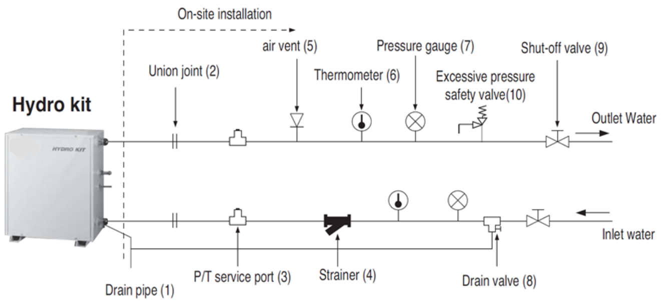
- In each zone, we recommend to add a pump. During maintenance, the pump can allow the operation.

- We recommend to use water piping expertize in order to maintain installation quality.

- Expansion tank needs to be designed based on total piping length and water volume.

- It is not necessary to install excessive pressure safety valve in each pipe. We recommend to install in main line.

Hydrokit Water Piping installation :



- For the water pipe system, we used a closed loop type.

- For the drain pipe size, we used the same diameter as the product connected or larger.

- We installed a natural drainage so that the drained water does not back flows.

- To replace the connected device easily, we installed the union joint.

- We installed the service port to clean the heat exchanger at each inlet and outlet of the water pipe.

- We installed the strainer on the horizontal pipe. (When dirt, trash, rusted pieces get into the water pipe system, it can cause problems to the product by corroding the metallic material.)

- We installed the air vent at the top of the water pipe. If the air vent is not installed at the top of the water pipe, there would be a lot of bubble in the water pipe. So a plate heat exchanger burst may happen because of the reduction of water flow rate(CH 14 is displayed in the remote controller) caused by a lot of bubble in the water pipe.

- We installed a thermometer and pressure gauge at the inlet and outlet of the water pipe.

- We installed the drain valve that can be used for draining the water inside when replacing the part or providing service.

- We installed the shut-off valve to block the water by closing the valve when replacing the part or cleaning.

- We installed excessive pressure safety valve that meets the design water pressure to prevent unit or water pipe damage at the pressure increase inside the water pipe system.

4. ROI calculation

For the ground heat source heat pumps, the heat is taken from a well , this heat is then transferred by the heat pump to the hot water circuit of the heating installation.

We have 2 outdoor units, the heat output of each outdoor unit is 63 kW. [3]

The air-water heat pump is a system that relies on the use of calories contained in the outside air to heat the water that is present in the heating network.

We have 5 outdoor units, the heat output of each outdoor unit is 63 kW. [4]

- The annual average consumption during two years is approximately 204,262 kW
- The average price of electricity in Morocco is about 1.1 MAD / kWh
- The price paid for one year is: 224 688.2 MAD
- The investment cost including equipment, installation and maintenance is: 2 000 000 MAD

➢ The gain in invoice in 1 year: 1 049 775.31 MAD /year

➢ Payback time (ROI) is approximately 1.9 years (22.86 months)

5. CONCLUSION

Very low-temperature geothermal energy in Morocco allows the production of thermal energy in a sustainable way. Indeed, the installation of geothermal heat pumps instead of boilers gives us a return on investment time generally less than 2 years.

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