



# Design of Cooling System for Storage Tank

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The aim of this project is to design and development sustainable system to cool down the temperature of the house tank in rang of (25 -30) °C. The system is consisted of heat exchanger which is similar to radiator of the car, solar pump, cooling fan, pipes and valves. The system is powered by a solar panel. Quality Function Deployment QFD process is used to define customer requirements and convert them into detailed engineering specifications, then generate different concepts design, and select the best design to develop. Several design criteria have been used as an example and are not limited to, easy to install and use, low cost, easy to maintain, last long time and sustainable to set the engineering specifications. SolidWork software is used to model the final design.

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## Introduction

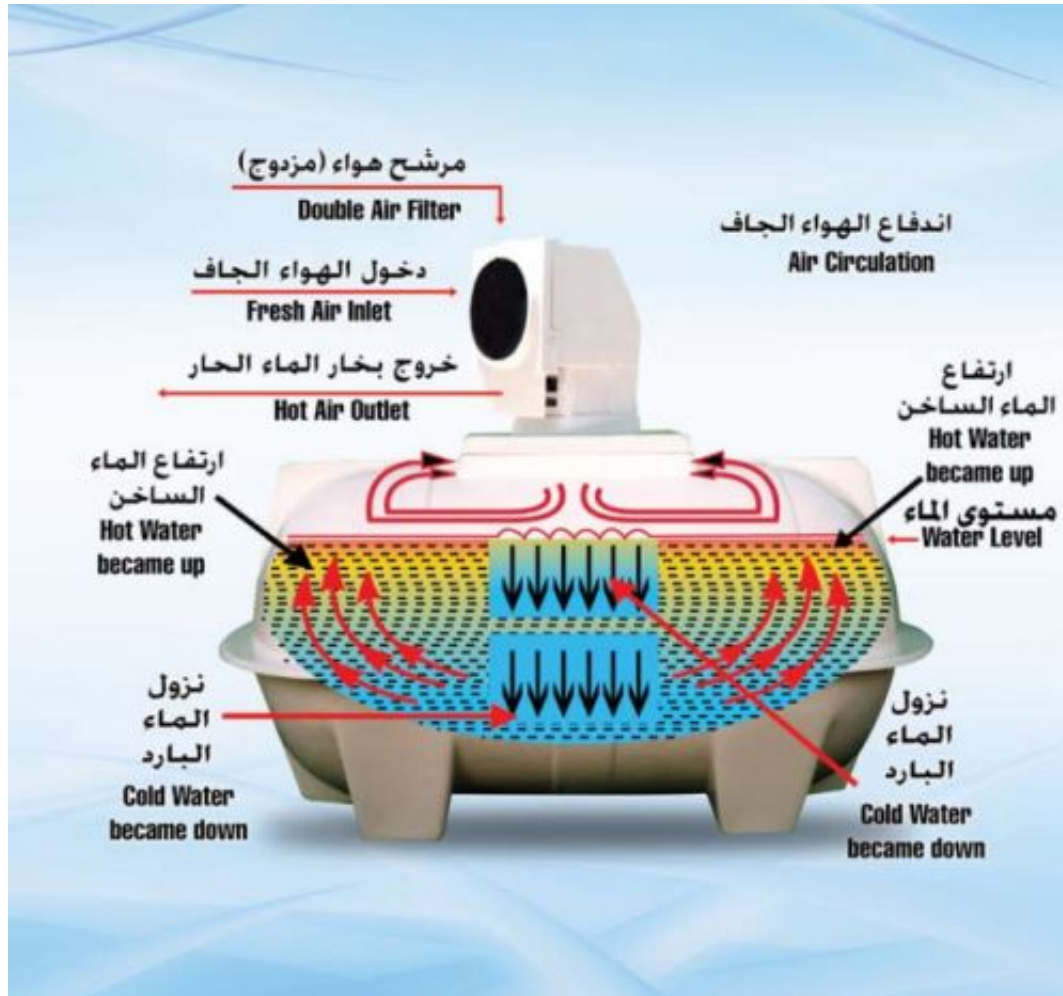
Due to the hot weather especially during the summer in Oman, the temperature of house water tank is increase as most homes and buildings have a water tank location placed on the roof. This causes the water to overheat and may reach more than 50°C. This temperature is inappropriate for bathing and sometimes causes water to lose by opening the valve and waiting until the water cools down to a suitable temperature for bathing. Several studies have been carried out by many researchers. Asif 2019 proposed to cover the tank with the mixture of calcium carbonate, white glue and water. He found that until about 2 pm, there was no change in water temperature. It was the same thing in the morning. By 5 pm, the water temperature increased by about 2-3 degrees.

Hassan and Karthik, 2018 studied the effect of solar irradiation on the water temperature in the overhead storage water tanks during the summer months. They used tank with shade, a tank with fiber glass insulation, and a tank having insulation along with shade. They found that the results from the water storage tank having insulation exhibited encouraging results. Stamps 2009 studied the effect of color netting shad on the horticulturists. He concluded that it is important that researchers provide careful and complete descriptions of experimental conditions when using this type of shading. One of the most famous systems is Domestic Water Cooling System, DANA 2001. In this system, the water temperature maintains to be below a 20°C during the summer such in the villas and hotels. In that cooling system, the chilled tank located on skids which is manufactured with piping's and fittings.

In addition, Buffer tanks are provided to stabiles the pressure and water flow to the chiller. As it use the thermostat valve to control the temperature. On the other hand, there is another way to cool the tank which is by using the AC (Air Conditioner). In this kind of method, the cold air which was produced from the AC is going to cool the tank's water until reaching an appropriate temperature and that is detected by a sensor. HUGHES, 2019, designed and developed tank cooling with Zero Power Cooler to temper water stored inside emergency tank showers in hot ambient climates. The night time ambient temperature is used to maintain the daytime temperature of the water, ensuring the delivery of safe and tepid water. Al Haram FiberGlass, 2010, designed a water cooling system can cool down and control the temperature in water tank as shown in Figure 1.

The proposed system's design consists of a radiator, which let the water to flow from the tank and

cool it, and then it goes back to tank as cooled water. Besides, this operation occurs with solar panel as main source of power, water pumps, pipes and battery.



**Figure 1.** Al Haram Water Cooling System

## Customers Requirements

Identification of customer's wants and needs is an important step in the product design. This step will produce a fact base of product specifications and useful to design team to experience product use in normal product environment. The design team should convert the customer's needs to engineering requirements for the product. . In this stage expresses needs in terms of what the product must do, not how it might do it. In this project gathering the customers' information is done by face to face interview. Table 1 presents customer's needs list and the Interpreting to engineering requirements. Relative importance is assign to each need. This is crucial sine the development team will to rely on that information to make trade-off and allocate resources during subsequent tasks of the system specification Muci-Küchler and Weaver 2004. The following scale was use to specify the relative importance of each need:

1. Feature is undesirable to most customers.
2. Feature is not important.
3. Feature would be nice to have, but is not necessary.
4. Feature is highly desirable.
5. Feature is critical.



Customer Statement	Interpreted Need	Importance
I want a suitable temperature.	Cooling system provide a suitable temperature.	5
I do not want the system to be affected by rust.	Cooling system is last long time.	2
I do not want the system to take large space on rooftop of my house.	Cooling system occupied less space.	3
While taking shower, I do not want the water flow to be weak.	Cooling system provide a proper water flow.	5
I do not want the system to be expensive.	Cooling system has a reasonable cost.	3
I do not want the system to consume mush power.	Cooling system is operated by renewable power.	5
I want the system to cool the water fast.	Cooling system supply water fast.	4
The system is easy to install.	Cooling system is easy to install.	2
The system should be quite.	System with minimum noise.	2

Table 1. Customer needs

## Engineering Specifications

There are many techniques used to generate engineering specifications. One of the best and currently most popular is called Quality Function Deployment (QFD), Ullman, 2010). QFD is a planning tool to translating customer needs into appropriate product development requirements, Developing the specifications or goals for the product, Finding out how the specifications measure the customers’ desires, determining how well the competition meets the goals, and developing numerical targets to work toward. In order to represent how engineering relates to a customer’s requirement, a specific symbols or numbers as follows:

⊖ = 9 = strong relationship

○ = 3 = medium relationship

Δ = 1 = weak relationship

Blank = 0 = no relationship at all

Table 1 presents QFD for proposed design of cooling system. The results show that the most important factor is the power needed for running the system. In addition the target specifications for the system are found.

## Concept Generation

This stage is about creating an innovative and different designs represent the team's idea. Subsequently, the comparison between those designs is made to select the best one. The following sketches shows the designs team' ideas.

### Concept (1):

Figure 2 presents design concept 1, in this concept, the system is located beside the tank with a base supported by three legs as a stand. This system consists of radiator and car battery that will be inside the frame. The radiator has as inlet and outlet to be connected to the tank. The pump and the thermostat valve are installed in the inlet pipe to supply water with required temperature and desired flow. Moreover, the system will be operated using an inclined solar panel at the top of the



frame as a renewable source of energy. Finally, the fan is installed at the back of the radiator which enables the radiator to get rid of the heat.

**Figure 2.** *Cooling system QFD*

### **Concept (2):**

This design shows the cooling system upper the tank, exactly in the tank cover as shown in Figure 3. It is fixed with a rotated rod fixed beside the tank. As well as, the system is combined inside rectangular frame. The solar panel located at the top of the system, the radiator is in the middle with the fan at the back of the radiator to reduce the temperature and keep the cooling process working effectively. The pipes of radiator let the water flow from the tank to the radiator by a pump, but the outlet flow without a water pump. The inlet flow from the tank passes through a thermostat, which control the flow of water in the radiator with respect to the temperature

### **Concept (3):**

In this concept, the system is installed inside a horizontal rectangular frame which is located beside the tank as shown in Figure 4. The battery and radiator installed inside the frame, while the fan is installed at the back of the radiator to get rid of the heat. In this model, the pump and thermostat valve are installed at the inlet pipe of the radiator. The overall system is supported by 4 legs as a stand.

## **Design Concept Selection**

Concept selection is often performed in two stages as a way to manage the complexity of evaluating dozens of product concepts. The first stage is screening is a quick, approximate evaluation aimed at producing a few viable alternatives. The second stage and for more careful analysis of these relatively few concepts scoring should be use. Screening process was used to select the best concept to develop as shown in Table 3. The selection criteria are listed along the left-hand side of the Table 3, These criteria are chosen based on the customer needs the team has identified, such as reasonable cost or efficiency. A relative score of “better than” (+), “same as” (0), or “worse than” (-) is placed in each cell of Table 3 to represent how each concept rates in comparison to the reference concept relative to the particular criterion. In general those concepts with more pluses and fewer minuses are ranked higher. At this point concept 1 is selected for further development.

**Figure 3.** *Design concept 1*

**Figure 4.** *Design concept 2*

**Figure 5.** *Design concept 3*

## **Results**

SolidWorks software was used to model concept 1 as shown in Figure 4. The system consist of radiator as heat exchanger, cooling fan , solar pump to circulate the water in the system, thermostat to regulate the temperature, solar panel with tilt angle of 27 degree, Mutasher et al. 2016, and the base structure. The next stage of this project to is carried out thermal calculations to



size all the components of the system.

Selection Criteria	Concepts		
	Concept 1 (reference)	Concept 2	Concept 3
Ease of installation	0 0 0 0 0 0 0 0	- 0 0 0 - - 0 -	0 - 0 - 0 0 0 0
Reasonable cost			
Power generation			
Reasonable size			
Durability			
Stability			
efficiency			
Ease of maintenance			
Sum +'s	0 8 0	0 4 4	0 6 2
Sum 0's			
Sum -'s			
Net score (Sum +'s- Sum -'s)	0	-4	-2
Rank	1	3	2
Continue?	yes	no	no

Table 2. Screening Table

Figure 6. Figure SolidWorks Prototype for cooling system

## Discussion

The tank's cooling system is designed to solve the common previous problem related to rising temperature in summer. Regarding to that, the customer requirements were collected and converted into interpreted needs. In addition, the QFD schedule was built to obtain the measurable design target in terms of engineering parameters. The idea of the system was shown through three different designs during concept generation. However in the concept selection process, the first design was chosen because it satisfies the customers in such aspects like the cost, maintenance, durability, stability, and installation. Moreover, the components of the system were designed with specific dimensions using "Solidworks" program. Then, they were assembled to be as one system. The cooling system of the tank is designed to be efficient as possible to serve the publics.

## Conclusions

All in all, the team's idea aims to provide suitable temperature for water by designing cooling system. The customers' requirements were gathered by face to face interview. Then, all these requirements were turned into interpreted needs and to QFD to found the target in terms of engineering parameters. Three different designs were generated to be evaluated and coming up with the best one among them. As a result of the evaluating process by figuring out the pros and cons of each concept, the final concept has been chosen. The chosen system is beside the tank with the three legs as a stand which has a reasonable cost due to the shape of the stand instead of having one with 4 legs. In addition, the shape of stand make the system more stable without need for adding an extra parts which means extra cost. Moreover, using a renewable energy as a source of power contributes to maintaining a lower cost not like using the electricity. This system keeps the water pump and thermostat valve inside to be protective from the atmospheric problems.

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