DESIGN OF STORAGE WATER HEATER

Er. Ankit Kishor Saxena[1], Er. Sumit Kumar Sharma[2], Dr. O. P. Upadhyay[3]

[1]*Mechanical Engineering Department, SRMSCET/ UP Technical University, (India)*

[2,3]*Mechanical Engineering Department, FET/ MJP Rohilkhand University, (India)*

ABSTRACT

Service water heating involves supply of hot water in places where large number of people reside under one roof. As localized hot water supply is not possible for each and every individual. Service hot water system became popular with advent of extensive migration from rural areas to cities or from one city to other and city's decentralised heating system and their limited supply with extensive increase in the hot water requirements in previous decades. Over the years the availability of energy resources have declined and there is lot of wastage of these resources due to carelessness in decentralised hot water system by using more fuel than needed.SWH serves the purpose to check the fuel consumption and keep the record of it in an efficient manner.

The paper "Design of Storage Water Heater" deals with increase of efficiency of SWH by modifying the design of heat exchanger to facilitate maximum heat transfer of energy content of the fuel to the water.

Keywords: Design, Economic, Storage Water Heater

I. INTRODUCTION

Water heating is a thermodynamic process that uses an energy source to heat water above its initial temperature. Fossil fuels (natural gas, liquefied petroleum gas, oil), or solid fuels are commonly used for heating water. These may be consumed directly or may produce electricity that, in turn, heats water. Electricity to heat water may also come from any other electrical source, such as nuclear power or renewable energy. Alternative energy such as solar energy, heat pumps, hot water heat recycling, and geothermal heating can also heat water, often in combination with backup systems powered by fossil fuels or electricity.

SWH systems may consist of distributed instantaneous heating and storage water systems and local boiling water units. SHW systems consist of four primary components, viz., the heat transfer equipment, the heating energy source, the piping distribution system, and the outlet devices or terminal units.

Nowadays, water heating systems based on the wood are using wood at an unprecedented scale very inefficiently which is causing the decline of wood as available energy resources. In our design we are using tubes instead of the a container for heating of the water which gives us a great efficiency in the heat transfer.

A hot water heating system has been designed in which wood is used as fuel along with the provisions of bio gas. The main components that have been used are the heating tank, heat exchange tubes, storage tank and furnace. Furthermore the system has been secured using the accessories and safety devices like over head pump, thermostat, float valve, water level indicator and vents. Certain assumptions have been taken as per the requirements so as to proceed with the calculations. The calculations that have been shown are variable depending upon the requirement of a place. The standard diameter of the pipes between the storage vessels has been taken, though the diameter of the pipes between the storage tank and the main tank has been calculated.

The design of the heating tank and the fire bed has been done. The material selection and the insulation material for the pipes and the tanks have been suitably chosen as per the required properties.

A service water heating system has:

(1) A heat energy source,

(2) Heat transfer equipment,

(3) A distribution system, and

(4) Terminal hot-water usage devices.

Heat energy sources may be:

(1) Fuel combustion,

(2) Electrical conversion,

(3) Solar energy,

(4) Recovered waste heat from such sources as flue gases

II. DESIGN

2.1 Design Data &Assumptions

- Cold water temperature : 10^{o}C
- Hot water temperature at supply: 60^{0} C − 65^{0} C
- Hot water temperature at Heater outlet : 80^{0} C − 85^{0} C
- Flow rate required supply : 0.35n
- Calorific value of wood : 3500 Kcal/Kg
- Specific heat of water : 4.186 KJ/Kg-^{o}C

2.2 Design Procedure

It includes design of

- Head to be maintained between the main tank and the storage tank
- Heating Tank
- Storage Tank
- Heating Tubes
- Connecting Pipes Diameters
- Firebox

2.2.1 Head To Be Maintained Between The Main Tank And The Storage Tank

Main tank is the tank in which the cold water of the building is stored. Storage tank is the tank in which the mixing of hot and cold water takes place simultaneously. The head between the main tank and inlet of the storage tank is taken to get the required flow rate, denoted by H i.e.

Required flow rate (Q) = 0.35n Litre/Sec.

Where

n= No. of taps

Now the head to be maintained is calculated with the help of the Bernoulli's equation

Applying Bernoulli equation between point 1 and 2

$P_1/\rho g + V_1^2/2g + H_1 = P_2/\rho g + V_2^2/2g + H_2$

$0 + 0 + H_1 = 0 + V_2^2/2g + 0$ (Losses are neglected in the equation)

$H_1 = V_2^2/2g$

But

$V_2 = Q/A$

Where

Q = Required flow rate from main tank

A = Area of the pipe from main tank

Therefore

$H_1 = (Q/A)^2 \times (1/2g)$

As per our design we are taking Q= 0.35n

Hence

$H_1 = (0.35n/A)^2 \times (1/2g) \times 10^{-6}$ m.

2.2.2 Head to be Maintained in the Storage Tank

In the storage tank there are two outlet points and two inlet points. To maintain a particular flow rate in the outlet pipe a particular head should be maintained. This head is measured with the help of Bernoulli's equation

Now applying Bernoulli's equation between free level of storage tank and supply outlet

$P_1/\rho g + V_1^2/2g + H_1 = P_2/\rho g + V_2^2/2g + H_2$

$0 + 0 + Hs = 0 + Vs^2/2g + 0$

$Hs = Vs^2/2g$

Where

Vs = Velocity of water in supply pipe viz. = Q/As = 0.35n/As

As = Area of the supply pipe

$H_s = (0.35n/A_s)^2 \times (1/2g) \times 10^{-6}$ m.

2.2.3 Recirculation Cycle to Maintain the Required Temperature

In the storage tank the mixing of cold water from the main tank and hot water from the heating tube occurs. To maintain the required temperature in the storage tank i.e. 65°C, we have to provide a particular flow rate of hot water into the storage tank. This flow rate can be calculated with the use of principle of mixing of two fluids at different temperatures.

According to the principle

Heat gained by the cold fluid = Heat lost by the hot fluid

$m_c c_p \Delta t_1 = m_h c_p \Delta t_2$

Where

m_c= Mass flow rate of the cold fluid

m_h= Mass flow rate of the hot fluid

c_p= Specific heat of the water

Δt_1 = Temperature difference between water of main tank and storage tank

Δt_2 = Temperature difference between water of heating tank and storage tank

$0.35n \times 4.187 \times (65-10) = m_h \times 4.187 \times (85-65)$

$m_h = 2.75 \times 0.35n$

$m_h = 2.75Q$

2.2.4 Diameter of the Tube Connecting the Heating and the Storage Tank

When the scavenging pump is not working, the level of the storage tank and the heating tank remain same and there would not be any flow of the water from the storage tank to the heating tank. But as soon as the scavenging pump sucks the water from the heating tubes the level in the heating tank goes down. This decrease in the level of the water of the heating tank produces a pressure difference between the storage and the heating tank. Due to this pressure difference the water flows from the storage tank to the heating tank with a velocity depending upon the difference in level of the two tanks. As shown here at a particular instant the level difference between the heating and storage tank is h. Now as this value of h is causing the flow of water from the storage tank to the heating tank therefore applying Bernoulli's equation between the free level of the storage tank and the outlet of the pipe connecting the two tanks, we get

$V^2/2g = h$

$V = \sqrt{2gh}$

Where

V= velocity in the pipe

h = difference in the level of two tanks

Now we have the velocity of the water flowing through the pipe connecting the storage and the heating tank. This velocity is used to get the diameter of the pipe by putting the value of the velocity in the required flow rate equation.

Required flow rate = 2.75Q

2.75Q = A x V

Where

A = area of the pipe connecting the two tanks viz. = πr^2

r = radius of the pipe = $\frac{Diameter}{2} = \frac{d}{2}$

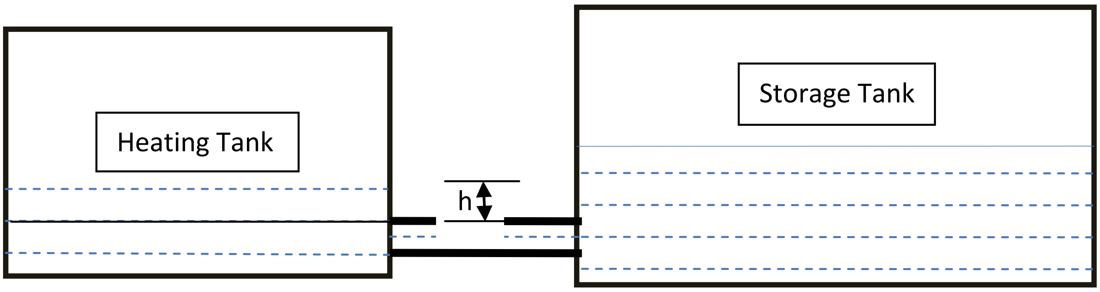

Fig No. 1 Head Between Heating Tank and Storage Tank

2.2.5 Heat Exchange Tubes

In a heating system the best way to get an economised and efficient heating is to increase the heat exchanging area. In order to get increased area we are using tubes for heating in our design. Using the tubes in our design we are trying to utilize the maximum heat generated by the combustion of the wood. The tubes of small diameter and less thickness will incorporate minimum loss in heat conduction from outer surface to the water flowing into the tubes due to less resistance to heat flow.

The tubes are fitted to the heating tank at an angle of about 15^0. This angle of inclination of the tubes will increase the surface area of heat exchange under the heating tank size limits. It will also help us to make the contact of all of the tubes to the flame as per our design. Increasing the inclination beyond this will increase the height of tube and consequently the flames will lose contact with the tubes. Hence deterring the heat exchange process. A proper space is provided between the consecutive tubes to maintain a proper flow of the flue gases through the spacing.

By using principle of conservation of energy, we get

Total heat supplied by the fuel = total heat gained by the water through the tubes

i.e.

(Mass of fuel) x (calorific value) = Heat gained by the water

$M_f .C_v = M_w.C_p.\Delta T$

where

M_f = Mass of fuel

C_v = Calorific Value of fuel

M_w = Mass flow rate of water in the tubes

ΔT = Temperature difference at inlet and outlet of tubes

Since ,heat generated by the fuel is transferred through the tube walls to water,

Therefore,

$M_f .C_v = U.A.\theta_m = M_w.C_p.\Delta T$

Where

θ_m = log mean temperature difference during heat exchange

U = Overall heat transfer coefficient

The average temperature of the flame is 900^0C(range 800^0C to 1200^0C).

Water enters the tube at 65C^0 and leaves at 85^0C under steady flow conditions. By using LMTD,

$$\text{LMTD} = \frac{\theta 1 - \theta 2}{\text{Ln}\ (\theta 1/\theta 2)}$$

$$\text{LMTD} = \frac{835 - 815}{\text{Ln}\ (835/815)}$$

$$\text{LMTD} = \frac{20}{.02424}$$

θ_m= 824.96 ^{0}C

by equating the heat transfer from fuel to water,

$U A\theta_m = M_w .C_p.\Delta T$

A = D LN

Where

D = diameter of the tube

L = lenght of the tube

N = number of tubes

$U..D.L.N.\theta_m = M_w .C_p.\Delta T$

U..D.L.N.825 = (0.35 x 2.75 x n) x 4.18 x 20

$$N = \frac{(0.35 \text{ x } 2.75 \text{ x n}) \text{ x } 4.18 \text{ x } 20}{825.U.\pi.D.L}$$

$$= \frac{0.0310n}{U.D.L}$$

Diameter of the heating tubes should be kept small for efficient heat transfer and to implement the concept of water tubes properly. Moreover the size of the firebed increases in case of less tubes of larger diameter. Hence small diameter tubes are preferred to use in the heating system.

2.2.6 Heating Tank

The storage tank is connected to the heating tank via a supply pipe. Since, both of the tanks are interconnected the level of water will be same in both the tanks. To maintain the required head at the supply outlet ,a definite head is maintained in the storage tank. The level of the water will be the same in heating tank.

herefore,

Height of the heating tank = level of water in storage tank + clearance

Clearance is given to maintain atmospheric pressure in the heating tank with the help of the vent and to accommodate steam that might generate.

The base of the storage tank is flat in which heating tubes are bolted. Tubes are fitted in the form of rectangular array which decides the size of the base of the tank

N_1 = Number of tubes along the width

N_2 = number of tubes along the length

N = Total number of tubes,equal to $N_1 \times N_2$

Total width of the base of the tank = $N_1D + S(N_1 + 1)$

Total length of the tube = $N_2D + S(N_2+1)$

S= spacing between tubes (depends upon the diameter)

2.2.7 Fire Box

Fire box is a place where the wood is charged for burning. The most important part of any hot water system is its combustion chamber or fire box. If it is not correctly sized or poorly designed the efficiency of whole system will suffer. The most common problem of centralized hot water system is poorly designed firebox.To keep the spacing between the wood and tube constant along the length, it is kept at the same inclination as the tubes i.e. 15^0. The size of the fire bed depends upon the number of tubes installed in the heating tank.

Total width of the fire bed = $N_1D + S(N_1 + 1)$

Total lenght of the tube = $N_2D + S(N_2+1)+L\cos 15^0 - S$

S= spacing between tubes (depends upon the diameter)

Underneath the fire bed is installed a low power blower to supply excess of air for complete combustion.The flue gases will leave the box through the sides of tank thereby giving the residual heat in the heating tank before leaving through chimney.The furnace door is kept just adequate in size so that logs of appropriate length is placed for efficient burning and acting as a check of workers negligence of charging furnace with large logs leading to inefficient burning of fuel. Inside lining of the firebox is made up of the fire bricks. As they trap the heat and thereby increasing the average temperature of the firebox.

III. CONCLUSION

Storage water heater is cost effective heating technology. It has many advantages over the existing systems. It ensures a proper flame contact as the tubes of the system are so designed that a maximum contact of the flame can occur with the tubes. With the direct contact of the flame with the tubes we can transfer a maximum amount of the heat to the tubes. This increased value of mean temperature results in a better heat transfer from the flame to the water flowing through tubes. In our design we are using the heat exchanger tubes so our system is heating the same amount of water in lesser time because the flow rate and the area in contact with the flame is higher.

Control over the process is achieved with the use of thermostat controlled over head pump, water lever indicator, the temperature of water remains 65 degree centigrade for most of the time of supply and at no time reaches beyond 85 degree centigrade. One of the most salient features of our design is that we have increased the capacity of the plant on tremendous scale without increasing the size of heating tank. We have actually decreased the size of heating tank. This modification has been achieved since water never stays in heating tank. It keeps on circulating. As the wood is used in the system, it can be more effectively used in those areas where supply of electricity is a big problem. It can also be combined with biogas, paddy husk etc. as a fuel catalyst.

The system can be modified for better heating efficiency. As a large amount of wood is used in heat generation, emission of large amount of flue gases will also be associated with it. If these flue gases are left un-utilised, they will carry a large amount of heat which can otherwise be utilized. Preheating serves this purpose of trapping this energy by heating the water coming from the main tank which is at 10 degree centigrade. Flue gases leaving the furnace comes in contact with the water from main tank just before it enters storage tank and gives the heat as it moves in counter direction of water and raise its temperature. Thus the temperature at which heat supplied to the water is raised and hence decreasing the amount of fuel used. There is a provision for the use of biogas that is generated in our college campus. This preheating of the water from the main tank along with the preheating with the flue gases will drastically decrease the consumption of the wood.

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