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Thermal Analysis on Heater Tank Used For Domestic Purposes



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ABSTRACT:

In this project we are up to do an analyze of a heater tank. It is necessary for a Engineer to analyze about the heat flow and the flow of the liquid as per model. With the advanced technology, by using the software the thermal flow and the analyzing of the model can be done without investing on production. So here we have modeled a heater tank using CATIAV5 and imported to ansys for analyzing with different case study. Then we have to set the boundary conditions with temperature as input and to evaluate results like temperature distribution, total heat flux and directional heat flux and tabulate. By flow analysis check flow of liquid by CFD analysis.. With the results obtained the better composition is achieved. By doing this project our knowledge about software can also be developed.

A Solar Domestic Hot Water (SDHW) system recovers the energy from the solar collector panel and transfers it to the domestic hot water tank. Based on the location and the orientation of the solar collector panel, one could easily estimate that such systems can meet the hot water demand fully or partially and accordingly design the auxiliary heating system such as a gas or an electric heater, to supplement the hot water demand. To design such a SDHW system from scratch and to meet the above criteria is an easy task. However, to retrofit the existing hot water cylinder in order to meet the tax benefit criteria is a challenge. The basic principle of solar energy is based on the concept of thermal storage.

The existing hot water cylinder volume is of the order of 80 to 120 litres, which is close to the hot water required for a family of three to four persons. Standard SDHW system, available in the market, to meet the tax benefit criteria requires to opt for a 300 litre capacity hot water storage tank. The objectives of this project are to understand the heat transfer characteristic of a SDHW system and to explore the fact that these modified hot water cylinder could be controlled in such a way that they operate efficiently. By controlling the auxiliary heating system, it is feasible that at certain times the solar energy would heat the water or may require additional energy from the auxiliary system. It is feasible to predict the solar energy output from the panel by means of a neural network.

So a simplified neural network is developed based on the function approximation technique. Once the experimental data is available, it is proposed to train the network with experimental data. It would be helpful in assessing the thermal stratification inside the tank as calculated by a dynamic SIMULINK model. Solar thermal hot water systems are amongst the easiest and most cost effective renewable energy systems to install, which makes them one of the most popular systems amongst consumers and developers. Should the modified solar thermal hot water systems be found to operate effectively with existing hot water cylinders then the cost of installing a new solar hot water system is likely to be reduced.

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This will stimulate and contribute to the carbon emission reductions required to meet INDIA 2020 carbon emission targets.

1. INTRODUCTION

1.1 The Solar Resource and Solar Domestic Hot Water (SDHW) system

The source of solar radiation is a fusion reaction-taking place inside the core of sun at a temperature of ~30,000 K. However, the sun's surface temperature is ~5762 K. To calculate the amount of energy received by the earth outside the atmosphere, also called solar constant, one has to assume that the sun is a black body at 5762 K, the mean distance between the sun and the earth is 1.5*1011 m and the sun's diameter is close to 1.39*109 m [2]. By using Stefan-Boltzmann radiation law, the value of solar constant is close to 1353 W/m2. However, the 'constant' is misnomer in term Solar Constant as it varies from day to day. The daily "solar constant" is calculated with the following formula:

$$I_o = 1353 \times \left[1 + 0.034 \times \cos\left(\frac{2 \times \pi \times N}{365}\right)\right] \quad (1)$$

Where

N is day number of the year or Julian date (for example, January 1 is day 1; December 31 is day 365.) Solar energy reaching a given location on the earth, called insolation, is attenuated as it travels through the atmosphere by means of reflection, absorption, scattering, before reaching the surface of the earth. For example, Ozone layer absorbs Ultra-Violet (UV) radiation while CO2 and water vapours absorbs infrared radiation. One can refer (table 1.0) tentative values of mean annual daily solar radiation reaching the earth's surface for various cities.

City	Solar Radiation, W/m2
Cairo	280
El Paso	240
Glasgow	100
Johannesburg	230
Mumbai	240
Naples	200
Rio de Janeiro	200
Seattle	125
Sydney	210
Tokyo	125

Table 1.0: Typical mean annual daily solar radiation for selected cities.

Let us analyze some basic terms to understand the components of solar radiation such as direct beam, diffuse components. On a clear sky, it is possible that the solar radiation can reach the earth's surface directly, without any attenuation as explained above. This component is termed as direct solar radiation. On a cloudy day, the solar radiation gets scattered, refracted. This component is termed as diffuse solar radiation and it reaches the earth's surface at range of different angle. Sum of diffuse and direct component is called Global Insolation. In summary, typical value of the global insolation varies, at particular location, as the condition in the sky changes with maximum in the range of 900-1000 W/m2. Figure 1.0 gives idea about variation in monthly global insolation at a particular location.

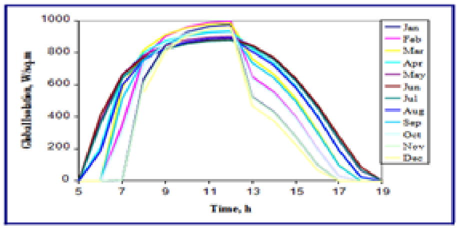

Figure 1.0: Monthly averaged global insolation at 32° N latitude

When solar radiation falls on a surface, it can be converted in to electrical power or thermal energy. Photovoltaic or PV cell is one of the solar technologies used for the electrical power generation. Solar heating is used for many applications such as crop drying in field, producing salt from seawater; meeting hot water demand, space heating etc. Effective solar radiation must be collected at a high temperature and transported or stored for later use. Solar Domestic Hot Water (SDHW) system is one of the examples of it. It uses the solar energy available in the sunlight to heat the water for household purpose. It supplements the existing gas or electric water heating system and provides heat for all hot water needs including showers, dishwashing, and laundry, cooking and even for space heating. Hot Water accounts for approximately 25% of the total energy used in a typical single-family home and can lead to savings of 85% on the utility bills over the costs of electric water

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heating [4]. Figure 1.1 gives idea about the average annual solar radiation available in. By an estimate, the average energy required is close to 3000-4000 kWh per year for domestic hot water purpose. It follows to achieve this demand a moderate solar collector panel with an area of 4-5 m2.

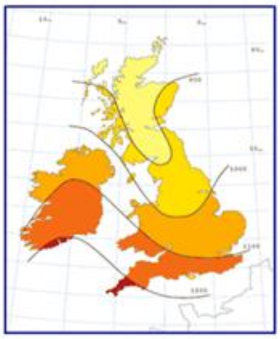

fig: map showing average annual solar radiation on a 30^0 inclined panel facing due south in kWh/m^2

To meet the hot water demand in the colder climate such as , primarily an auxiliary system is preferred over past decades due to its cheap and easy availability of gas or electricity. As is committed to Kyoto protocol, it has set a target of achieving 14% of heating requirements from the renewable heat sources, such as solar, by 2020. Therefore financial incentives and tax exemptions are available for the installation of a solar thermal systems . These incentives require that hot water cylinder has a 'dedicated solar volume' defined as a proportion of the volume of the hot water cylinder that can be heated only by the solar system and not by the auxilliary one. To design such a SDHW system from scratch and to meet the above criterion is quite easy task. However, to retrofit or to modify the existing hot water cylinder in order to meet the above design criterion is a challenge to the designer. The basic principle of solar energy based heating system is based on the concept of thermal storage. The existing hot water cylinder volume is of the order of 80 to 120 litres, which is close to the hot water required for a family of three to four person. Standard SDHW system, available in market, to meet the ‘ dedicated solar volume’ criterion requires to opt for 300 litre capacity hot water storage tank.

To design such a SDHW system from scratch and to meet the above criterion is quite easy task. However, to retrofit or to modify the existing hot water cylinder in order to meet the above design criterion is a challenge to the designer. The basic principle of solar energy based heating system is based on the concept of thermal storage. The existing hot water cylinder volume is of the order of 80 to 120 litres, which is close to the hot water required for a family of three to four person. Standard SDHW system, available in market, to meet the ‘ dedicated solar volume’ criterion requires to opt for 300 litre capacity hot water storage tank.

BACKGROUND & SDHW SYSTEM DESCRIPTION

Growth and development are the key factors in human life and it always put challenges before him. Be in industry, agriculture, energy, space or environment, the options offered by engineers, academia or scientists are awesome such as cars, aeroplane, computers, roads, buildings, electricity for lighting, operating the home appliances and heating or cooling the residential, industrial or shopping mall. All these equipments require energy in the form of heat or electricity. To meet the energy demand, natural resources are utilised such as fossil fuels like coal, oil, natural gas, termed as non-renewable energy sources or nuclear fission based energy resources utilizing natural Uranium as fuel. One can easily infer from figure 2.0 [10] that there is continuous depletion of natural resources. The higher standards of living coupled with population explosion are the popular explanation of such pattern.

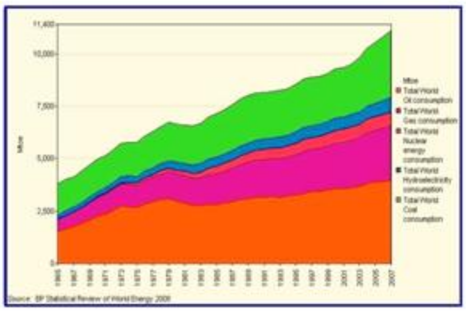

fig: consumption pattern of natural resources from 1965

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Let us get the idea about the supply or availability of natural resources and demand or present day consumption pattern. Figure 2.1 gives a generic idea about the world energy resources, its comparison to present day consumption pattern. The natural resources are limited and will be exhausted in the future if we continue to exploit the natural resources in an unsustainable manner. Figure 2.1 also suggest that solar energy has good potential to play significant role in the energy carving society. Not only solar energy, wind energy, bio-fuels, tidal energy, wave energy etc termed as renewable energy, are better candidate for heat or electricity generation.

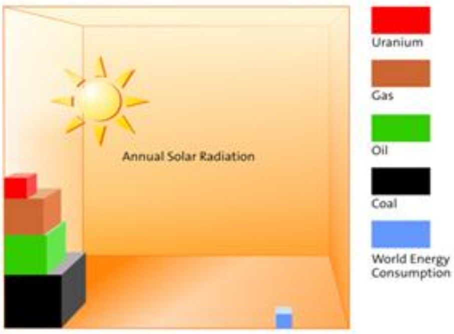

fig: world energy reserve and energy consumption

Let us again look in to main components of the renewable energy and in particular to Hot water heating systems. In 2006, the hot water demand supplied by the renewable energy source was close to 1.3%. Traditional biomass such as wood, waste, alcohol etc contributes 13% of total renewable energy share. As we have seen that in the colder climate, the hot water accounts for approximately 25% of the total energy consumed. Therefore, a lot of scope exists in meeting the hot water demand by means of the renewable energy particularly by Solar Collector systems. Figure 2.3 depicts the solar hot water / Heating capacity around the world in 2007. Although it is very small fraction of total energy share of energy share presently, yet it has great potential and have good competitor to other technology as it has least impact on the global warming and minimum impact on the GHG emission.

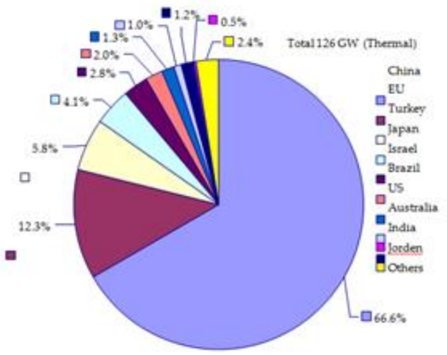

fig: solar hot water/heating capacity existing 2007

Let us study the , where hot water demand is sufficiently high. The main consumers of electricity are the domestic and industrial sectors. It is interesting to note that 33% of total power produced in the (close to 392979 GWh) is used for the domestic application . In 2004, the percentage of coal, gas and oil in total electricity production is close to 74%. In the same year, power stations in the emitted 47 million tonnes of carbon. By an estimate, it accounts for 30% of the 's total carbon dioxide emissions in that year. Under Kyoto Protocol, the government is committed to reduce the carbon emission to 12.5% below 1990 levels by 2008 to 2012 and 20% of electrical supply from the renewable energy resource by 2020. To meet the above-mentioned targets, it is pertinent to opt for the integration of renewable technology to the built environment and implement zero energy building design concept.

SDHW System Description

A SDHW system uses the solar radiation to heat the water. It connects to a home’s existing gas or electric water heating system, compliments the source of heat for all hot water needs including showers, dishwashing, clothes washing, cooking etc. It consists of a solar radiation collector panel, a storage tank, a pump, a heat exchanger, piping units, an auxiliary heating unit, a heater control panel. Figure-2.4 gives classification of the SDHW system based on the solar collector panel type, auxiliary heater type and based on the principle of heat transfer.

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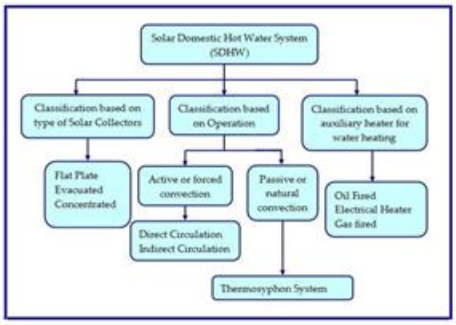

fig: classification of SDHW system

A basic flat plate solar collector is shown in figure 2.5. Although it looks a simple piece of equipment to absorb the solar radiation and transfer to the fluid flowing in the tubes, however the mechanism of heat transfer is quite involved. All modes of heat transfer, viz. conduction, convection and radiation needs attention in the thermal analysis. The absorber plate absorbs solar radiation and in turn transfers the heat to the fluid by means of conduction and convection. A fraction of absorbed heat would be conducted and convected to the ambient via thermal insulation and some would be irradiated back to the surrounding. Heat transfer mechanism is so involved that it is not amenable to the hand calculation. Chapter 3 presents a simplified mathematical model for the SDHW configuration.

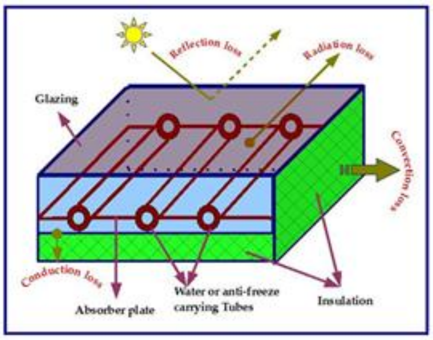

fig: basic components of a flat plate collector along with heat loss mechanism

Active-Direct SDHW Configuration:

A direct (open) configuration are defined as systems in which the collector directly transfer the heat to hot cylinder without any intermediate heat exchanger and the heat transfer fluid is water. These systems require external supply of power to operate the pump for circulation of water through the solar collector. Cold Water enters at the bottom of the hot water cylinder and in turn passes through the solar collector, gets heated and delivers energy at the top portion of hot water cylinder. However, the hot water requirement is typical at constant temperature and sunshine's varies throughout the day, so auxiliary heater, attached to the cylinder, is available to compliment the demand at constant temperature. Figure 2.6 depicts schematic of Active-direct SDHW configuration.

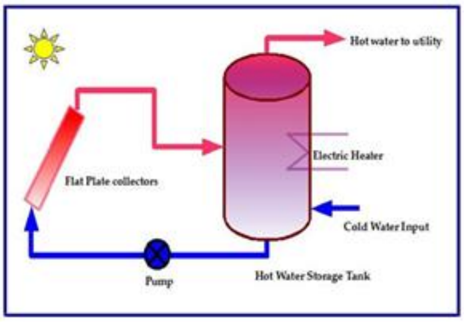

fig: schematic of active-direct SDHW with electrical heater

Active-Indirect SDHW Configuration:

An indirect (close loop) configuration is defined as a circuit in which the heat transfer fluid does not mix with the working fluid (water). Heat transfer fluid is antifreeze for example a mixture of water with ethylene or propylene glycol and these systems requires heat exchanger to transfer the useful solar energy to hot water cylinder. Figure 2.7 depicts the schematic of an active –indirect SDHW system with the electrical heater. Active indirect SDHW configuration is prevalent in the cold climate like in Europe or the. It is because as the ambient temperature goes below 0° in winter, it leads to freezing of the water inside the tubes and leading to rupture of the tubes.

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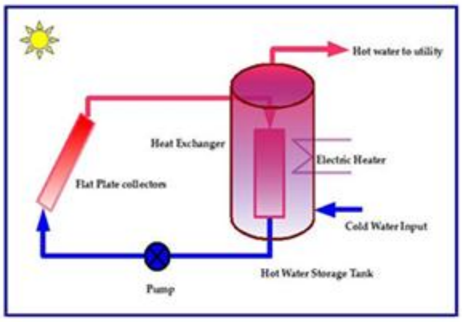

fig: schematic of active-indirect SDHW with electrical heater

AIM:

Aim of the project is to study thermal behaviour of two basic configurations of SDHW tanks, for a generic hot water demand in India and to investigate the efficacy of the thermal stratification on performance of the system as a whole. It also includes study of temperature control in the tank and the auxiliary heater control on the performance of the SDHW system. The challenge in SDHW technology is to match the supply with demand. In this project, the study aims to understand the mismatch between supply and demand of hot water for the domestic application and to investigate the control strategies for the hot water storage tank in order to smoothen out the mismatch between supply and demand.

Project Objectives:

The objectives of the project are to understand the heat transfer characteristic of SDHW system and to explore the fact that these modified hot water cylinder could be controlled in such a way that it operate efficiently. By controlling an auxiliary heating system, it is feasible that at certain times only the solar themal system would heat the water in the hot water tank, making the entire volume of the hot water cylinder the dedicated solar volume.

The objectives of the project are as follows.

- To better understand the physics behind the whole process of Solar Domestic Hot Water (SDHW) system.
- To develop a thermal model of active (direct and indirect) SDHW configuration in Simulink.
- To model the heat transfer phenomena in a solar collector panel and predict the heat input to the hot water storage tank.
- To model of an auxiliary heater in the hot water tank and carry out a control strategy modelling from demand side requirement.
- To better understand the thermal stratification concept in SDHW tank.
- To research and establish the number of days when a solar heating system can meet the hot water demand independently

Energy Performance Analysis:

The energy performance indices evaluated in this study include: energy collected, energy delivered and supply pipe losses, solar fraction, collector efficiency and system efficiency.

Energy Collected:

The useful energy collected by the solar energy collector is given as: Q c= mCP (Tc,o- Tc,i)

Energy Delivered And Supply Pipe Losses:

The useful energy delivered by the solar coil to the hot water tank is given as Q d = mCp (Tsc,i -Tsc,o)
Supply pipe losses were due to the temperature drop as the solar fluid flowed between the collector outlet and the solar coil inlet to the hot water tank. These losses were calculated as:
QL= mCp (Tsc,i - Tsc,i)

Solar Fraction:

The solar fraction (SF) is the ratio of solar heat yield to the total energy requirement for water heating and is given as: SF $=\frac{Qs}{QS+Qaux}$

Collector Efficiency:

The collector efficiency was calculated as:

$$\eta_C=\frac{mc_p(T_c,o-T_c,i)}{A_cG_t}$$

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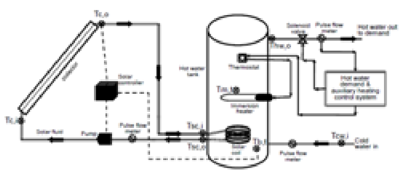
System Efficiency:

The system efficiency was calculated as

$$\eta_s = \frac{mC_p(Tsc,-Tsc,o)}{A_c G_t}$$

Flow chart of the daily operation of the PLC



Schematic diagram of the experimental setup

Water Heater Technologies:

Electric, gas and solar water heaters are each categorically unique in relation to the efficiency they can achieve heating water. Since each technology is inherently different than another, each technology will have its criteria based on its own merits. Certain technologies will have criteria that are exclusive. DOE is intent on establishing a program that does not favor one energy source over another. The energy consumption and savings calculations are based on the DOE test procedure, 1which accounts for standby energy as well as energy consumed from additional sources. All figures for the technology profiles are in Tables 1 and 2 on pages nine and ten. For reference, the DOE residential product classes are included on page eleven.

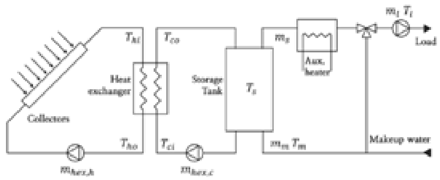
Mathematical Model of SWH System:

A schematic diagram of an indirect forced SWH system with a flat plate solar collector array, a heat exchanger, a storage tank, and an auxiliary heater is shown in Figure 1.

Solar energy absorbed by a collector array is transferred to the storage tank through an external heat exchanger. When hot water is demanded, heat stored in the tank is supplied to the load. If the storage tank temperature is below the desired hot water temperature, an auxiliary heater is placed in series with the tank and the load supply line is switched on. At any instant in time, the energy balance of a well-mixed storage tank can be described as:

$$(\rho_w C_{p,w} V_s)\frac{dT_s}{dt} = |q_{Ts} - q_{Ls} - q_l - q_d$$

where ρw, Cp,w are the density (kg/m3) and the specific heat of water (J/kg·°C); Vs is the volume of a storage tank (m3); qTS, ql, qd, and qLs are the solar energy supplied to a storage tank (W), the heat loss of a storage tank (W), the discharged heat to avoid overheating of a storage tank (W), and the solar energy extracted from the storage tank (W), respectively.



Schematic diagram of the SWH system considered in this study

The solar energy supplied to the tank (qTS) is the energy transferred from the useful heat gain of the collector array (qu) through a heat exchanger according to the differential temperature control. The solar useful gain of identical collector modules in series is

$$q_u = A_c N_{c,s}[F_R(\tau\alpha)I_T - R_R U_L(T_{ho} - T_a)]$$

where Ac is the gross area of a single collector module (m2); Nc,s is the number of identical collectors in series; FR(τα) and FRUL are the intercept and the slope of the efficiency curve of identical collector modules in series; IT is the solar irradiance on the tilted surface (W/m2); Tho is the hot stream outlet temperature of the heat exchanger (°C); Ta is the outdoor dry-bulb temperature (°C); and the + sign indicates that the collector fluid circulates between the

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collector array and the hot side of an external heat exchanger only when solar useful heat gain becomes positive, respectively. For identical collector modules in series, the intercept and slope of the efficiency curve can be estimated as:

$$F_R(\tau\alpha) = F_{R1}(\tau\alpha)_1 \left[\frac{1 - \left(1 - \frac{A_c F_{R1}(\tau\alpha)_1}{m_c C_{p,c}}\right)^{N_{c,s}}}{N_{c,s} \frac{A_c F_{R1}(\tau\alpha)_1}{m_c C_{p,c}}} \right]$$

$$F_R U_L = F_{R1} U_{L1} \left[\frac{1 - \left(1 - \frac{A_c F_{R1}(\tau\alpha)_1}{m_c C_{p,c}}\right)^{N_{c,s}}}{N_{c,s} \frac{A_c F_{R1}(\tau\alpha)_1}{m_c C_{p,c}}} \right]$$

Where FR1(τα)1 and FR1UL1 are the intercept and the slope of the efficiency curve of a single collector; mc is the mass flow rate of the collector fluid (kg/s); and Cp,c is the specific heat of the collector fluid (J/kg·°C) To calculate qTs, hot and cold stream outlet temperatures for the plate heat exchanger must be known. Both outlet temperatures can be determined by the effectiveness-number of heat transfer units (NTU-ε) analysis. The NTU-ε method uses three dimensionless parameters, such as the heat exchanger effectiveness (ε), number of exchanger heat transfer units (NTU), and capacity rate ratio (cr). For a given counter-flow heat exchanger, the three parameters can generally be expressed as

$$\varepsilon = \begin{cases} \dfrac{1 - exp[-NTU(1 - c_r)]}{1 - c_r exp[-NTU(1 - c_r)]}, c_r \neq 1 \\ \dfrac{NTU}{NTU + 1}, c_r \neq 1 \end{cases}$$

$$c_r = \frac{C_{hex,min}}{C_{hex,max}}$$

$$NTU = \frac{UA_{hex}}{C_{hex,min}}$$

Where UAhex is product of the overall heat transfer coefficient and area of a heat exchanger (W/°C); Chex,min and Chex,max are the smaller and larger values between the hot fluid capacity rate (Chex,h) and the cold fluid capacity rate (Chex,c). The capacity rates of the fluid on the hot and cold sides of the heat exchanger are given as follows:

$$C_{hex,h} = m_c N_{c,p} C_{p,c}$$

$$C_{hex,c} = m_c N_{c,p} C_{p,w}$$

Where Nc,p is the number of parallel connections in the collector array. Therefore, the heat transfer rate (i.e., solar energy supplied to the tank), hot stream outlet temperature, and cold stream outlet temperature can be determined as:

$$q_{Ts} = \begin{cases} \varepsilon C_{hex,h}(T_{hi} - T_{ci}), C_{hex,min} = C_{hex,h} \\ \varepsilon C_{hex,c}(T_{hi} - T_{ci}), C_{hex,min} = C_{hex,c} \end{cases}$$

$$T_{ho} = T_{hi} - \frac{q_{Ts}}{C_{hex,h}}$$

$$T_{co} = T_{ci} - \frac{q_{Ts}}{C_{hex,c}}$$

Where Thi and Tho are the hot stream inlet and outlet temperatures of the heat exchanger (°C) and Tci and Tco are the cold stream inlet and outlet temperatures of the heat exchanger (°C). To satisfy the desired hot water temperature and flow rate, the storage tank discharge flow rate is mixed with make-up water. By considering the mass and energy balance at the mixing junction the flow rate drawn from the tank is determined as:

$$m_s = \begin{cases} m_l \left(\dfrac{T_l - T_m}{T_s - T_m}\right), T_s > T_l \\ m_l, T_s \leq T_l \end{cases}$$

Where ms is the mass flow rate from the storage tank to the load (kg/s); ml is the mass flow rate of th desired hot water load (kg/s); Tl is the desired hot water temperature (°C); and Tm is the make-up water temperature (°C). Therefore, the solar energy supplied from the storage tank to the load (qLS) can be estimated as:

$$q_{Ls} = m_s C_{p,w}(T_s - T_m)$$

If the storage tank temperature is less than the desired hot water temperature, water discharged from the tank

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is heated by an auxiliary heater. Auxiliary heating energy can be calculated as:

$$q_{aux} = \begin{cases} 0, T_s > T_l \\ m_l C_{p,w}(T_l - T_s), T_s > T_l \end{cases}$$

Meanwhile, the storage tank loss (ql) to the ambient air can be expressed as:

$$q_{aux} = \begin{cases} 0, T_s > T_l \\ m_l C_{p,w}(T_l - T_s), T_s \leq T_l \end{cases}$$

Meanwhile, the storage tank loss (ql) to the ambient air can be expressed as:

$$q_{aux} = \begin{cases} 0, T_s > T_l \\ m_l C_{p,w}(T_l - T_s), T_s \leq T_l \end{cases}$$

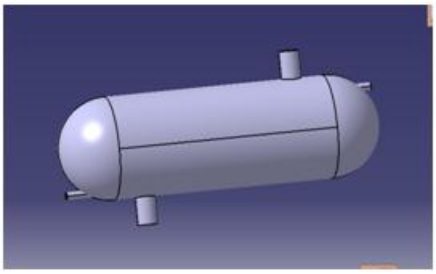
Where Us and As are the heat loss coefficient (W/m2·°C) and the surface area (m2) of a storage tank and Tamb is the ambient temperature (°C). In this paper, an optimization method is developed to design a SWH system for low temperature applications (below 100 °C) such as a residential hot water system. So if the storage tank temperature is greater than the maximum allowable temperature (Ts,max), the surplus heat will be discharged to avoid overheating of the storage tank. The discharged flow rate and heat can be calculated as:

$$T_{s,f} = T_s + \frac{(q_{Ts} - q_{Ls} - q_l - Q_d)3{,}600}{\rho_w C_{p,w} V_s}\Delta t$$

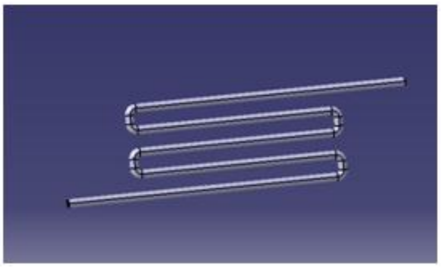
Where Ts,f is the final storage tank temperature at the end of any time step. In this optimization method, the SWH system is operated to meet the hot water demand using differential temperature control on an hourly basis. Hourly demands and weather conditions are required as input data. In the proposed method, the number of heat exchangers is fixed as one because this is the common configuration of forced circulation SWH systems in South Korea. Furthermore, a counter-flow type heat exchanger with UAhex of 3000 W/°C is used. For the thermal performance of an auxiliary heater, a simple boiler is modeled with its overall efficiency and part load ratio from the device capacity and the energy required to meet the load.

Result:

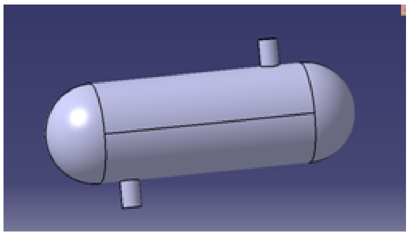
CATIA Model:



Assembly model of heater tank



Hot tubes



Cold water Tank

Conclusions:

The objectives of the project are to evaluate the retrofitted or modified single hot water cylinder performance and its feasibility to meet the “dedicated solar volume” requirement. Therefore, the modified single hot water cylinder (case-2) is analyzed and compared with the twin hot water tank (case-1) to assess the thermal performance. It is observed that the modified single cylinder water tank meets the “dedicated solar volume” requirement partially at least three days in July and a day in April out of six days considered in a month for both the load cases with an assumption that the tank is thermally stratified. However, as the mixing of the fluid starts, its potential to meet the “dedicated solar volume” requirement deteriorates.

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For a year, it is observed that case-2 partially meets the criterion of the "dedicated solar volume" for close to 67 days. The maximum and minimum value of solar energy contribution in meeting the hot water demand are 25% and 10 % respectively for case-1. For case-2, the maximum and minimum value of solar energy contribution are 30% and 15 % respectively. However, as mixing progresses inside the tank for case-2, the system performance moves towards the case-1 and deteriorates further. Low flow SDHW configuration performs better for the SDHW configuration in terms of building thermal stratification and enhances solar fraction utilisation. The influencing parameters for assessing the thermal performance are the thermal stratification in the tank and the hot water demand profile. These two factors determine the SDHW system performance. Optimum tank capacity is another factor, which needs attention in the design of SDHW system. In summary, it is feasible to do suitable modifications in a single storage tank to attain thermal stratification inside the tank and achieve the objectives.

Future Works:

Although efforts are made to capture various parameters influencing the retrofitting of existing hot water cylinder, yet a good scope exist in further exploring and substantiating the outcome of this study presented in the project. Following areas are listed for quick reference for further exploring the thermal modelling and control of SDHW systems. Modelling of mixing phenomena inside the tank and its experimental validation would be next step in assessing the realistic behaviour of a retrofitted single cylinder water tank. It will not only boost the confidence in dynamic modelling but also help in exploring and substantiating the thermal mixing or diffusion of energy inside the tank. To understand the impact of geometric parameters on thermal stratification, the tank inlet or outlet, geometry needs attention. One could extend the better understanding of the subject by taking into account into the geometric factors in order to optimize the geometric parameters for a retrofit model.

SDHW performance or more than one panel. Same point is also applicable to higher capacity storage tank such 200-400 litres capacity water tanks.

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