

Experimental Analysis on Charging Ports Location and Orientation on Solar Domestic Hot Water Storage Tank System

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ABSTRACT: An experimental analysis on influence of flow disturbance due to charging port location and orientation has been carried out in the model tank to understand the same influence of disturbance in stratification because of charging port location for solar domestic hot water (SDHW) storage tank system. Multiple cases have been taken under consideration for analysis of the system with horizontal, vertical and inclined orientation of schemes. In this experimental model study set up the charging inlet has been considered directly to the storage tank, which is already being half or partially filled to understand the stratification disturbance due to flow from different charging location and orientation. No indirect heat exchanging medium like heat exchanger has been considered for charging of water in to the storage tank. Charging of hot water into the storage tank and discharging of hot water from the same storage tank to serve the purpose and domestic requirement, has been taken under consideration for analysis because due to charging and discharging of water, the disturbance on thermal stratification of storage tank occurs. This stratification disturbance cannot be eliminated. But it can be reduced down by proper installation of charging ports. Hence the influence of flow disturbance, rise of water level and temperature growth is in main focus and centre of attraction of this study and analysis.

KEYWORDS: Flow disturbance, charging, solar domestic hot water storage tank.

I. INTRODUCTION

A storage tank is most necessary to store solar domestic hot water. This storage tank consists of normal ambient temperature cold water at the bottom of the tank, to feed into the solar panel to get heated up and heated hot solar water from the solar collector system is stored at the top part of the tank. The tank is filled with ambient water from the domestic water tap line supply system at the bottom side of the tank. From the bottom of the tank the cold water is supplied to the solar panel system, either by motor or by due to gravity system. In this study analysis system the normal water is carried out from the bottom of the tank, because at the bottom of the tank water pressure is more and it is being done due to gravity flow, without the use of pump and motor system. The water gets heated up in the solar panel system and then it is charged in the SDHW storage tank for storing and to discharge as per requirement and use. Initially the tank can be maintained with 50% full of cold water. After getting desirable hot water temperature at the outlet of the solar panel, the charging of tank with hot water gets started. In the mean time the normal cold water is get occupied in the solar panel for heating and obtaining the desired temperature. The makeup water line system maintains the level of cold normal water level in the system. This heating of normal cold water in the solar panel system and charging of hot water into the storage tank is carried out batch wise after of few time interval. The temperature of hot water at the outlet of the solar panel system can be sensed automatically using temperature sensor. The minimum desired sensing temperature to be 50°C, to open the solar panel outlet valve either automatically or manually. After achieving such minimum hot temperature of 50°C to fulfill the minimum domestic need to serve the various hot water demand, the solar domestic hot water storage tank to be filled up with this solar hot water bearing minimum of 50°C.

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Two temperature sensors can be installed to monitor the cold water feeding and makeup water temperature. The feeding of cold water in to the solar panel can be supplied directly from the tap water line system also and in the storage tank only hot water to be stored. But this plan and idea of maintaining half of the tank filled with cold normal water and then

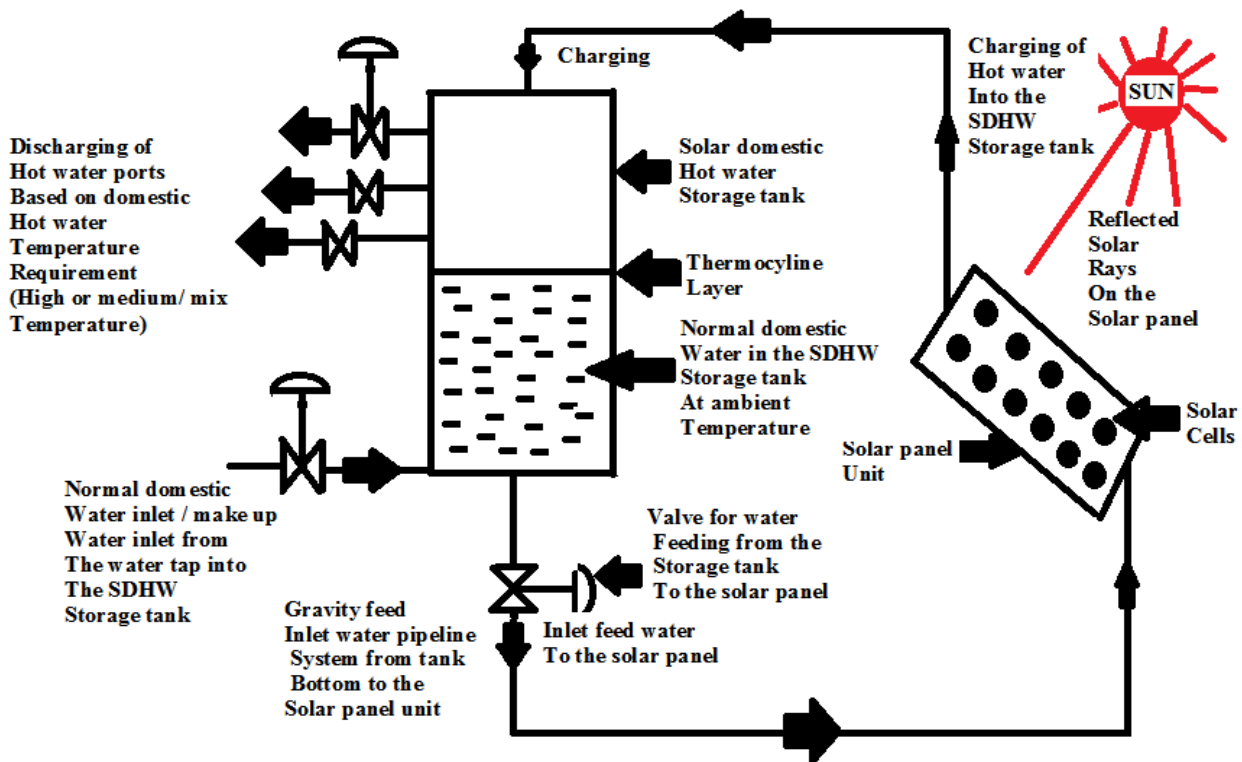


Fig. 1: Schematic diagram of solar domestic hot water system with single charging port and with multiple discharging ports as per hot water temperature requirement or demand (Hot or medium / mix temperature).

Charging of hot water into the storage tank is due to the phenomena of unable to store and maintain the hot water temperature for a longer time period in the storage tank. So to avoid the loss of temperature of hot water into the storage tank, it has been planned and proposed to maintain half or quarter volume of tank filled with cold water. Because when the charging of hot water will take place at the top of the tank then the hot water temperature can be supplied to heat cold water. By doing this the loss of temperature of hot water can be avoided, rather it could be transfer to cold water to gain some temperature and to provide medium temperature zone, to fulfill the requirement and purpose to take shower without mixing extra cold water. It is advisable to maintain three or four taps with a temperature sensor to sense the hot water temperature continuously. Such hot water discharging tap at the centre of the tank with a temperature sensor to sense the hot water temperature continuously. Such hot water outlet port can be provided at a distance of 25 mm, 150 mm, 250 mm and 350 mm, 450 mm 550mm from the top part of the tank with temperature sensor to sense the temperature continuously to have information about the temperature at different hot section of the storage tank for discharging of hot water as per availability of hot water ad as per requirement of hot water temperature as per demand, use and requirement of hot water for different purpose and need. If require more discharging ports can be fitted and analysis can be carried out based on objective of purpose of use and requirement of domestic need. This system is considered due to unavailability of Sun light all the time and discontinues charging of hot water into the storage tank and to avoid loss of heat and temperature from the thickness and insulation of the storage tank. From the storage tank the hot water can be discharged hot or mix with varying temperature range from 25° C to 90° C to serve the purpose as per requirement of drinking hot water or moderate hot water, bathing hot water, cloth and utensils washing moderate hot water and for cooking of rice, vegetable where preheated solar hot water can be utilized to save gas and

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electricity or preheated solar hot water can be utilized to prepare tea, coffee, lemon tea, green tea etc. The schematic diagram of solar domestic hot water storage system with a storage solar domestic hot water storage tank has been illustrated in the Fig. 1.

II. EXPERIMENTAL ANALYSIS

An experimental small model storage tank, of capacity approximately 16 liters has been taken under consideration, especially to understand the flow impact and disturbances during charging. The dimensions of the tank are 260 mm diameter, height 310 mm, thickness 1 mm. The tank is a small plastic barrel cut from the top for experimental analysis purpose. The prime focus in this experiment is to visualize and analyze the flow disturbance due to charging port location. One more plastic container of capacity 7 litres, of diameter 200mm, height 240mm, thickness 1 mm with outlet port of 12 mm size, has been taken to provide inlet water to the storage tank. The outlet port of supply water tank is having 12 mm valve which is connected with a nylon pipe to supply water in the storage tank. Half of the supply water tank is filled with normal ambient water. The red color is mixed in the water to understand the flow. The water supply container tank is kept vertically on a stool at a static height of 460 mm from the ground datum line, to provide gravity feed supply to the storage tank. Means the static pressure head of the charging supply water system for analysis is kept at a height of 460mm from the ground datum level. While the model hot water storage tank is kept on the floor to receive and store water from the supply tank. The schematic diagram of the experimental model set up is as shown in the Fig. 2. The actual model set up is as shown in Fig. 3 with the nomenclatures of the set up requisite device for the model set up. The Fig. 4 shows about the supply water container getting filled with normal water. In continuation Fig. 5 shows that the color is getting mixed into the supply water tank to observe flow inlet influence from the supply tank to the storage tank. The Fig. 6 illustrates that the experimental model set up is ready, to observe flow disturbances for different cases considered under study.

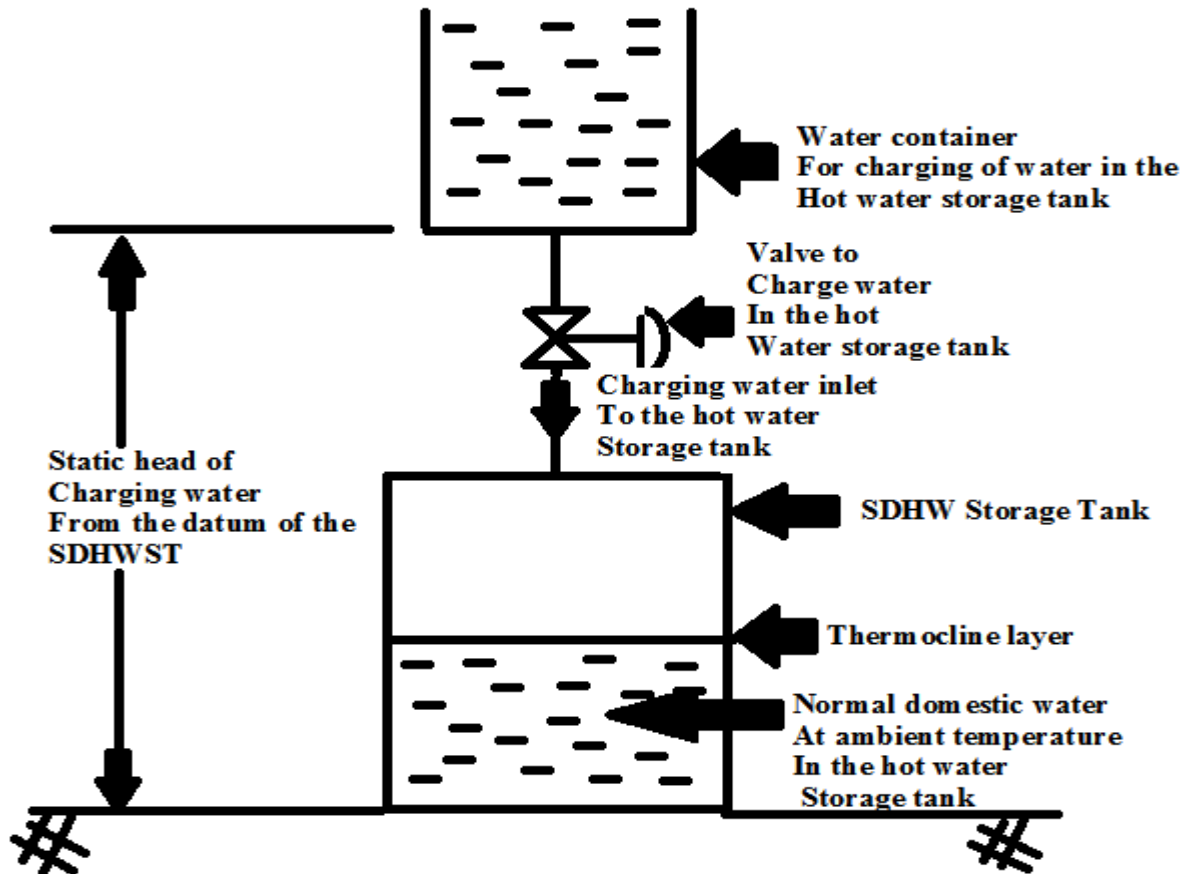


Fig.2: Schematic diagram of the Model experimental set up for study and analysis of inlet charging water in the solar domestic hot water storage tank.

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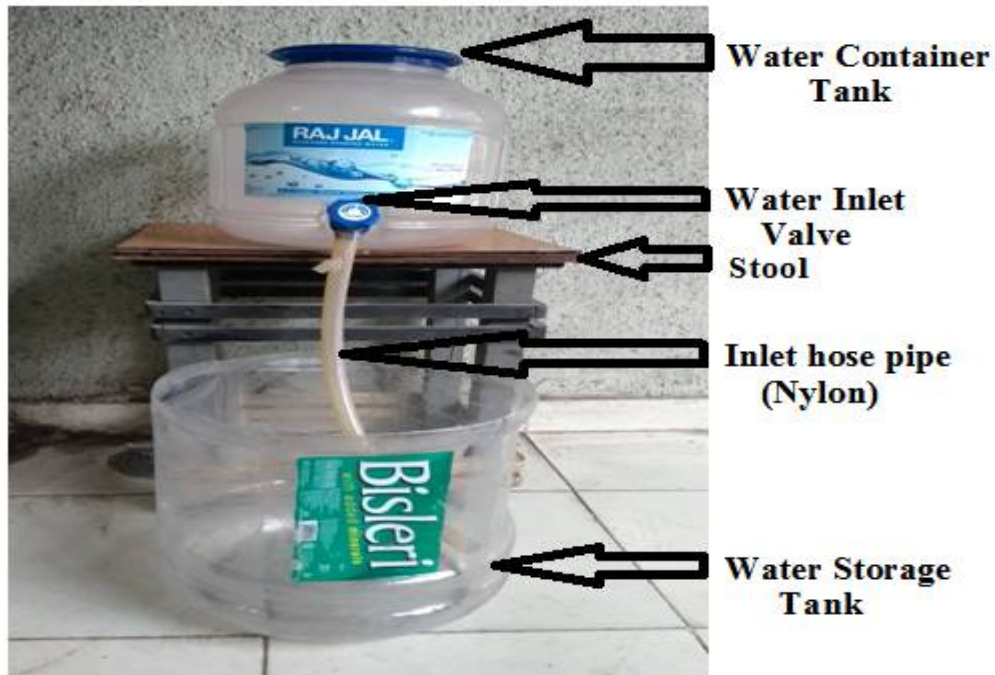


Fig. 3: Experimental study analysis model set up.



Fig.4: Filling of normal water in the water supply tank.

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Fig.5: Mixing of color in the water supply tank.

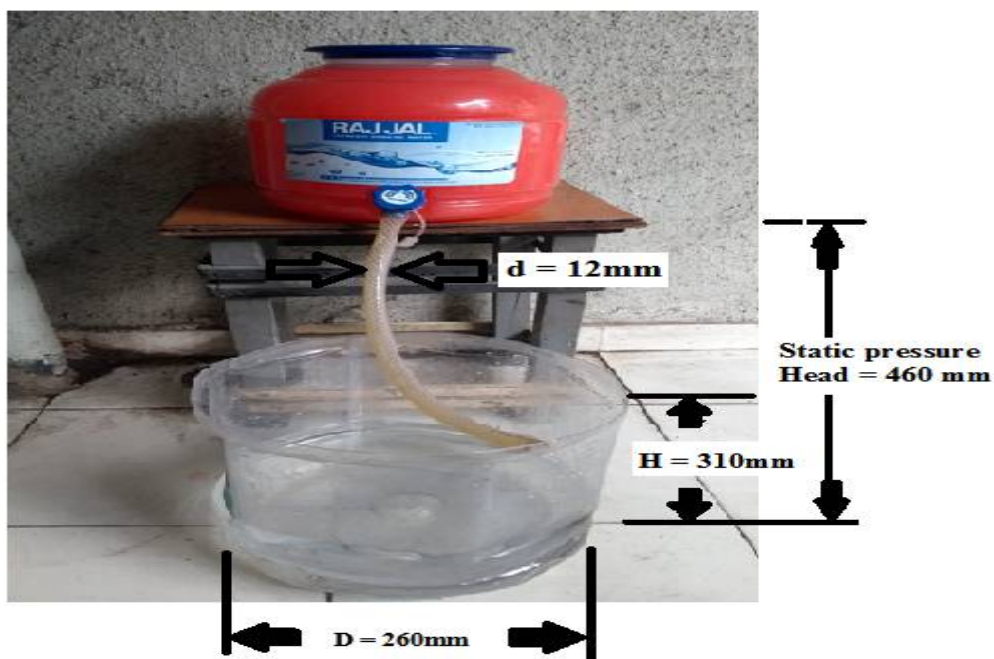


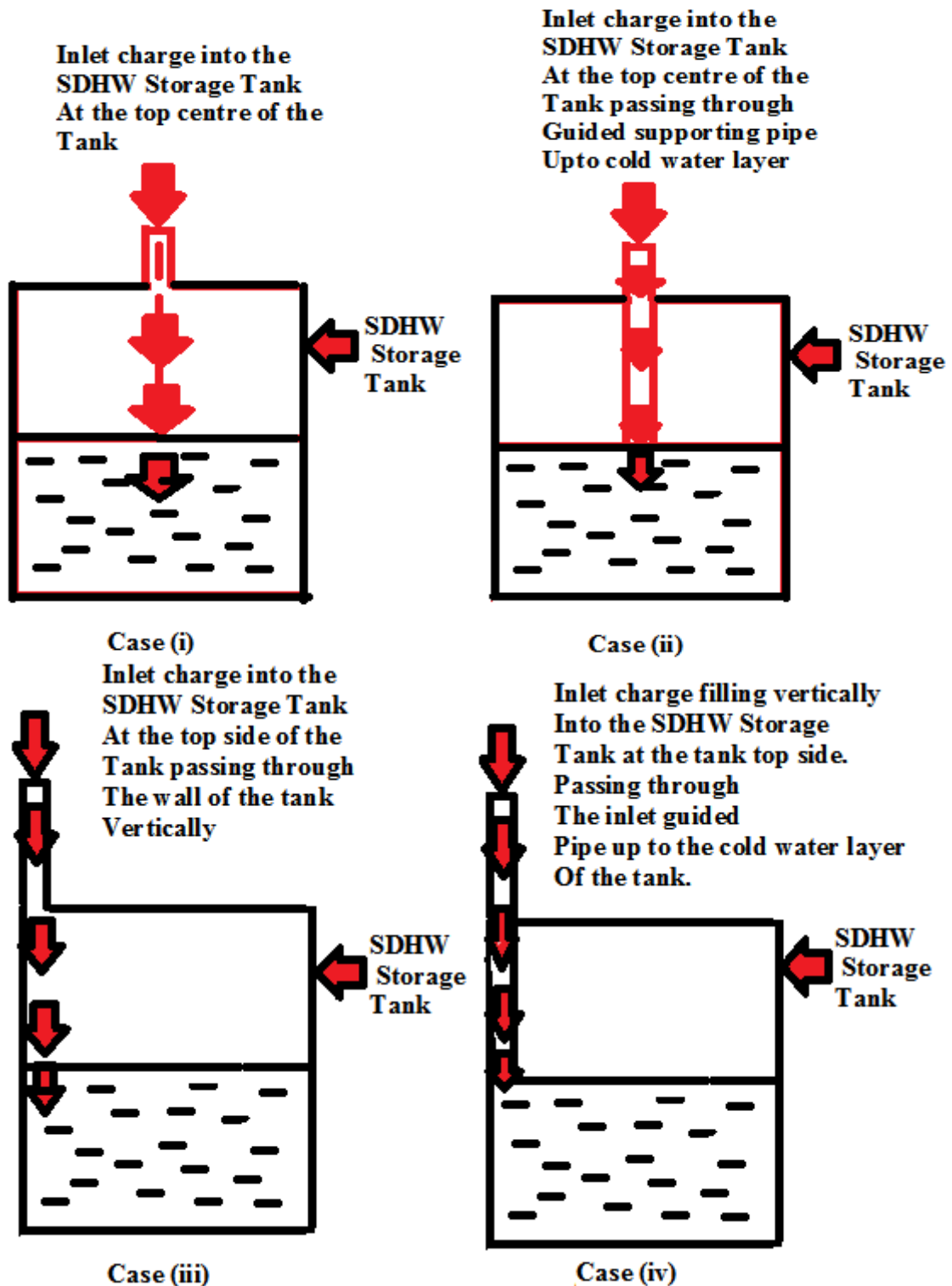
Fig.6: Ready model set up to observe flow influence during charging of water in the storage tank.

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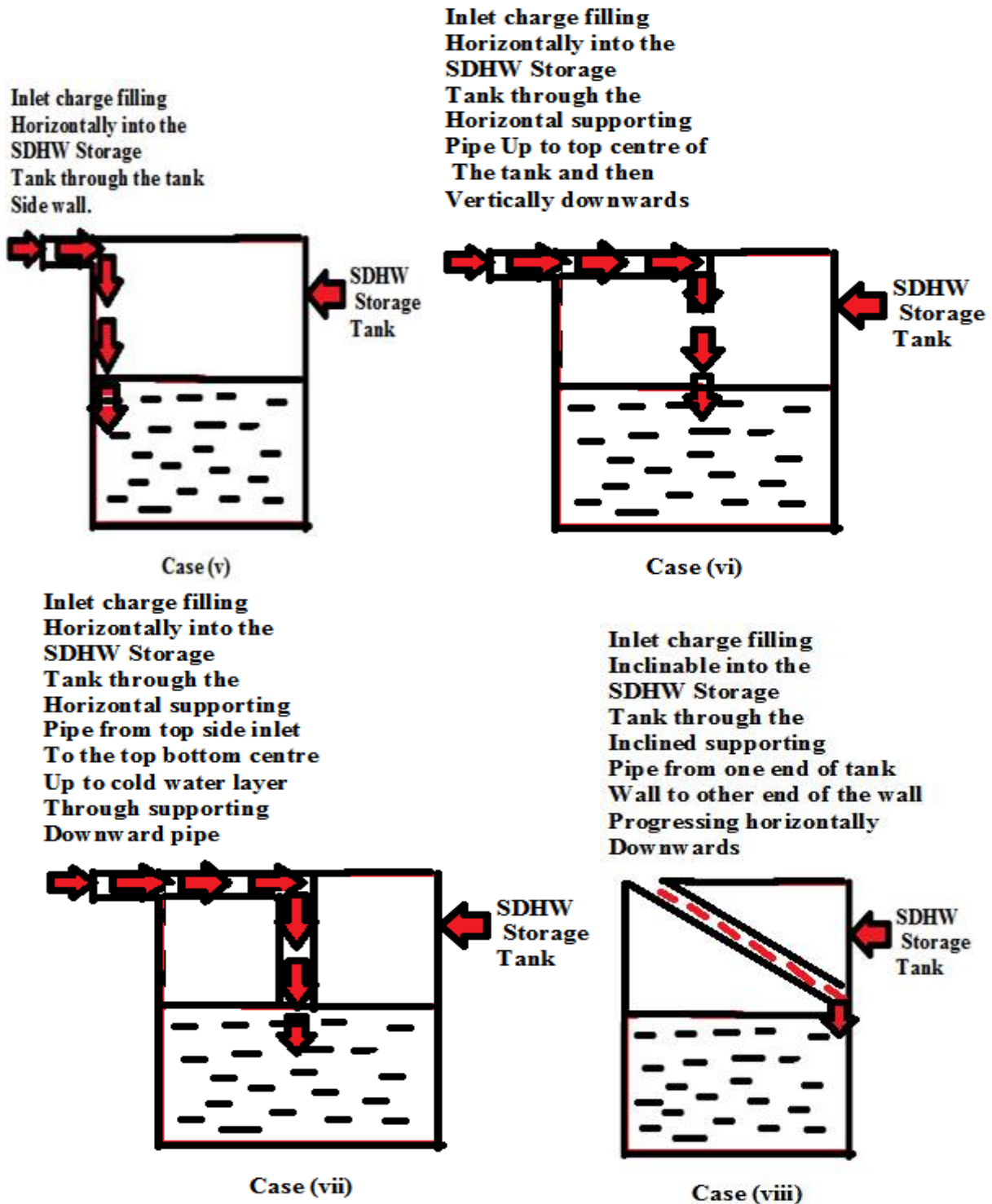


Fig.7: Schematic diagram of cases (i) to (viii) under experimental study and analysis.

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III. RESULTS AND DISCUSSIONS

The eight experimental cases have been taken under consideration for experimental study and analysis. For all the cases it has been considered that cold water is being filled up by gravity to the solar panel. Initially the half of the SDHW storage tank is filled up with cold water. The cold water enters into the solar panel for heating purpose and to charge into the SDHW storage tank. The makeup water line supplies the cold water into the SDHW storage tank to maintain the minimum half portion cold water level into the SDHW storage tank. Hence make up water line from the domestic water tape line compensates the reduction of water level from the SDHW storage tank due to transfer of cold water from the SDHW storage tank to the solar panel pipe. The charging of hot water starts after the solar panel line received the minimum desired hot water in the range from 50 to 90 degree centigrade.

Here the in this experimental analysis the charging fluid flow at different inlet port has been taken under main study and consideration. To understand the flow disturbance of fluid due to improper guide to the charging fluid and location of charge port has been analyzed in different eight cases. The die color is introduced into the charging fluid to visualize and identified the influence of flow disturbance due to random selection of inlet charging port.

The charging fluid is supplied to the SDHW storage tank due to gravity flow vertically downwards. To find out the velocity of the charging fluid, the charging valve full opened and collected water for 5 cm rise of water level in the tank. Time taken to raise the water level in the tank has been noted down, which is approximately 102 seconds.

Then used the relation, discharge equal to volume flow rate upon time of flow to raise 05 cm height water level in the storage tank, to find velocity and type of flow.

$$Q = V / t \dots \text{in m}^3 / \text{Sec.}$$

Where, Q = Flow rate in $\text{m}^3 / \text{Sec.}$

$$V = \text{Volume of the water storage tank for 5 cm height water collection in m}^3 \\ = (\pi \times D^2 \times h) / 4 \text{ in m}^3$$

$$D = \text{Diameter of the model storage tank} = 26 \text{ cm} = 0.26 \text{ m.}$$

$$h = \text{Height of water level rise into the storage tank} = 5 \text{ cm} = .05 \text{ m}$$

$$V = (\pi \times 0.26^2 \times 0.05) / 4 \\ = 0.00265 \text{ m}^3$$

$$t = \text{time required to fill 5 cm level of water into the storage tank in seconds} \\ = 102 \text{ sec.}$$

$$Q = (0.00265 / 102) = 0.000026 \\ = 26.025 \times 10^{-6} \text{ m}^3 / \text{sec.}$$

Also we know from the continuity equation that the rate of flow is,

$$\text{Also, } Q = a \times V \dots \text{in m}^3 / \text{sec}$$

Where, a = Area of the outlet charging pipe = $(\pi \times d^4) / 4 \dots \text{in m}^2$

V = Velocity of flow from the charging pipe into the tank.

d = Diameter of the charging pipe is 12 mm = 0.012 m

$$Q = ((\pi \times d^4) / 4) \times V \\ 26.025 \times 10^{-6} = ((\pi \times 0.012^4) / 4) \times V$$

Therefore, V = 0.2363 m / sec.

To understand the type of flow for average velocity of 0.2363 m / sec, used the relation of Reynold's Number (Re).

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We know that, $Re = (\rho \times V \times d) / \mu$

Where, ρ = Density of water taken as 1000 kg / m^3

V = Velocity of flow through the charging pipe into the storage tank = 0.2363 m/sec

d = Diameter of the charging pipe = $12 \text{ mm} = 0.012 \text{ m}$

μ = Viscosity of water at normal temperature = $0.891 \times 10^{-3} \text{ kg / m-sec}$

Therefore, $Re = (1000 \times 0.2363 \times 0.012) / 0.891 \times 10^{-3}$

$Re = 3183$ (Transitional flow)

As the obtained Reynold's Number is 3183, which is below 4000 that means the flow is transitional and tends to turbulent flow. After doing calculations from the experimental values to find velocity of vertically down word charging fluid and Reynolds number, it became prime objective of the experiment to visualize the flow disturbance and to find and identify the lesser flow disturbing charging port to reduce down the thermal stratification of SDWH storage tank due to charging of water into the storage tank.

The experimental image of cases (i) is as shown in Fig. 8. It is observed from the experimental image that due to charging from at the centre of the tank without having pipe support to the charge fluid, there is having flow penetration and hence flow disturbance from the centre towards developing the wall of the tank, with bubble formation and wavy formation due to gravity flow inlet and without any reducing guiding support to the charging fluid.

The experimental image of case (ii) is as shown in the Fig. 9. This experimental image shows that, even though the charging fluid enters at the centre of the tank vertically down ward, but due to guiding support of the charging fluid by the charging pipe, the flow penetration, disturbance and bubble and wavy formation is less compared with case (i).

The Fig. 10 shows the experimental image of case (iii). While conducting the case (iii) experiment it was observed that there is guided support of the vertically downward flow of charging fluid through the tank wall. But due to long distance of flow to settle down in the tank some local are disturbance of flow takes place with local area wavy form flow disturbance and with bubble formation of water.

The Fig. 11 represents the image of case (iv). In this case there is pipe guided support for the vertically down ward flow passing through the wall of the tank up to the mid of the tank where there is cold water layer, and the charging fluid starts mixing and rising water level from this particular local area zone. No as such flow disturbance, not as much flow penetration, no wavy form and bubble formation has been observed because of the guided flow of the charging fluid to the tank cold water layer level.

The Fig. 12 is about experimental image of case (v). in this case the charging water enters horizontally from the top side of the tank, exactly touching the wall of the tank. There is no flow disturbance, wavy form and bubble formation observed in this case. In this case when the charge before in touch with the cold layer zone, it got enough space to spread around the vertical wall of the tank, due to which velocity of flow reduced down and no as such undesired flow disturbance has been observed.

The Fig. 13 shows the experimental image of case (vi). The charging here is takes place horizontally but without touching the tank wall. Directly the charging fluid hits at the centre of the cold water layer. The flow penetration is much as there is no support to the charging fluid and from the top centre of the tank the charging fluid hits the cold water layer vertically down wards due to gravity flow. Also it was observed the wavy forms development much and progression of flow disturbance in the form of waves and bubbles from the centre of the tank to the walls of the tank. There is totally a massacre of the stratification of the storage tank.

The Fig. 14 presents the experimental image of case (vii). Here the charging water enters horizontally at the top centre of the tank and then the charge pass through the guided pipe up to the mid of the tank from where the cold water layer starts and stratification to be maintained. it was observed during the experiment that there is very less or minor flow disturbance. No as such wavy formation and development of stratification disturbances observed or occurred from the centre of the water layer zone to the adjacent walls of the tank. Only some minor bubble formation observed. Such bubbles also collapsed very fast without creating or forming any flow disturbance.

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Here the Fig. 15 shows the experimental image of case (viii). In this case the charge is supplied inclined way. This flow hits the wall of the tank horizontally and then the water level rises. Here also in this case very rare flow disturbance occurred. The flow hitting initially to the tank wall is the vital factor not to disturb much the stratification of water.

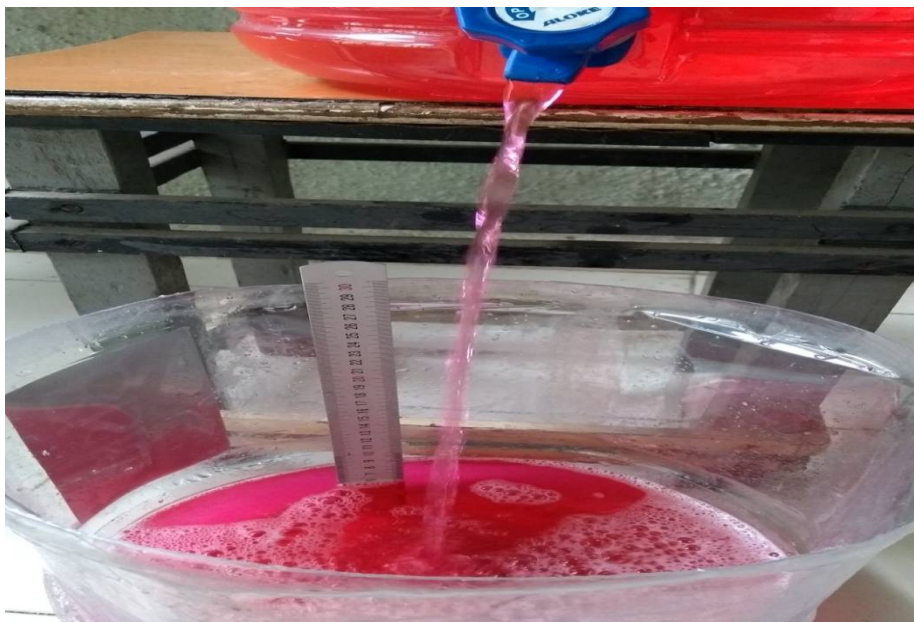


Fig.8: Experimental image of case (i)

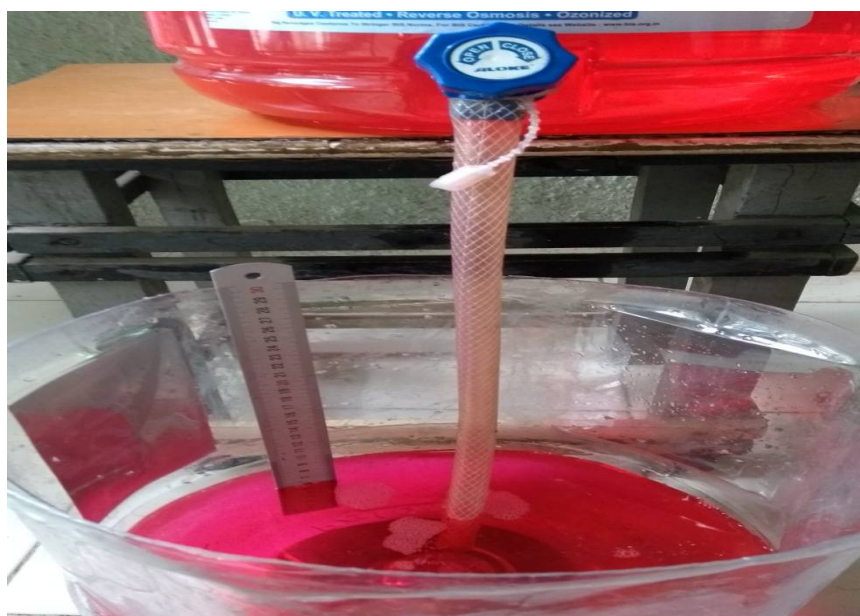


Fig.9: Experimental image of case (ii).

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Fig.10: Experimental image of case (iii).



Fig.11: Experimental image of case (iv).

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Fig.12: Experimental image of case (v).



Fig.13: Experimental image of case (vi).

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Fig.14: Experimental image of case (vii).



Fig.15: Experimental image of case (viii).

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IV. CONCLUSIONS

Multiple different experimental cases were taken under study and observation to visualize and understand the flow disturbance and disturbance of stratification of thermal water storage tank. Here only the flow analysis and flow disturbance has been taken under consideration. The thermal behavior is neglected in this experimental analysis, even though the study is about disturbance of thermal stratification of SDHW storage tank. The prime factor to neglect the hot temperature of the charging fluid and to perform the charging experiment in the storage tank, with the normal atmospheric temperature water is due to understanding of influence of flow penetration and flow disturbance and stratification layer disturbance, because of charging ports location and orientation. The flow disturbance influence was observed experimentally in different cases of the experiment. From these different experimental cases it can be concluded that the cases of direct hitting the cold layer zone should be avoided as there is much more flow disturbance. The case (i) & (vi), where the charge enters from the centre of the tank and hits the cold water layer, should be avoided as there is no proper guide to the charge fluid and charge water hits the cold water layer at the centre of the cold water layer due to gravity flow, stored potential energy and head at a kinetic velocity, which creates much flow disturbances with disturbed flow propagation from the centre of the tank to the adjacent walls of the tank. Hence the full tank circumferentially experiences unstratification and flow disturbance of water layers.

Rest all other cases can be implemented based on the design and cost effectiveness of the set up. As in other case no as such major flow disturbance has been observed. Because the other cases start from case (ii), case (iii), case (iv), case (v), case (vii) and case (viii) is having guided support to the charging fluid either by charging pipe or through the wall of the storage tank and no direct hitting penetration of the cold water layer, where we are suppose to maintain stratified storage of water of cold and hot water zone with minimal mixed unstratified zone.

in which the charge is being guided by the pipe and placed upto the cold layer zone Only after consideration

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