NUMERICAL INVESTIGATION ON SOLAR FLAT PLATE COLLECTORS CONNECTED IN SERIES WITH DIFFERENT MASS FLOW RATES FOR THE GIVEN DEMAND

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***Abstract*:** Energy obtained from the sun can be converted in to useful work in many ways. Out of which most efficient method to convert cold water in to hot water for domestic purposes is by means of passing working fluid water through the flat plate collectors. Various research works are made as a mean to improve the performance of solar flat plate collector. Purpose of this work is to replace the electric water heaters which are being used in our institute (NIT TRICHY) with solar flat plate collectors, according to the demand of hot water in hostels. This contains the modelling of flat plate collector and simulation to find out the best combination of mass flow rate and number of collectors connected in series to get higher temperatures . Software used for the simulation is "SOLIDWORKS 2016". In addition to this, experiments were done to compare the efficiencies of conventional electric water heater and the induction water heater.

***IndexTerms*-Solar flat plate collector (SFPC) , electric water heater , SOLIDWORKS**

I. INTRODUCTION:

Hot water production is one of the most interesting application in solar energy and the demand for hot water greatly increases particularly in the residential use principal components of solar hot water systems are solar collectors and thermal storage tank. In collective use, we use number of collectors which are fixed in a position in order to get an optimized capture over a year. Solar collectors may be connected together in series or in parallel or in parallel-series. Despite the fact that parallel connection is preferred by several users, it causes however some problems such as heat losses and pressure drop. When collectors are mounted in series, mass flow rate is assumed to be the same in each collector and the outlet water temperature increases from a collector to the another. This leads to increase of the difference between the inlet and outlet temperature of the collector.

II. METHADOLOGY

Initially, demand of hot water in hostels of our institute (NIT Trichy) is found out. Comparison of efficiencies of conventional water heater and induction water heater is done . Then the 3D-model of the flat plate collectors was made in SOLIDWORKS 2016 and flow simulation was done in COSMOS (Flow Simulation part of SOLIDWORKS 2016). The Simulation was run for two collectors in series , three collectors in series and four in series with different inlet mass flow rates (forced circulation) simulation is done for transient state for a time period of 210 minutes.

Demand :

Total no. of students = 1500 (girls hostel)
Hot water used by each student = 10 lpd.
Total demand of hot water =15000 lpd
No. of working hours of heaters per day = 4hrs
Units consumed per day =(1.15*4)=4.6MWh

Table: 2.1 Details of geysers being used in institute

Type of heater	No.
2kw rating of 25 liters capacity (boys hostel)	20
3kw rating of 25 liters capacity (girls hostel) *	25
Total	45

Total power: (2*20+3*25) =1.15MW.

III. Modeling of flat plate collector

Modeling is done using SOLIDWORKS2016 dimensions of each collector is given below
Absorption area, AC= 1.44m2 (0.8*1.8)
Working fluid = Water
Collector tilt, θ = 22°
Head tube size = Φ25.4mm * t2mm (2 pcs.)
Riser tube diameter = Φ19mm * t2mm (6 pcs)
Glass cover = 3 mm thick glass cover with unit transmittance

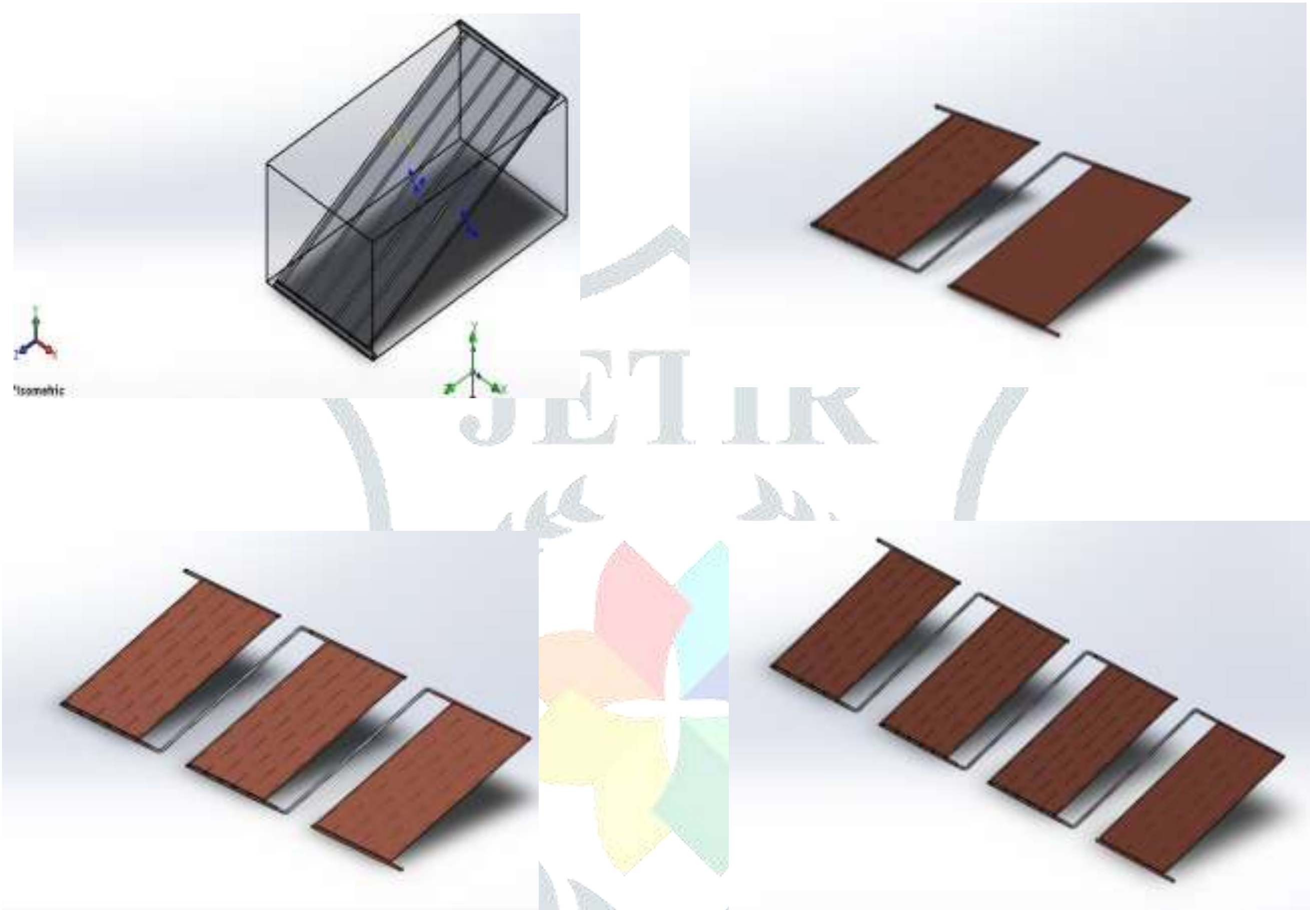


Figure:3.1 Modelling of SFPC in series done in SOLIDWORKS

Assumptions

Some assumptions and considerations taken for the purpose of simulations and they are as follows:

1. Inclination of FPC 22 degree from the horizontal plane.
2. Side walls to be perfectly adiabatic.
3. Initial inlet fluid temperature 303K
4. Ambient temperature 303K
5. Neglecting Loss coefficient.
6. Glass plate transmittance is taken as 1.
7. Single Phase Fluid
8. Radiation is considered only from top of the absorber plate.

Simulation analysis

The solar insolation is not kept constant but instead it is varied with the hours of the days, the data fed to the software is the actual practical data fetched from the pyranometer installed at the LHC. The insolation taken is the data for 210mins with the reading at 30min intervals which can be seen below:

Table:3.1 Insolation data with time

Time (min)	Solar insolation (W/m^2)
0	600
30	700
60	800
90	900
120	800
150	750
180	700
210	600

The transient state case also includes the time variability for which the simulation will run. We have taken it to be 210 mins with the time interval of 30min. Each case with variable mass flow rate for different combination of series connected SFPC. outlet temperatures for different combinations is taken as results.

IV. RESULTS

Instead of electric heaters we can use SFPC. Power consumption of SFPC is almost zero. So, here we are trying to find the suitable mass flow rate of water with no. Of SFPC connected in series. Mass flow rates of 0.01 kg/s is given for two SFPCconnected in series , 0.01 kg/s ,0.025 kg/s , 0.0075 kg/s are taken for three SFPC in series and 0.1kg/s, 0.05kg/s ,0.025kg/s,0.01kg/s for four in series. Temperature raise in each case are in given below tables

4.1Two SFPC in series

Table:4.1 Temperature raise for two SFPC in series

Mass flow rate (kg/s)	Velocity (m/s)	Inlet water temperature (^oc)	Outlet temperature (^oc)	Temperature raise
0.01	0.0352	30	46	16

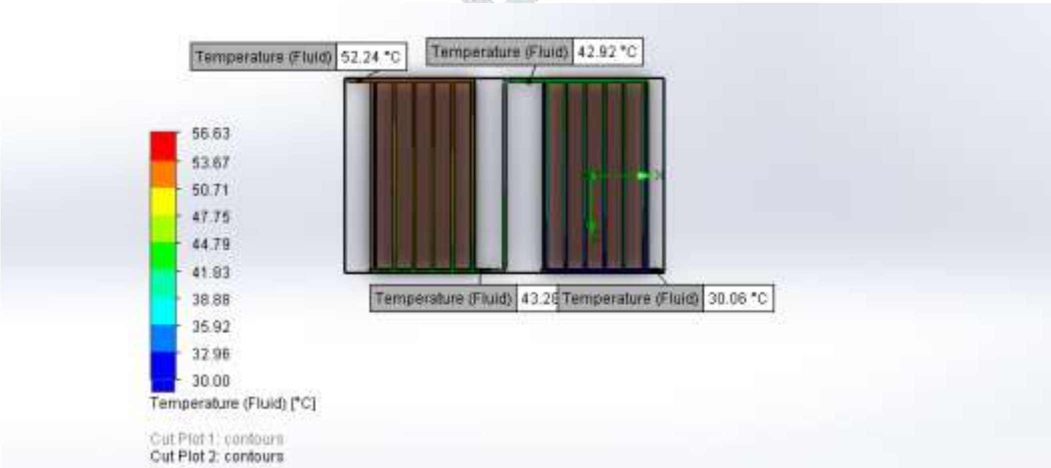


Figure:4.1 Temperature contours of two SFPC connected in series

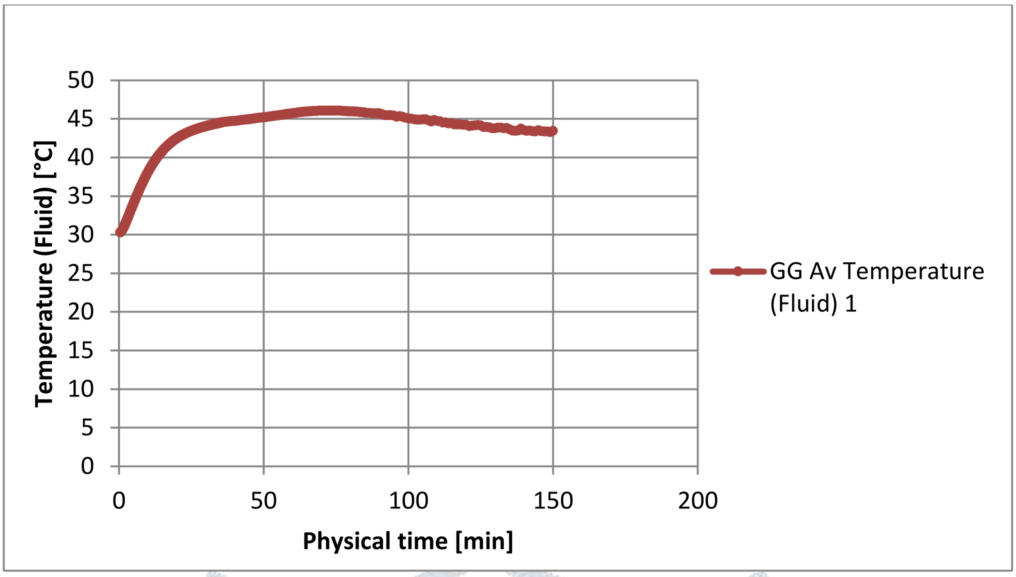


Figure4.2 Temperature of fluid with time for flow rate 0.01kg/s

4.2 Three SFPC in series

Table:4.2 Temperature raise for three SFPC in series

Mass flow rate (kg/s)	Velocity (m/s)	Inlet water temperature (^oc)	Outlet temperature (^oc)	Temperature raise
0.025	0.088	30	44	14
0.01	0.0352	30	56	26
0.0075	0.0176	30	60	30

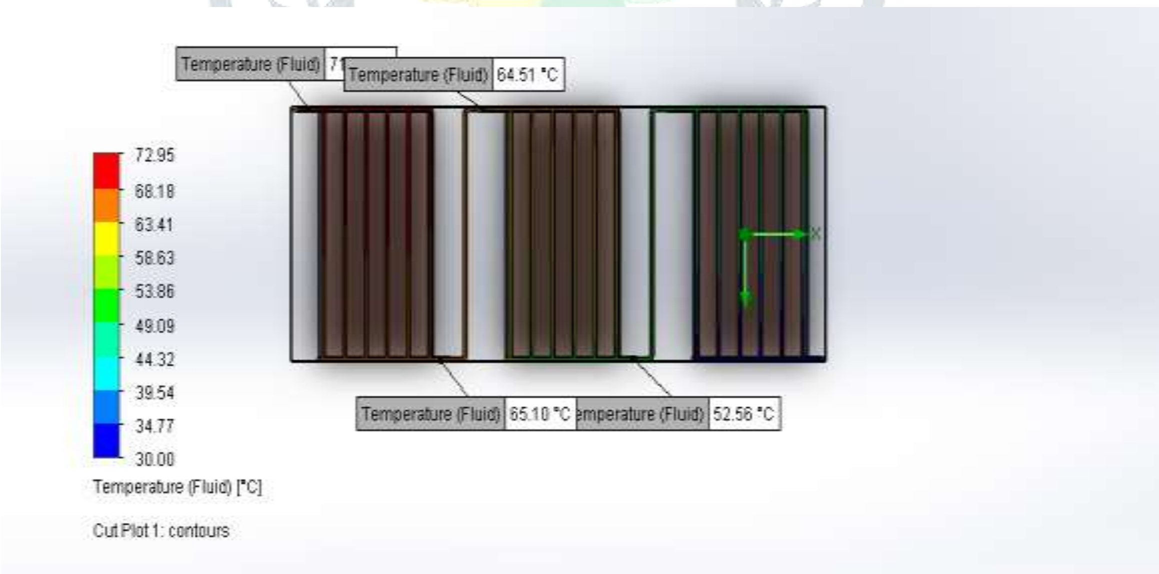
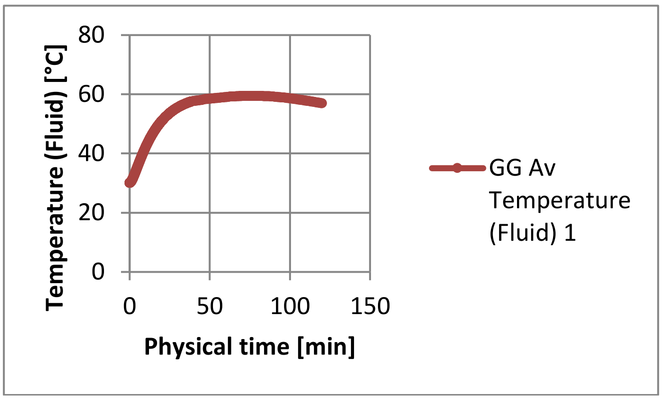
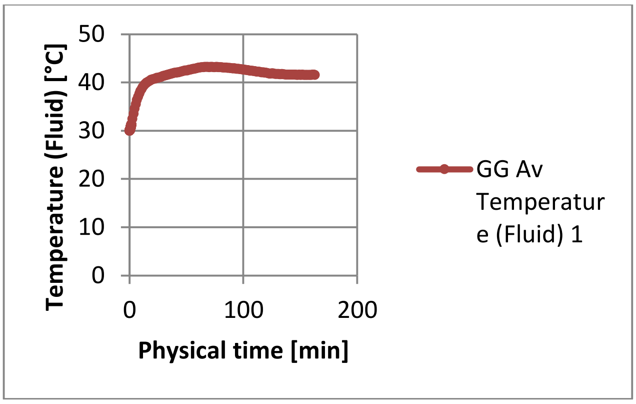


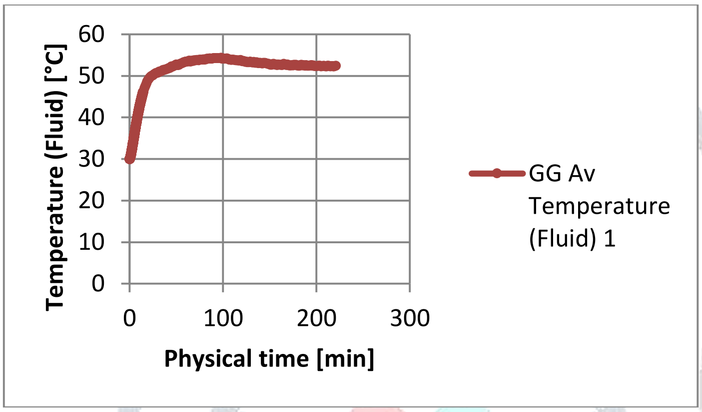
Figure: **Error! No text of specified style in document.**.1 Temperature contour for mass flow rate 0.0075kg/s (3 SFPC in series)



(a) mass flow rate 0.0075kg/s (3 SFPC in series)



(b) mass flow rate 0.025kg/s (3 SFPC in series)



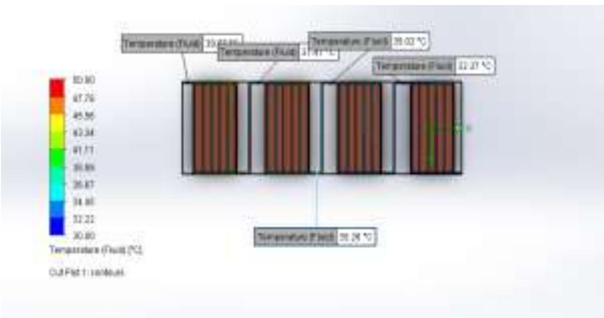
(c) mass flow rate 0.01kg/s

Figure4.4 Temperature raise with time for mass flow rates (a), (b),(c) for 3 SFPC in series

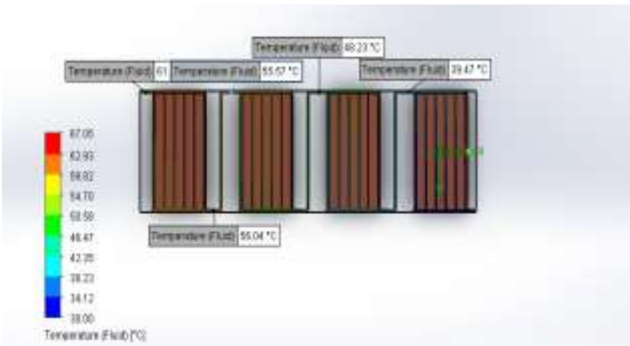
4.3 Four SFPC in series

Table: 4.3Temperature raise for four SFPC in series

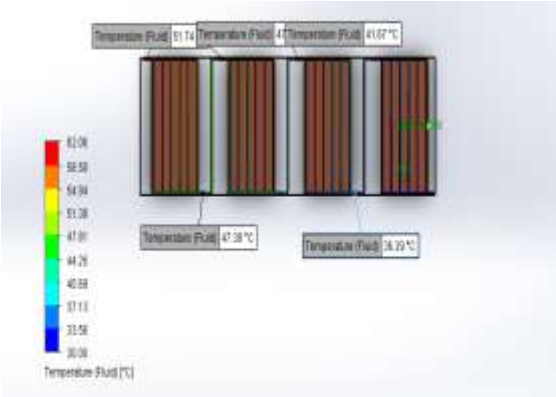
Mass flow rate (kg/s)	**Velocity (m/s)**	**Inlet water temperature (°c)**	**Outlet temperature (°c)**	**Temperature raise**
0.1	0.326	30	35.6	5.6
0.05	0.176	30	43	13
0.025	0.088	30	52	22
0.01	0.0352	30	69	39



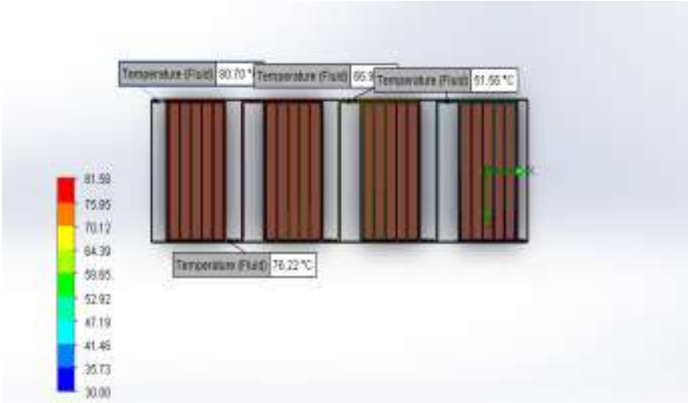
(a) Mass flow rate 0.1kg/s



(b) Mass flow rate 0.25 kg/s



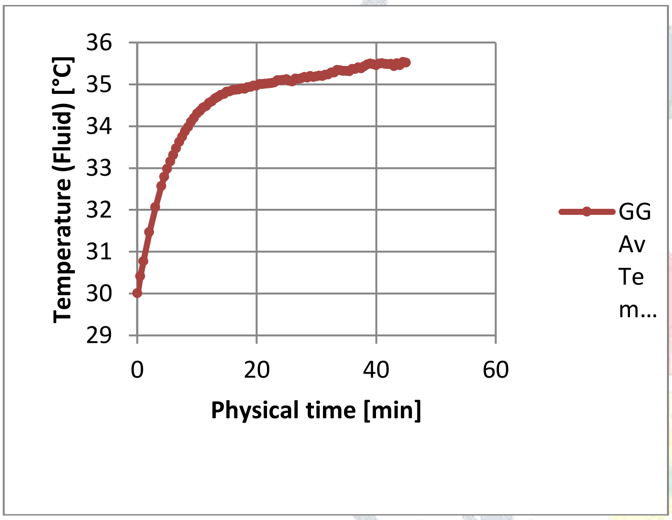
(b) Mass flow rate 0.05kg/s



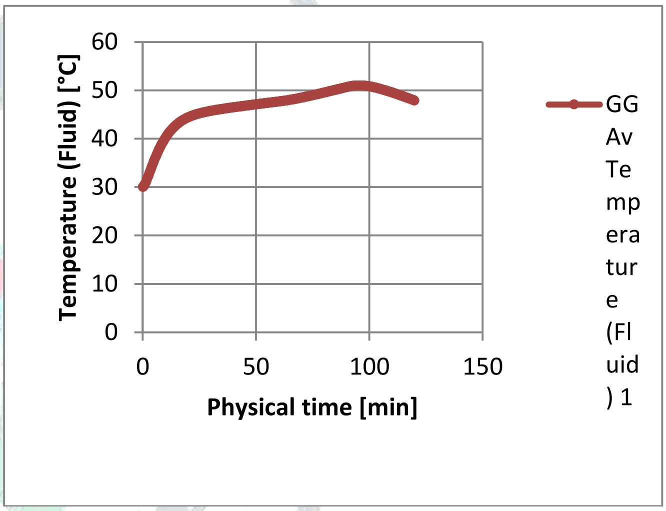
Mass flow rate 0.01kg/s

Figure:4.5 Temperature contours of four SFPC connected in series

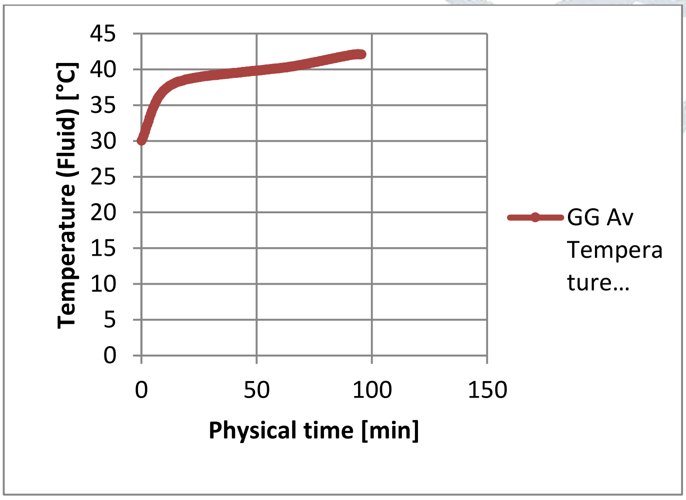
We can see that in each case the as mass flow rate is reducing the outlet temperature at each collector which are in series is raising. Temperature raise of first collector is more compared to the next collector.



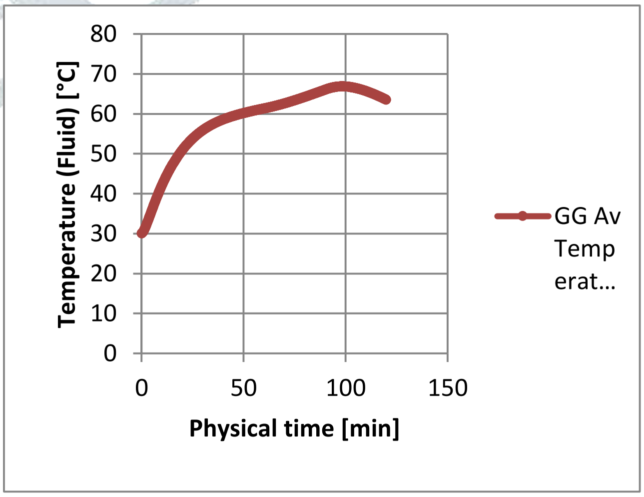
(a) Mass flow rate 0.1 kg/s



(b) Mass flow rate 0.25kg/s



(c)Mass flow rate 0.05kg/s



(d) Mass flow rate 0.01kg/s

Figure: **Error! No text of specified style in document.**.2 Temperature raise with time for mass flow rates (a), (b),(c),(d) for 4 SFPC in series

Finally , required temperature with required quantity of hot water is obtained with mass flow rate of 0.1kg/s for 4nos. of SFPC in series. Temperature obtained for 0.1kg/s mass flow rate is 69^{o}c,quantity of water obtained is 2160 liters of hot water per day .

V. CONCLUSIONS

- In SFPC as mass flow rate is decreasing outlet temperature of water is increasing.
- As number of collectors in series are increasing outlet temperature is increasing.
- When solar insolation is more temperature of water is high .
- We can choose best combination according to our requirement of outlet water temperature and quantity of water required.
- For the demand in our institute hostel we can choose 4nos.of SFPCs of area 1.44m^2 each in series with mass flow rate of 0.01kg/s outlet temperature obtained is 69^{o}c.

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