Performance Analysis of Hot Water Storage Tank in Solar Water Heating System with Different Insulation Using ANSYS

Dr. Dheeraj. S. Deshmukh
Associate Professor,
Mechanical Engineering
DBACER ,YCCE Campus,
Wanadongri, Nagpur

Mahesh V. Kulkarni
Research Scholar & Asstt. Prof.
Mechanical Engineering
SSBT`s, COET,
Bambhori, Jalgaon

Dr. S. P. Shekhawat
Professor, & HOD
Mechanical Engineering
SSBT`s, COET
Bambhori, Jalgaon

Abstract – Analysis of solar domestic hot water (SDHW) storage tank carried out by using CATIA and ANSYS software. The tank fluid is in steady mode. The storage tanks made up of MS plate, 50 mm Polyurethane, Glass wool and Rockwool insulation, outer-cladding cover. Hot water storage tank model made in CATIA software and effect of different insulation materials such as Polyurethane, Glass wool and Rockwool analyzed in ANSYS. Due to improper insulation material the constant hot water temperature inside the tank drops after of certain period due to heat diffusion and natural convection from the tank walls and it is difficult to get constant temperature all the time. To keep constant temperature polyurethane is best insulation than Glass wool and Rockwool. Also for minimum night heat losses polyurethane is best insulation than Glass wool and Rockwool

Keywords— Polyurethane, Glass wool, Rockwool, Solar Hot Water Storage Tank, CATIA and ANSYS

I. INTRODUCTION

To minimize the loss of heat during the night the heat insulation of the storage tank of a solar thermal system is of vital importance. Typical insulation materials are foamed polyurethane, polyethylene or polypropylene, at least 100 mm thick. Alternatively also organic materials made from cellulose or raw wool can be used, demanding a somewhat higher thickness or more layers of insulation to get the same effect. Since solar storage tanks are thermally stratified – with cold-water layers at the bottom and hot-water layers at the top – many state-of-the-art tanks are asymmetrically insulated, meaning an increasing insulation thickness from bottom to top.

II. *TYPES OF INSULATING MATERIALS*

POLYURETHANE FOAM

Polyurethane foam is widely used in high resiliency flexible foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires, automotive suspension bushings, electrical potting compounds, seals, gaskets, carpet underlay, and hard plastic parts (such as for electronic instruments).

One of the best commercially available choices of insulation material is polyurethane foam. It has good thermal insulating properties, low moisture-vapour permeability, and high resistance to water absorption, relatively high mechanical strength and low density. In addition, it is relatively easy and economical to install.

Polyurethane foam is effective as an insulator because it has a high proportion (90 percent minimum) of non-connected closed microcells, filled with inert gas. Until recently, the inert gas most commonly used in polyurethane foams was R-11 (trichlorofluoromethane).

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Fig.1 Polyurethane foam

GLASS FIBRE (GLASSWOOL)

Rigid board panels can be made with compressed fibre glass. These lightweight insulation boards have relatively high R-values for their thickness.

Fig.2 Glasswool

ROCKWOOL

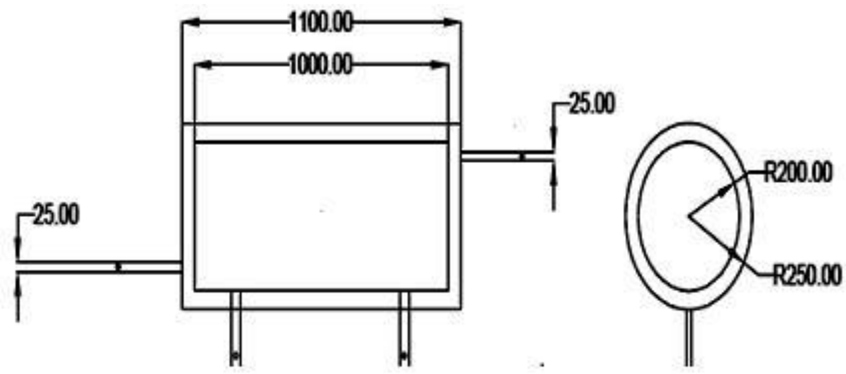
Rockwool is general name for fibre materials that are formed by spinning or drawing molten minerals. Applications of rockwool includes thermal insulation, filtration, soundproofing, hydroponic growth medium

Though the individual fibers conduct heat very well, when pressed into rolls and sheets, their ability to partition air makes them excellent insulators and sound absorbers. Though not immune to the effects of a sufficiently hot fire, the fire resistance of fiberglass, stone wool, and ceramic fibers makes them common building materials when passive fire protection is required, being used as spray fireproofing, in stud cavities in drywall assemblies and as packing materials in firestops.

Other uses are in resin bonded panels, as filler in compounds for gaskets, in brake pads, in plastics in the automotive industry, as a filtering medium, and as a growth medium in hydroponics.

Mineral fibers are produced in the same way, without binder. The fiber as such is used as a raw material for its reinforcing purposes in various applications, such as friction materials, gaskets, plastics, and coatings.

III. *DIMENSIONS SPECIFICATION OF TANK*

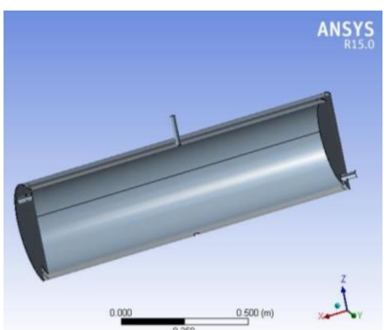


Length of tank = 1100 mm
Diameter of pipe = 25 mm
Diameter of tank = 500 mm
Layer 1 is of stainless steel of 2mm thickness
Layer 2 is of insulation of 50mm thickness
Layer 3 is of stainless steel of 2mm thickness
Capacity of tank = 120 liters

IV. ANALYSIS OF SOLAR WATER STORAGE TANK

Steps In ANSYS For Analysis Of Solar Water Storage Tank

1.Create the model (Geometry) in CATIA.
2.Import the geometry from CATIA to ANSYS software.
3.Mesh the model.
4.Applying the Load and obtaining the solution
4.1 Defining the analysis type
4.2 Applying loads
4.2.1 Constant Temperature
4.2.2 Heat Flow Rate
4.2.3 Convections
4.2.3 Heat Fluxes
4.2.4 Heat Generation Rates
4.3 Applying the Boundary Conditions
5.Reviewing the Analysis report



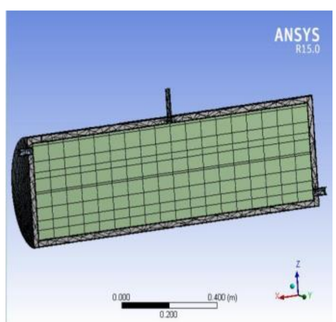


Fig. Geometry imported to ANSYS from CATIA **Fig. Mesh the geometry**

Since solar water storage tank having three layers it occurred convection layer by layer simultaneously.Hence design of tank in ANSYS given below

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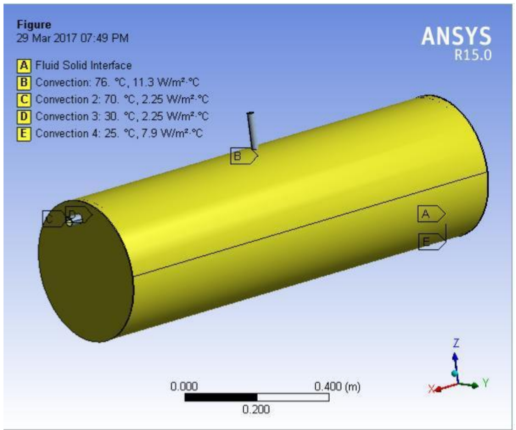


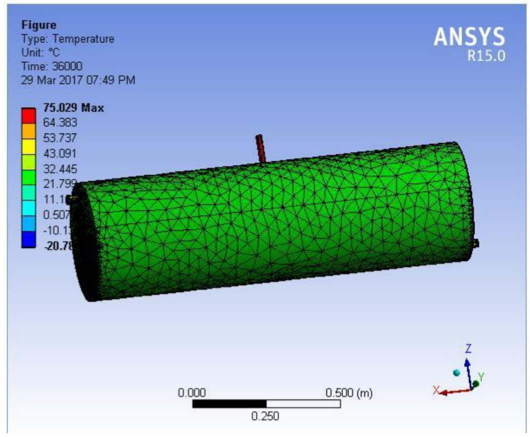


Fig.

Fig. Design of tank Fig.- Apply Heat Flux In ANSYS

Since solar storage tank has contact with sun so it will be goes through heat flux. Hence design of tank in ANSYS for heat fluxes :

Object Name	Fluid Solid Interface	Convection	Convection 2	Convection 3	Convection 4
Film Coefficient		11.3 W/m²·°C	2.25 W/m²·°C		7.9 W/m²·°C
Ambient Temperature		76°	70°	30°	25°

Table - convection value

V. *RESULT*

FOR POLYURETHANE

Object Name	Temp Global Max (°c)	Temp Global Min (°c)	Temp (°c)	Temp 1 (°c)	Temp 2 (°c)	Temp 3 (°c)	Temp 4 (°c)	Temp 5 (°c)
Min	75.029	-21.418	71.557	71.532	71.57	71.541	65.208	64.106
Max	76.665	46.475	75.786	75.787	75.789	75.78	75.202	75.009

Table. Temperature variation for polyurethane

Time (s)	Minimum (W/m²)	Maximum (W/m²)
360	1.9607e-003	6480.6
720	5.6688e-004	11056

1800	3.2531e-005	17195
5040	3.1829e-003	20905
8640	3.3541e-002	21473
12240	3.9079e-002	21406
15840	4.1972e-002	21263
19440	4.3501e-002	21141
23040	4.4179e-002	21045
26640	4.4521e-002	20971
30240	4.4816e-002	20911
33840	4.5009e-002	20863
36000	4.5066e-002	20837

Table – Heat Flux variation for polyurethane

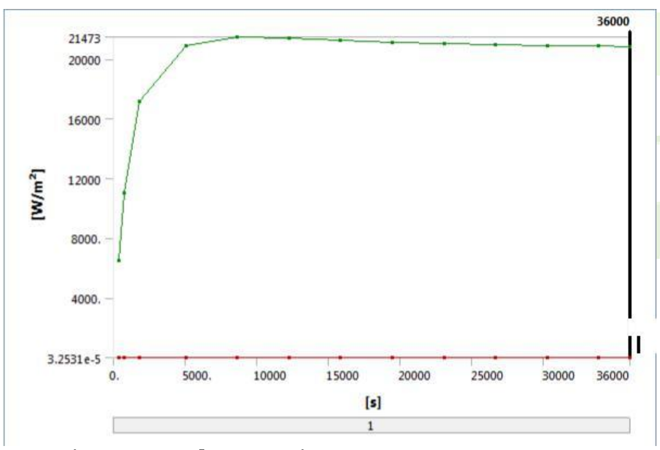


Fig.- Heat Flux VS Time

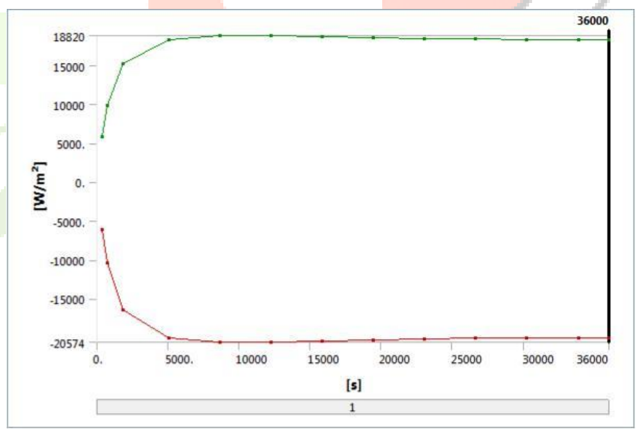


Fig. -Directional heat flux VS Time

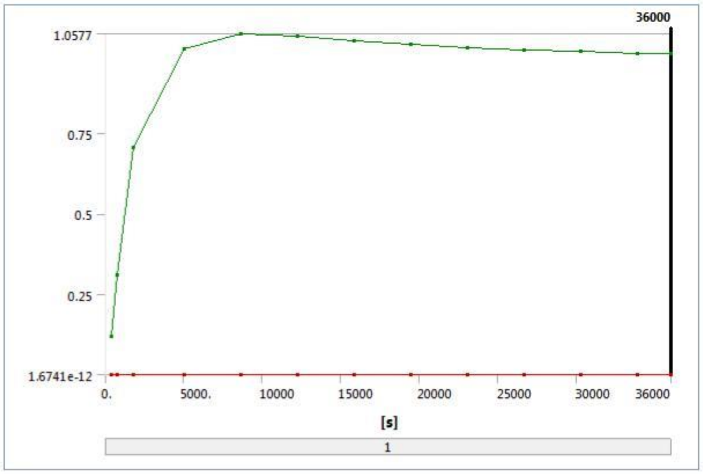
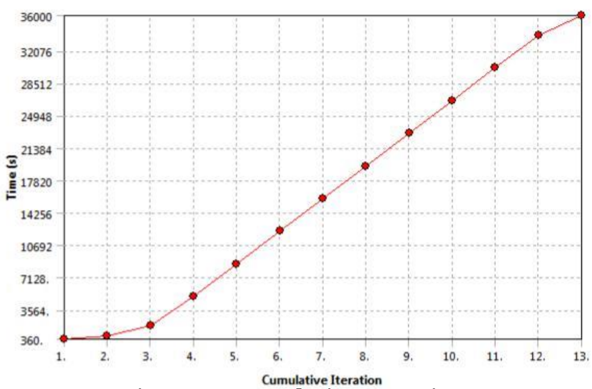
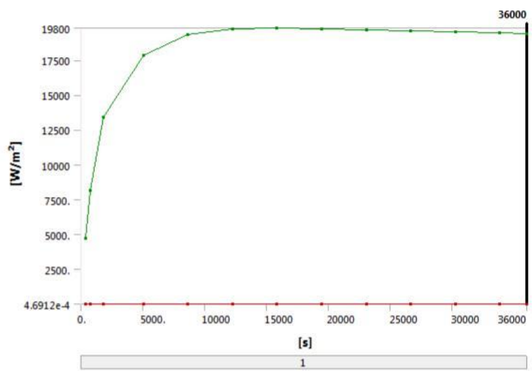


Fig. -Thermal Error VS Time

RESULT FOR GLASS FIBRE



Time VS Cumulative Iteration



Heat Flux VS Time

Hence for Glass Fibre insulation material Heat Flux variations are **:**

Time (s)	Minimum (w/m²)	Maximum (w/m²)
360	3.5395e-003	4717.8
720	1.6334e-003	8169
1800	4.6912e-004	13380
5040	5.9342e-003	17865
8640	2.4175e-002	19317
12240	5.1937e-002	19729
15840	5.4985e-002	19800
19440	5.7368e-002	19575
23040	5.9005e-002	19679

26640	**6.0162e-002**	**19596**
30240	**6.0939e-002**	**19520**
33840	**6.1449e-002**	**19453**
36000	**6.1599e-002**	**19416**

Table - for Glass Fibre insulation material Heat Flux variations

Hence for Glass Fibre insulation material temperature variations are **:**

Time (s)	Minimum (°c)	Maximum (°c)
360	**58.703**	**79.575**
720	**44.841**	**80.757**
1800	**21.802**	**79.495**
5040	**-0.40305**	**75.998**
8640	**-8.6942**	**75.978**
12240	**-11.756**	**75.983**
15840	**-12.93**	**75.869**
19440	**-13.357**	**75.776**
23040	**-13.472**	**75.629**
26640	**-13.456**	**75.461**
30240	**-13.338**	**75.267**
33840	**-13.229**	**75.055**
36000	**-13.245**	**74.922**

Table - Glass Fibre insulation material temperature variations

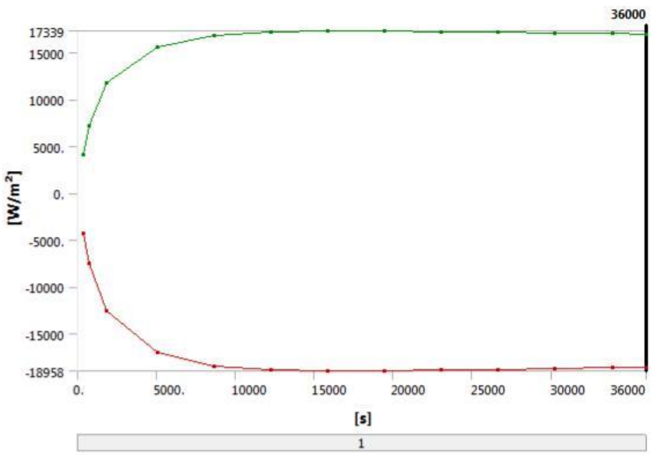


Fig Directional heat flux VS Time for Glasswool

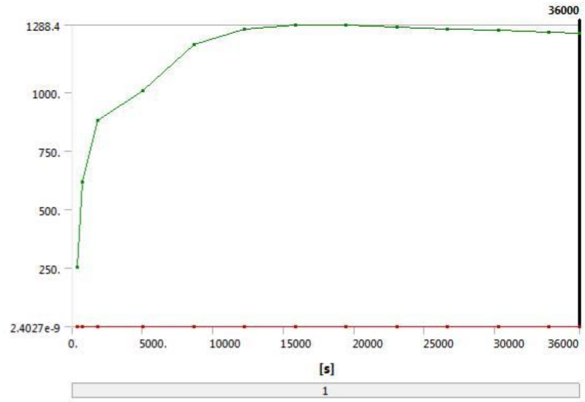


Fig. -Thermal Error VS Time for Glasswool

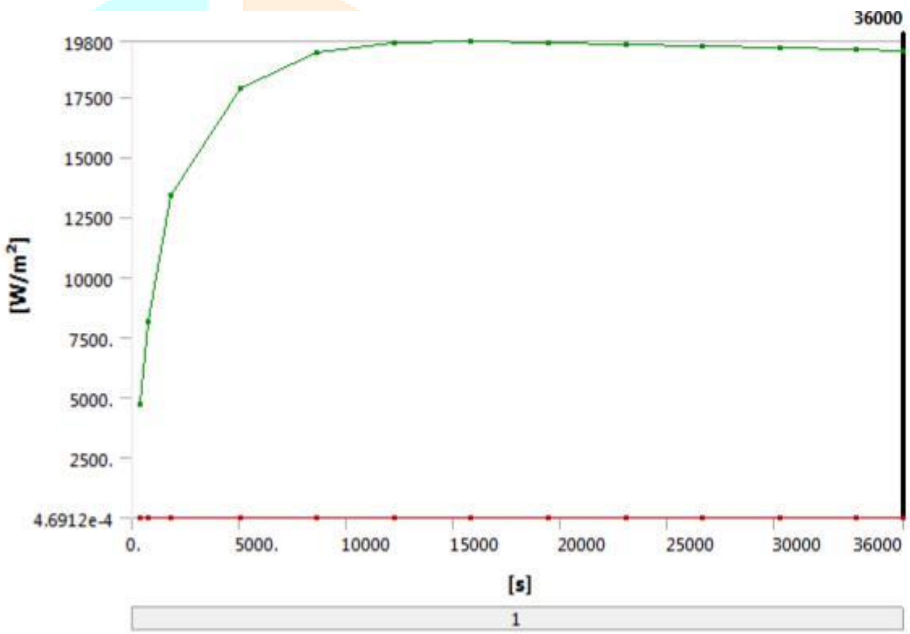


Fig. Heat Flux VS Time for Glasswool

RESULT FOR ROCKWOOL

Object Name	Temp Global Max (°c)	Temp Global Min (°c)	Temp (°c)	Temp 1 (°c)	Temp 2 (°c)	Temp 3 (°c)	Temp 4 (°c)	Temp 5 (°c)
Min	74.393	-9.7959	68.746	68.719	68.768	68.727	63.7	62.739
Max	76.61	54.968	75.674	75.675	75.679	75.665	75.175	74.992

Table Temperature variation for Rockwool

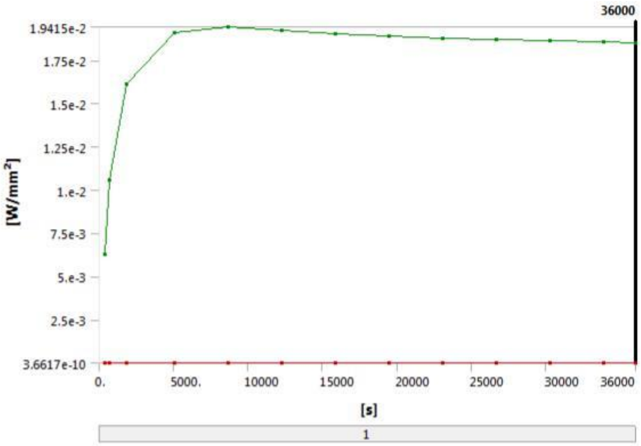


Fig.-Total Heat Flux VS Time for Rockwool

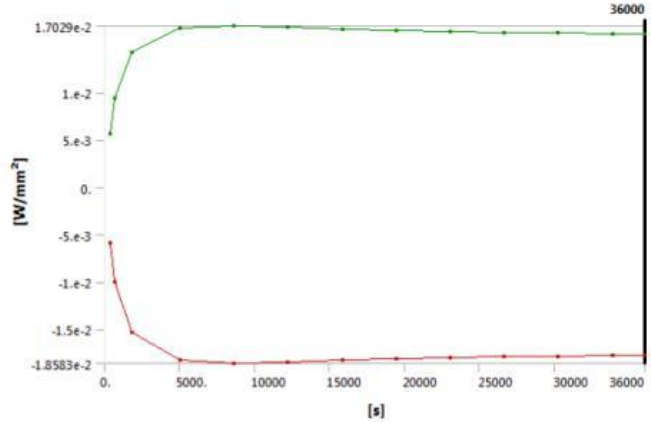


Fig. Directional Heat Flux VS Time for Rockwool

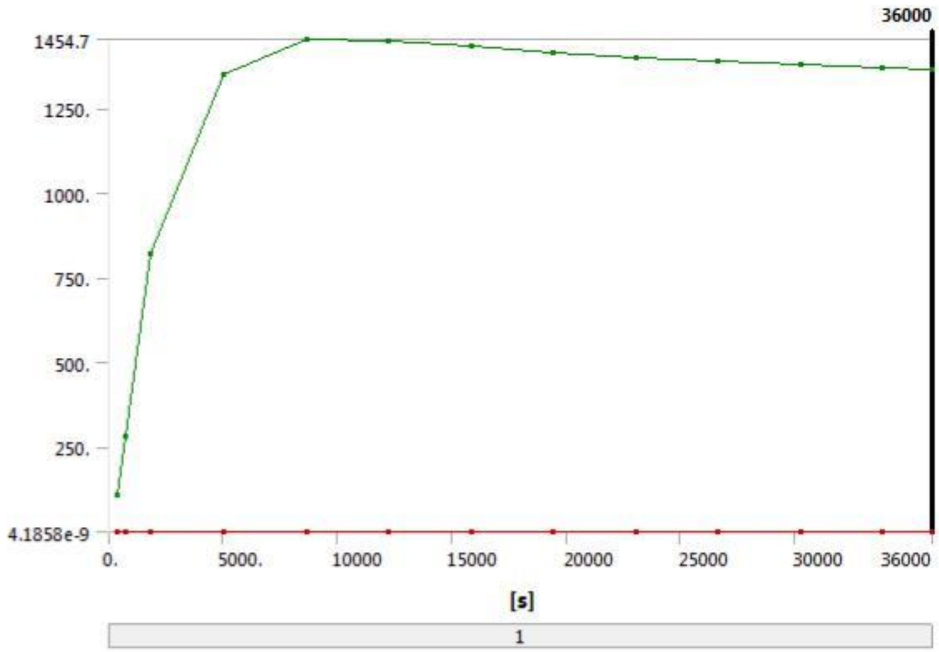


Fig Thermal Error VS Time for Rockwool

VI. CONCLUSIONS

Polyurethane, Glass wool and Rockwool insulation make a significant contribution to maintain temperature inside solar hot water storage tank. As changing insulation material in solar hot water storage tank its performance observed with ANSYS software. Different performance parameter such as night heat losses and temperature variation observed for Polyurethane, Glass wool and Rockwool insulation material. Form analysis it is observed that Polyurethane is most efficient thermal insulation. Polyurethane reduces night heat loss and maintains highest temperature in solar water hot water tank than Glass wool & Rockwool. It concluded that there are some aspects which altered while changing insulation materials simultaneously.

Temperature: Highest temperature occurred at Polyurethane, by then Glass fibre and last one at Rockwool.

Heat Flux: There are night heat losses occurred due to heat flux, thermal error as it also goes decreasing from Polyurethane, Glass fibre and Rockwool.

Life: Among the three insulations, life of Solar Water Storage Tank with insulation of Polyurethare is more than Glass wool and Rockwool.

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