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Design Analysis and Comparative Performance Evaluation of Fin in Heat pipe

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Abstract*— Overheating is the most common problem in electronic components which leads to failure of electronic devices. Normally the fan assisted air cooling is used but limitations of air cooling to liquid cooling in many demanding applications proves that the liquid cooling is more effective and compact. Conventionally liquid cooling component cold plates that include tube embedded in plate aluminum vacuum-brazed and copper brazed types are common in use. Tube-in-plate cold plate materials consist of copper or stainless-steel tubes that are pressed into a channeled aluminium or copper extrusion or machined plate. These devices show moderate performance with high gradient of temperatures and poor performance with low gradients of temperature. Copper heat pipe with Sintered copper mesh with working fluid to be used in the copper heat pipe is ethanol -methanol (60-40 %) with filling ratio of 50 % of volume of heat pipe is used to develop the heat exchanger where in the evaporator and condenser ends carry helical fins in plain and staggered form. Paper work include selection of heat pipes, design, analysis and fabrication of heat pipe enclosure tower as to surface area and number of fins, steady state thermal analysis using Ansys workbench 16.0 is done. Test rig is fabricated and testing has been done by varying flow rate of water (medium for liquid heat load) and flow rate of air. The heat transfer rate, Heat transfer coefficient has been determined for individual cases and then later compared.

Index Terms – Heat pipe, Liquid cooler, Plain & Staggered fin.

I. INTRODUCTION

Heat pipe with plain and staggered fins are one of the most efficient passive heat transfer devices. A heat pipe is a structure with very high thermal conductivity that enables the transportation of heat. In general, heat pipes are passive thermal transfer devices able to transport large amounts of heat over relatively long distances, with no moving parts, using phase change processes and vapour diffusion. The main structure of a heat pipe consists of an evacuated tube partially filled with a working fluid that exists in both liquid and vapour phases. The addition of heat pipes within systems allows a full utilization of the thermal superconductor property by allowing a high heat transfer rate, making the system ideal for a number of industries and applications. The basic operation is a continuous cycle. The working fluid is located at the bottom of the pipe; the addition of a heat source allows the liquid pool to evaporate. The difference in densities between the vapour and fluid, allows the vapour to reach the cool condenser section. The difference in wall temperature causes the vapour to condensate and releasing the latent heat, allowing the fluid to return to the liquid pool located in the evaporator, by the influence of gravity or by some sort of capillary wicking structure (wicked heat pipes). Embedding heat pipes into the existing heat sink or applying a spiral radial fin structure heat sink to increase its heat spreading and rejection efficiency can do the job without a costly product redesign [1].

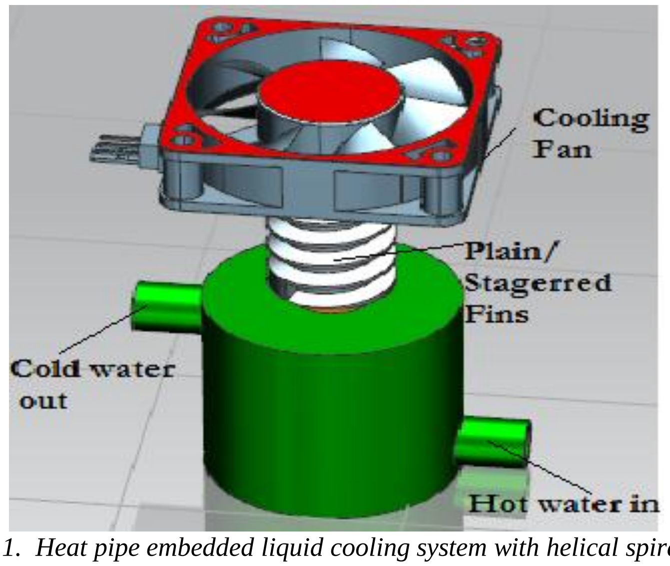

Fig. 1. Heat pipe embedded liquid cooling system with helical spiral fin

II. OBJECTIVES

1. Design and development of innovative cooling tower heat extraction system using heat pipes.
2. Design of helical fin heat sink in continuous and staggered form.
3. Design and development of test rig to evaluate performance and heat transfer ability of copper heat pipe with sintered copper wick.
4. Comparative performance evaluation of plain and staggered fin.

III. DESIGN & ANALYSIS

A. Copper Heat Pipe / Plain Copper Pipe System

The central concept of the model is to extract the latent heat from the heat source hence we use the heat pipe. The heat pipe has the following specification.

- Material of pipe: Copper
- Wick structure: Sintered copper
- Material of wick: Copper
- Working fluid: Ethanol+ Methanol (60-40) ratio
- Size: 20 mm diameter
- Length: 75 mm
- Filling ratio: 50% volume of pipe

B. Hot Water Circulation Mechanism

This is made of the base block made from Mild steel, hollow at the centre receives the heat pipe at the top and the inlet hole is at the bottom of back end whereas water exits the front-end top. Flow rate of water is controlled using flow control valve.

C. Heat Transfer Capability for Above Heat Pipe

Table 1. Maximum watts at different temperature

DIAMETER	20^0C	30^0C
20 mm	210 WATT	240 WATT

D. Design of Helical Plain Fin
Material: Aluminium

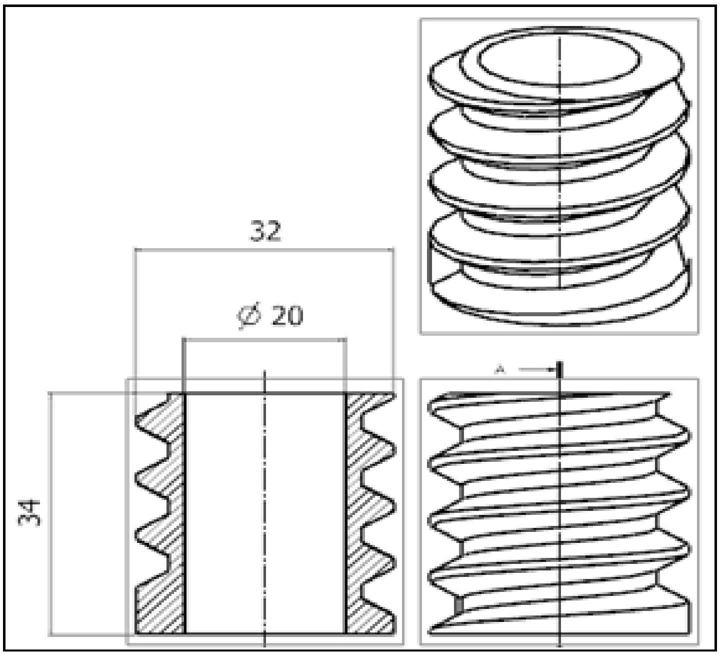

Fig. 2. Helical plain fin

E. Thermal Analysis of Helical Plain Fin

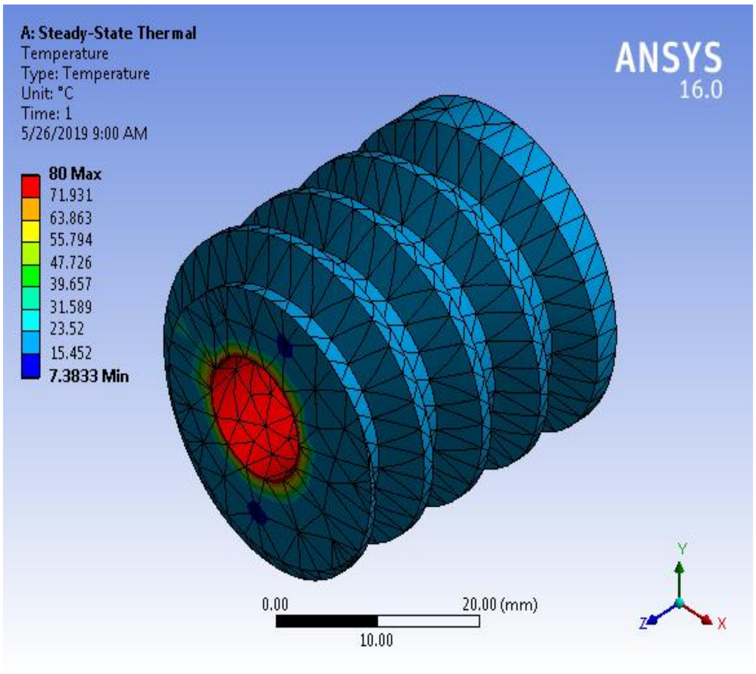

Fig. 3. Temperature analysis of plain fin

Temperature variation contour is obtained when given boundary condition are applied to the problem. The results obtained from ANSYS software simulation for temperature contour is shown in Fig. 3. We can say that at the center the heat pipe is in contact with aluminium block therefore maximum temperature exists there. After that it is entered the fin section where heat is dissipated.

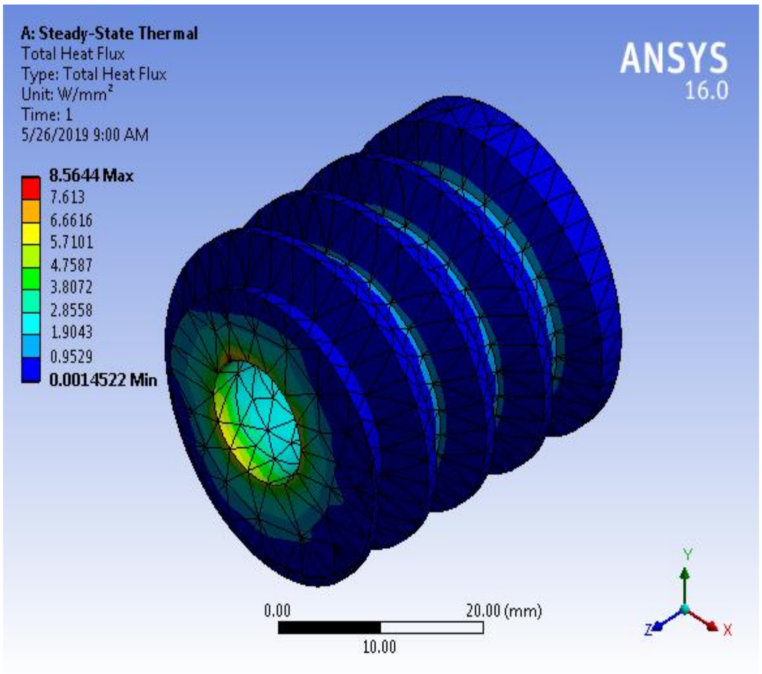

Fig. 4. Heat flux analysis of plain fin

The thermal analysis of the plain fins shows that the total heat flux is 8.5644 watt/mm^2.

F. Design of Helical Staggered Fin

Material: Aluminium

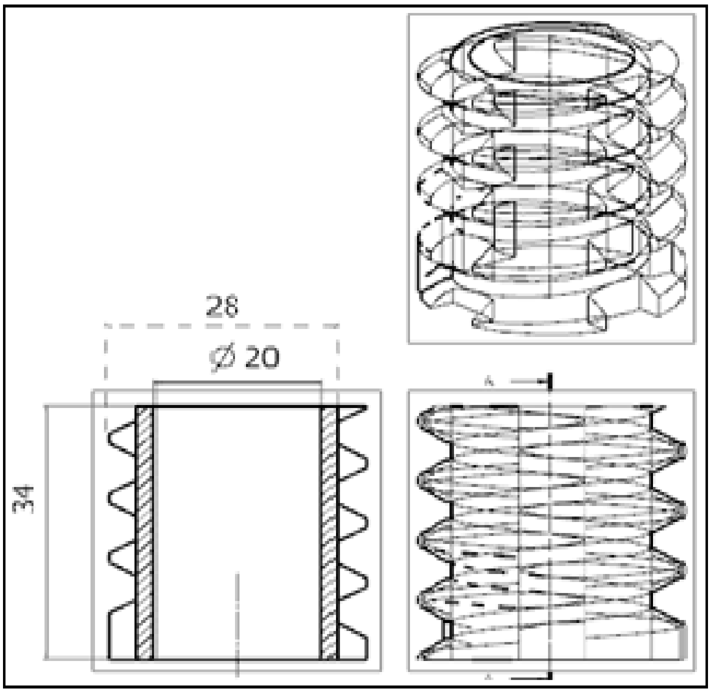

Fig. 5. Helical Staggered fin

G. Thermal Analysis of Helical Staggered Fin

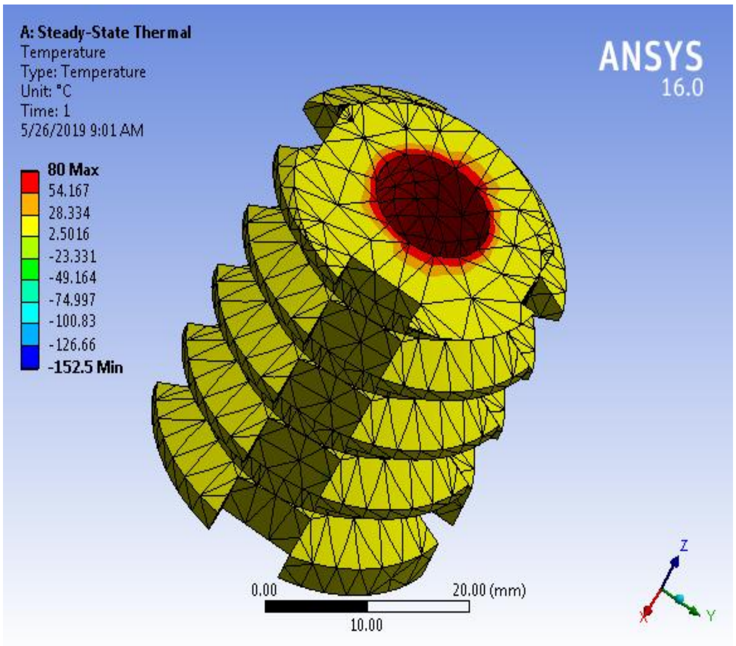

Fig. 6. Temperature analysis of staggered fin

Temperature variation contour is obtained when given boundary condition are applied to the problem. The results obtained from ANSYS software simulation for temperature contour is shown in Fig. 6. We can say that at the center the heat pipe is in contact with aluminium block therefore maximum temperature exists there. After that it is entered the fin section where heat is dissipated.

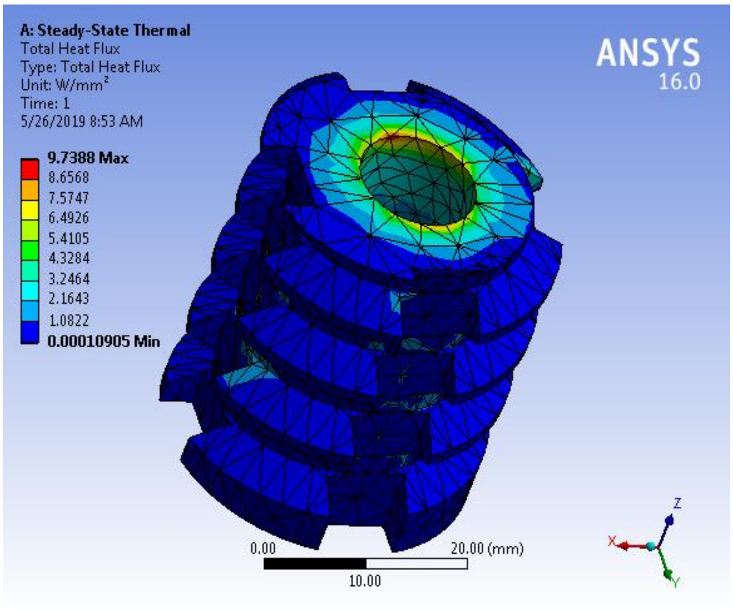

Fig. 7. Heat flux analysis of plain fin

The thermal analysis of the staggered fins shows that the total heat flux is 9.7388 watt/mm^2, hence the increment in heat flux is due to the extra area exposed that is created by the slots in staggered fins.

IV.TEST & TRIAL

A. Experimental set-up

Fig.8. Experimental set-up

B. Procedure of Test & Trial on Equipment with Plain & Staggered Fins

1. Heat water in tank with heater up to desired temperature (say 80˚C).
2. Note water inlet temperature (Th_i).
3. Open valve partially, collect water in beaker (50ml).
4. Measure stop watch time required to fill 200 ml in beaker.
5. Take hot water outlet temperature (Th_o).
6. Form observation table.

V. DIFFERENT EQUATIONS

1. Heat Transfer Rate of Water & Air
   (a) $Q_{water} = m_h C_{ph} (\Delta T)_{water}$
   (b) $Q_{air} = m_c C_{pc}(\Delta T)_{air}$

2. Logarithmic Mean Temperature Difference (LMTD)
   LMTD $(\theta_m) = \theta_1 - \theta_2/\ln(\theta_1/\theta_2)$

3.Effectiveness (ε)
   $(\varepsilon) = C_h (T_{hi} - T_{ho})/C_{min} (T_{hi} - T_{ai})$

4. Overall Heat Transfer Coefficient (U)
   $(U) = Q_c /A\ \theta_m$

VI. RESULT & DISCUSSION

A. Comparison Graph of Plain & Staggered Fin for Heat Transfer Rate & Mass Flow Rate of Water

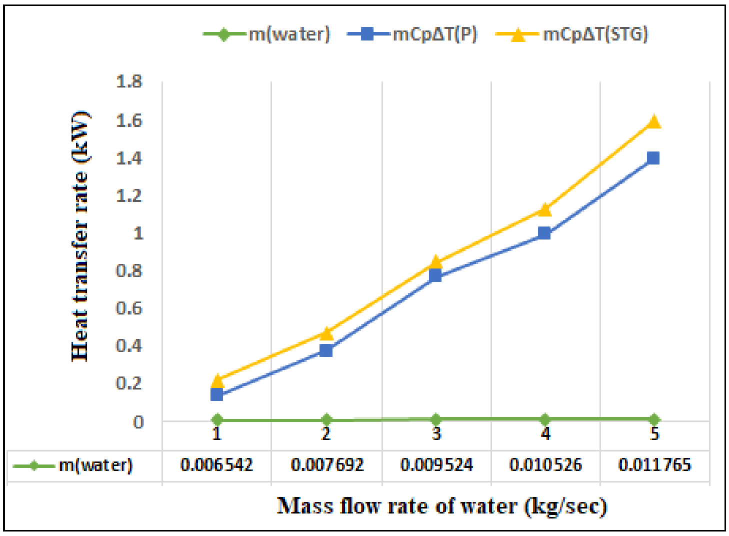

Fig. 9. Heat transfer rate Vs Mass flow rate of water

The comparison shows that the heat transfer ability of the staggered fin heat exchanger is better than that of the plain fin heat exchanger, this is as a result of increased exposed area due to the slot and better air motion.

B. Comparison Graph of Plain & Staggered Fin for LMTD & Mass Flow Rate of Water

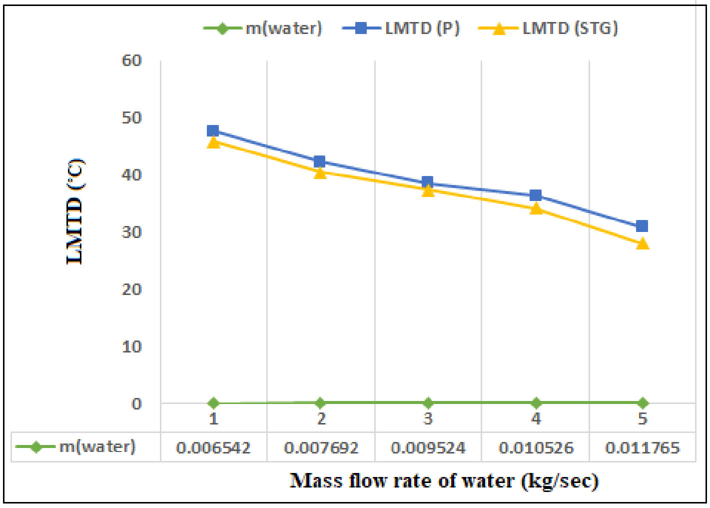

Fig. 10. LMTD Vs Mass flow rate of water

The comparison shows that the LMTD of staggered fin is slightly lower than that of the plain fin. LMTD decreases as mass flow rate of water increases.

C. Comparison Graph of Plain & Staggered Fin for Effectiveness & Mass Flow Rate of Water

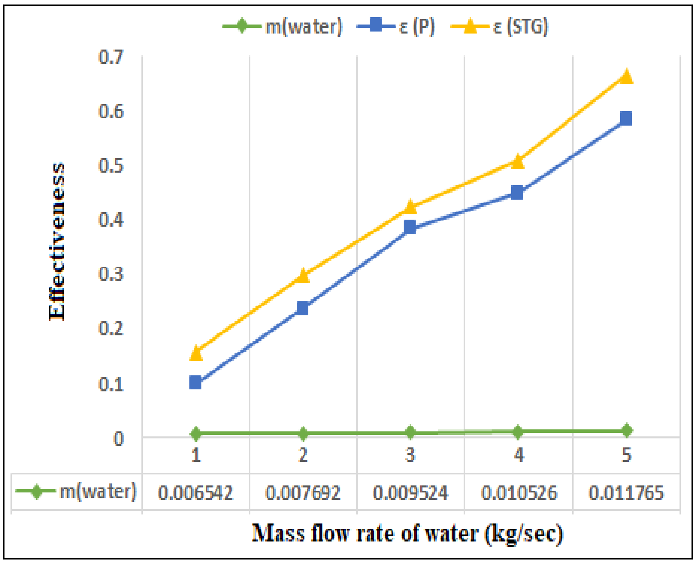

Fig. 11. Effectiveness Vs Mass flow rate of water

The comparison shows that the Effectiveness of the staggered fin heat exchanger is better than that of the plain fin heat exchanger, this is as a result of increased exposed area due to the slot and better air motion.

D. Comparison Graph of Plain & Staggered Fin for Overall Heat Transfer Coefficient & Mass Flow Rate of Water

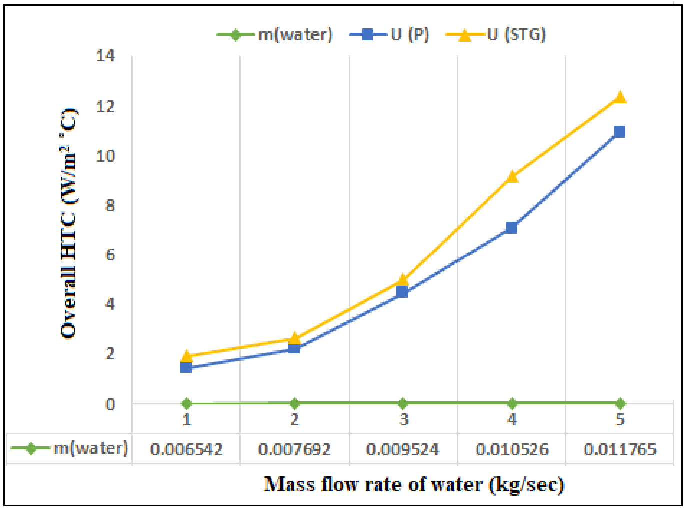

Fig. 12. Overall heat transfer coefficient Vs Mass flow rate of water

The comparison shows that the overall heat transfer Coefficient of the staggered fin heat exchanger is better than that of the plain fin heat exchanger, this is as a result of increased exposed area due to the slot and better air motion.

VII. CONCLUSION

1. The analysis of the Plain fins shows the maximum heat flux is 8.56 watt /mm^2.
2. The analysis of the Staggered fins shows the maximum heat flux is 9.73 watt /mm^2.
3. Testing revealed that the heat transfer ability of the staggered fin heat exchanger is better than that plain fin heat exchanger, this is as a result of increased exposed area due to the slot and better air motion.
4. Testing revealed that the LMTD of staggered fins is slightly lower than that of the plain fins.
5. Testing revealed that the overall heat transfer coefficient of the staggered fin heat exchanger is better than that of plain fin heat exchanger, this is as a result of increased exposed area due to slot and better air motion.

VIII. NOMENCLATURE

Symbol	Variable	Unit
T_{hi}	Inlet temperature of hot fluid	˚C
T_{ho}	Outlet temperature of hot fluid	˚C
T_{ci}	Inlet temperature of cold fluid	˚C
T_{co}	Outlet temperature of hot fluid	˚C
m_h	Mass flow rate of hot fluid	kg/sec
m_c	Mass flow rate of cold fluid	kg/sec
C_{ph}	Specific heat of hot fluid	kJ/kg ˚C
C_{pc}	Specific heat of cold fluid	kJ/kg ˚C
ε	Effectiveness	-
C_h	Hot fluid capacity rate	kJ/sec ˚C
U	Overall heat transfer coefficient	kW/m^2 ˚C

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