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Determination of Thermal Characteristics of Evaporator with Phase Change Material Chamber In Refrigerator

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ABSTRACT:

The refrigerator and cold storages are generally found in most of the countries and they are one of the most energy demanding appliances because of their continuous operation. A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units.

In this thesis, the thermal characteristics of evaporator in refrigerator are analyzed and compared for with pcm chamber and without pcm chamber at different refrigerants HFC – 134A, Ethylene glycol and propylene glycol and water. CFD analysis is done on the evaporator to determine the heat transfer coefficients without pcm and with pcm. Thermal analysis is also done by varying two materials for the evaporator Copper and Aluminum.

3D modeling is done in Pro/Engineer and analysis is done in Ansys.

I. INTRODUCTION

The Refrigeration systems are directly or indirectly responsible for Global Warming problems which refer to the rise in temperature of Earth's atmosphere and ocean. During early 1990, after water heater a frost freezer was the second most expensive and energy consuming home appliance. It was compulsory for appliance makers to include labels which list an estimate of the annual cost of running the appliance, so consumers could compare energy usage and costs.

Most frozen and chilled foods are sensitive to temperature fluctuations. Thermal Energy storage systems (TES) will use phase change materials (PCM) for storage of heat and cold at shifted time. Phase change material (PCM) melts within a narrow temperature range, and while in transition state absorbs a large amount of heat, thus rise in the refrigerator temperature is minimum. PCM with a suitable melting temperature may be used to provide thermal capacity for maintaining suitable recommended internal temperature during power failure. TES could be the most appropriate way and method to correct the gap between the demand and supply of energy and therefore it has become a very attractive technology.

The most alarming environmental disorder namely "Global Warming" refers to the rising temperature of Earth's atmosphere and ocean and its projected continuation. The heat from the Sun is entrapped in the Earth and thus increases the temperature of the atmosphere by Greenhouse Effect. Refrigeration system is directly and invisibly responsible for Global Warming problem. For the typical home of the early 1990s, a frost-free refrigerator or freezer was the second most expensive home appliance to operate besides the water heater. Appliance makers were required to include labels listing an estimate of the annual cost of running each appliance so consumers could compare costs and energy usage.

[1] A refrigerator (colloquially fridge) is a common household appliance that consists of a thermally

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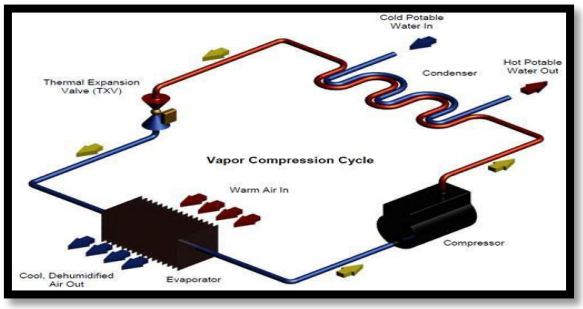
insulated compartment and a heat pump (mechanical, electronic, or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room.

[2] Domestic refrigerators are among the most energy demanding appliances in a household due to their continuous operation

[3] The domestic refrigerator is one found in almost all the homes for storing food, vegetables, fruits, beverages, and much more.

[4] Materials that can store thermal energy reversible over a long time period are often referred to as latent heat storage materials. It also helped in heat transfer via conduction.

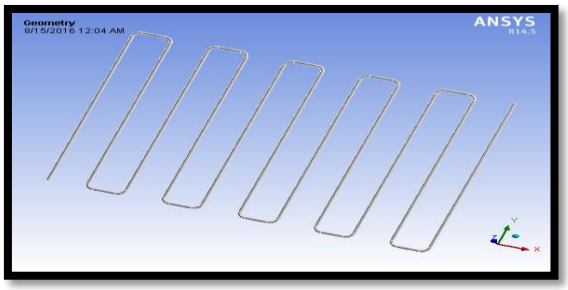


CFD ANALYSIS OF EVAPORATOR

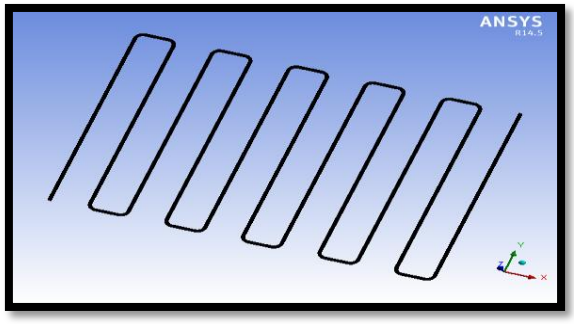
CASE 1- WITH-OUT PCM MATERIAL

FLUID: – ETHELYNE GLYCOL

IMPORTED MODEL



MESHED MODEL



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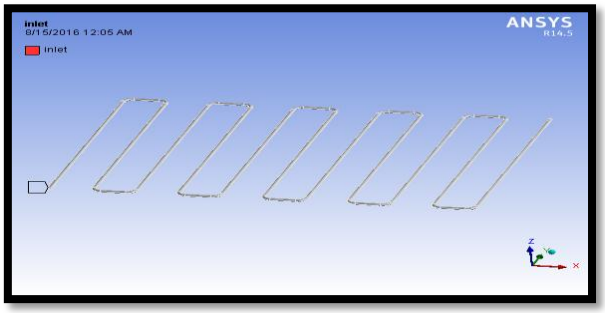

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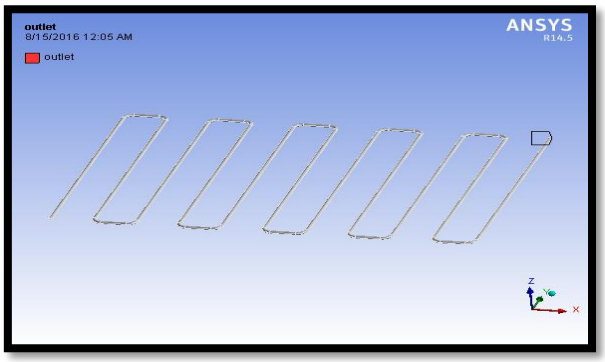
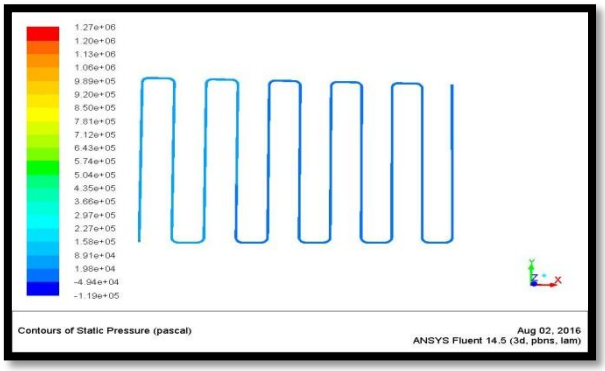
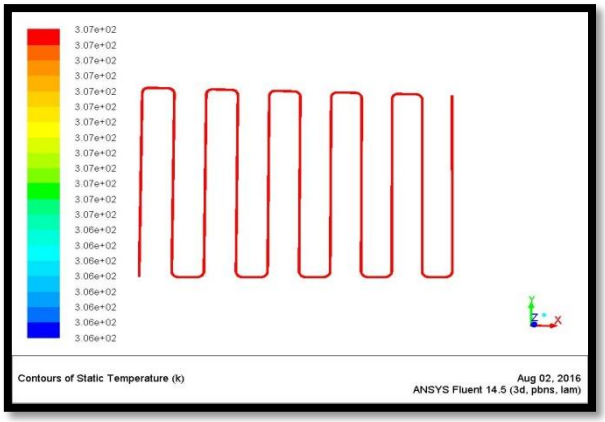


PRESSURE



TEMPERATURE



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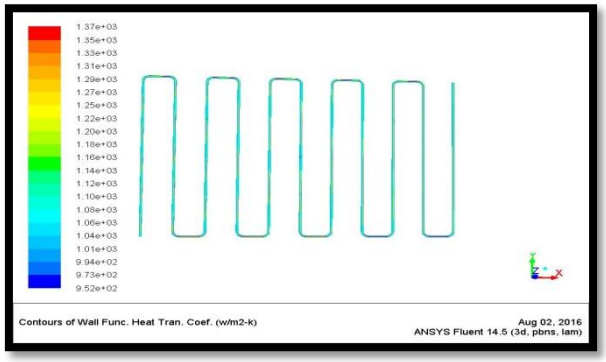
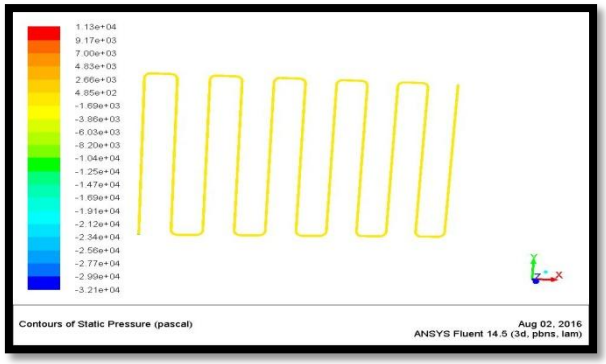
HEAT TRANSFER COEFFICIENT



FLUID - PROPYLENE
PRESSURE



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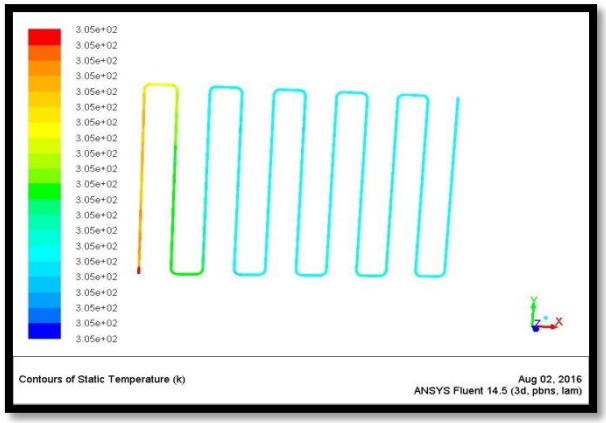

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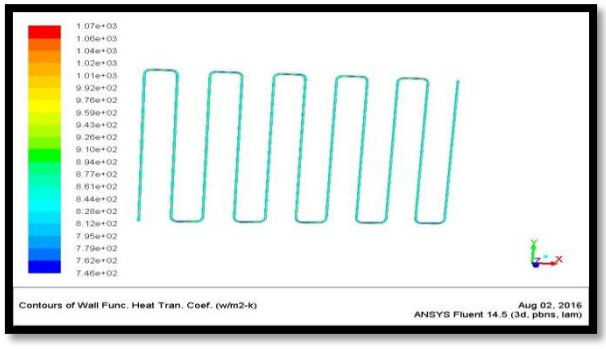
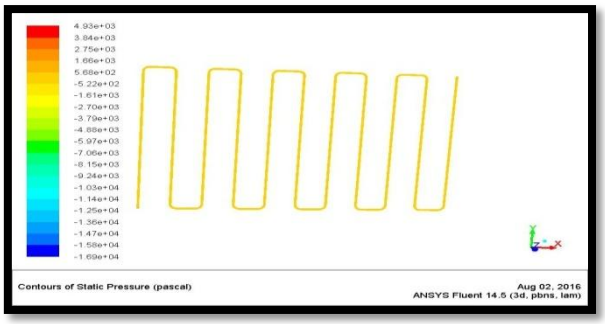


FLUID - R134A
PRESSURE



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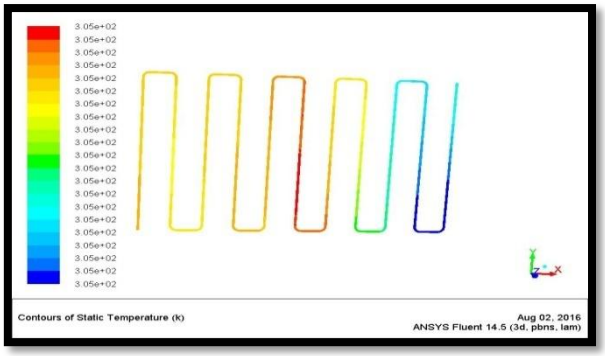

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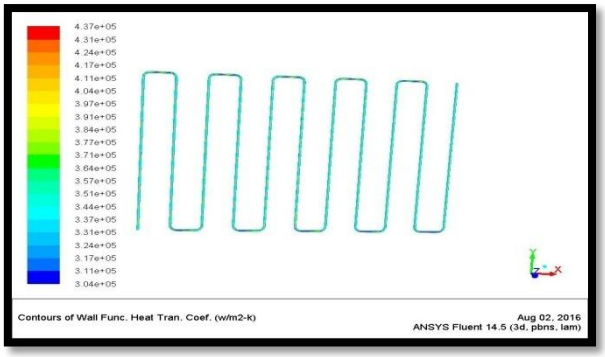
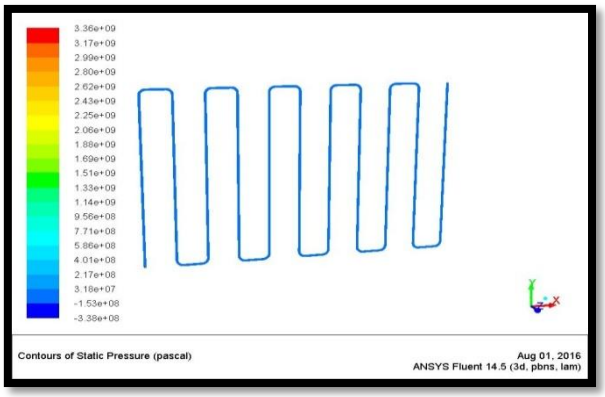


FLUID - WATER
PRESSURE



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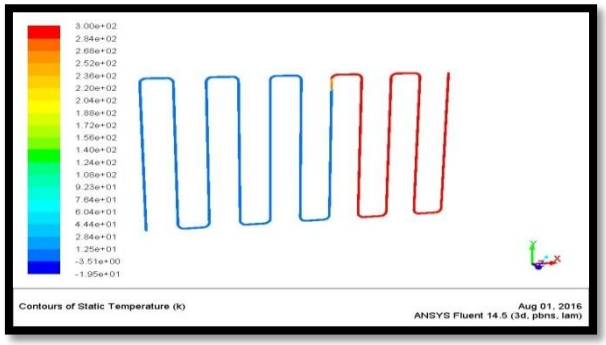

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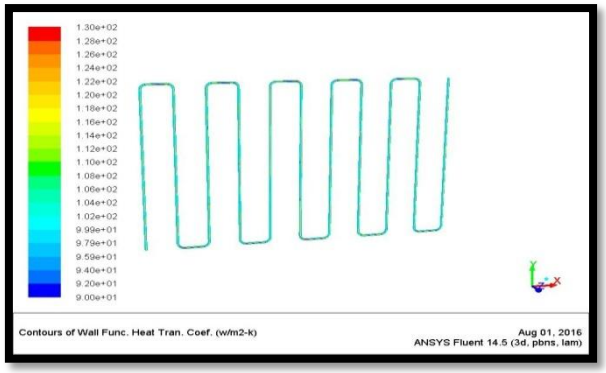
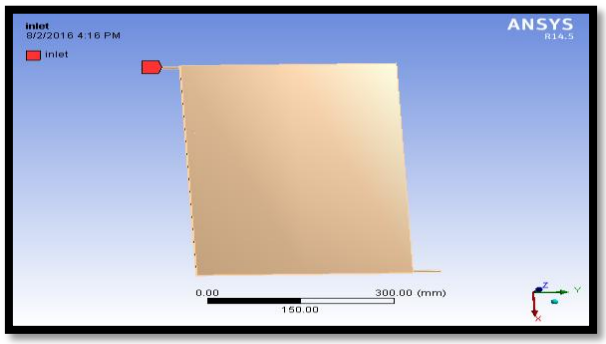


CASE 2- WITH PCM MATERIAL
FLUID - ETHYLENE GLYCOL
INLET



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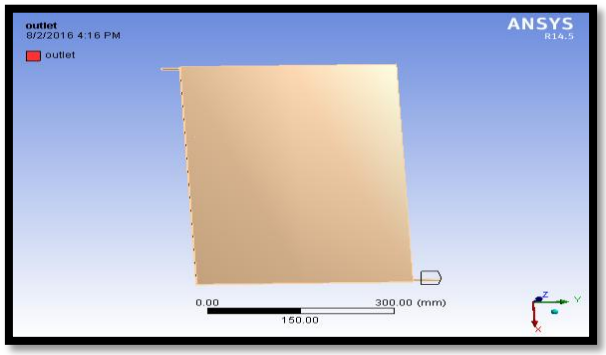

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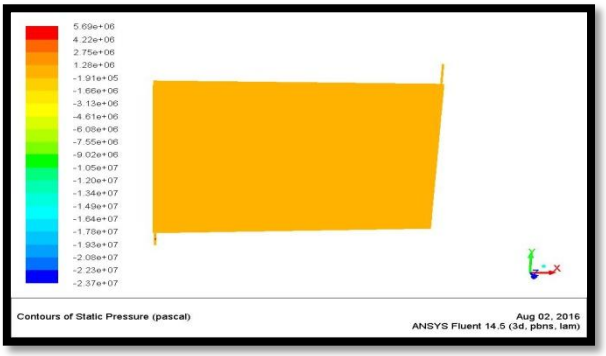

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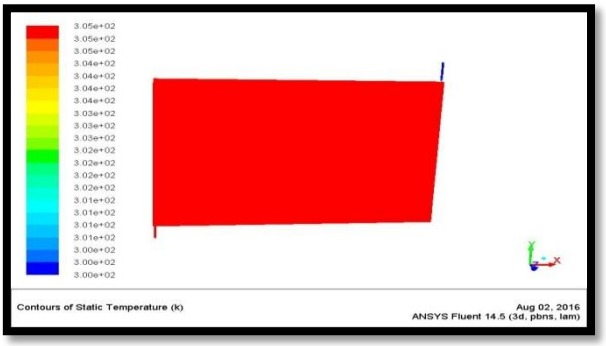

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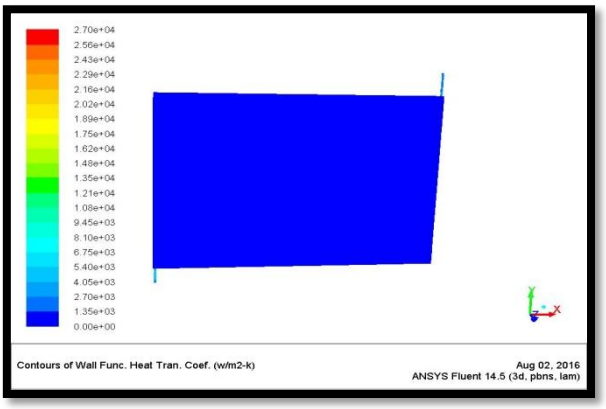
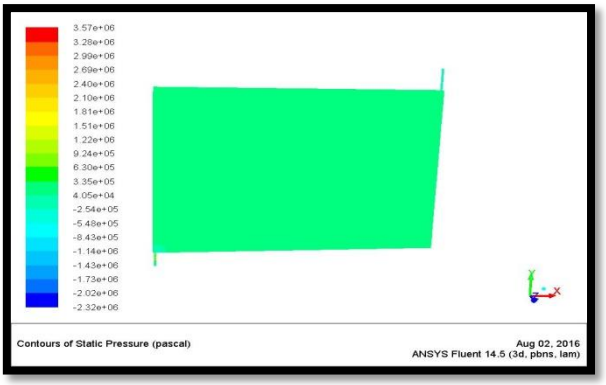


FLUID - PROPYLENE
PRESSURE



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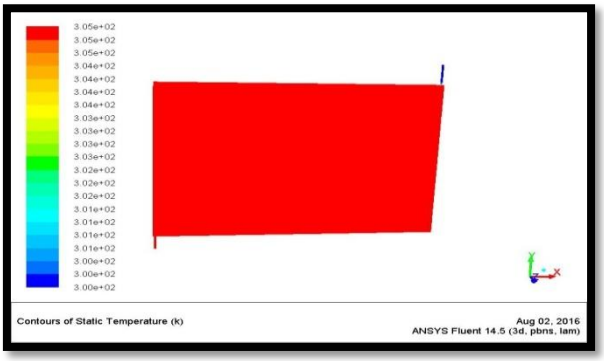

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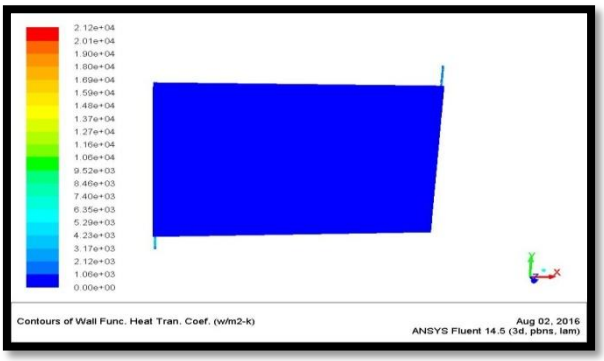
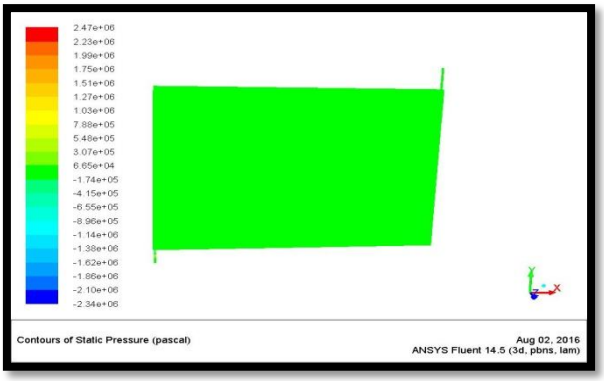


FLUID - R134A PRESSURE



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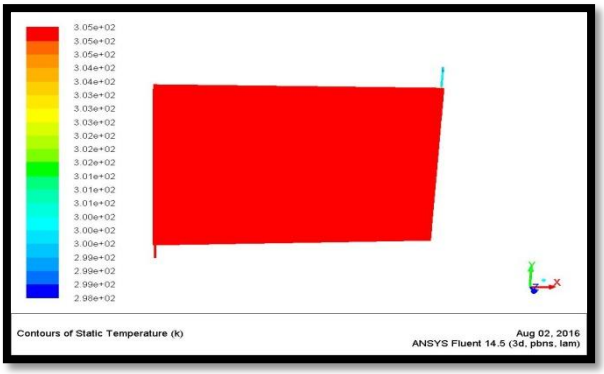

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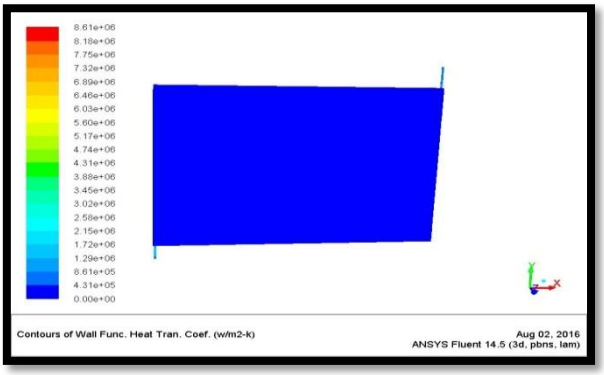
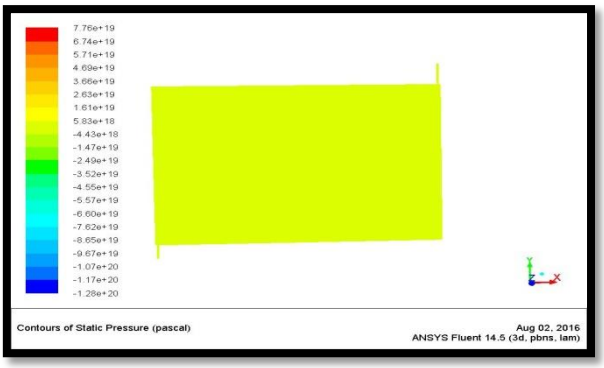


FLUID - WATER PRESSURE



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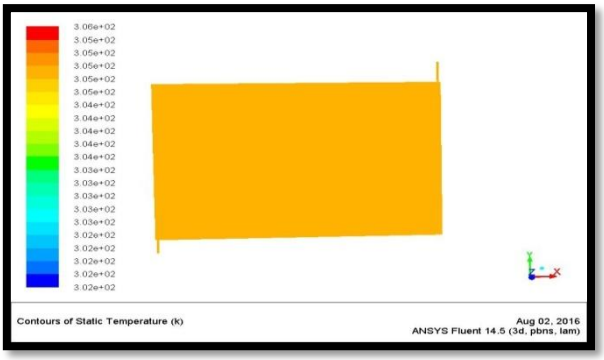
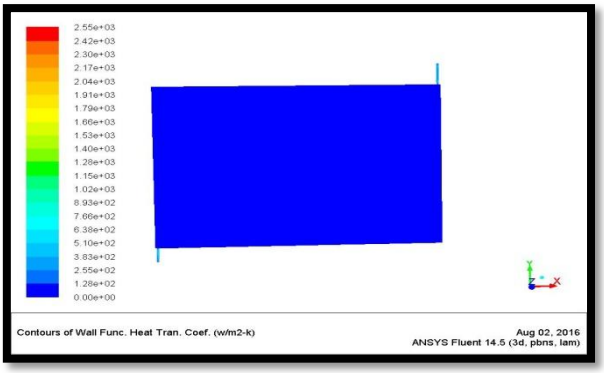


HEAT TRANSFER COEFFICIENT



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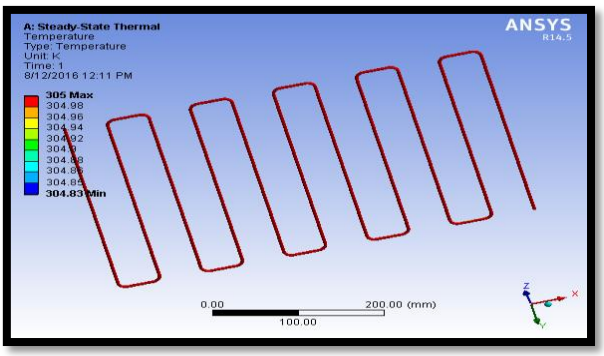
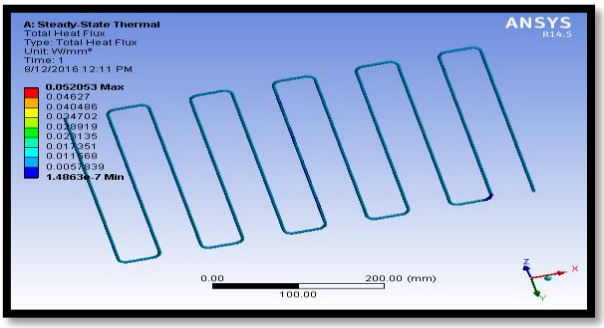
RESULTS TABLE

		WITH-OUT PCM	WITH PCM
ETHYLENE GLYCOL	PRESSURE (Pa)	1.27E+06	5.69E+06
	TEMPERATURE (K)	3.07E+02	3.05E+02
	HEAT TRANSFER COEFFICIENT (W/m2k)	1.37E+03	2.7E04
	MASS FLOW RATE (Kg/sec)	-0.00013361222	-0.55072808
	TOTAL HEAT TRANSFER RATE (W)	-3.0251379	-13515.311
PROPELYNE	PRESSURE (Pa)	1.13E+04	3.57e+06
	TEMPERATURE (K)	3.05E+02	3.05e+02
	HEAT TRANSFER COEFFICIENT (W/m2k)	1.07E+03	2.12e+04
	MASS FLOW RATE (Kg/sec)	-6.4715169e-7	-0.25768137
	TOTAL HEAT TRANSFER RATE (W)	-0.011133548	-4501.8867
R134a	PRESSURE (Pa)	4.93e+03	2.47e+06
	TEMPERATURE (K)	3.05e+02	3.05e+02
	HEAT TRANSFER COEFFICIENT (W/m2k)	4.37e+05	8.61e+06
	MASS FLOW RATE (Kg/sec)	-2.3265429e-08	-0.073329151
	TOTAL HEAT TRANSFER RATE (W)	-2.2297354e-05	-432.48193
WATER	PRESSURE (Pa)	3.36e+09	7.76e+19
	TEMPERATURE (K)	3.00e+02	3.06e+02
	HEAT TRANSFER COEFFICIENT (W/m^{2}K)	1.3e+02	2.55e+03
	MASS FLOW RATE (Kg/sec)	-3.9632523e-05	-0.060402621
	TOTAL HEAT TRANSFER RATE (W)	0.095922515	-539.76111

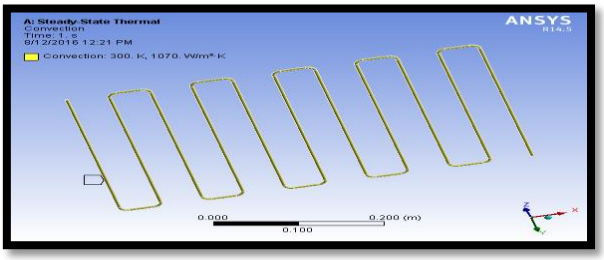
THERMAL ANALYSIS WITHOUT PCM ETHYLENE GLYCOL TEMPERATURE



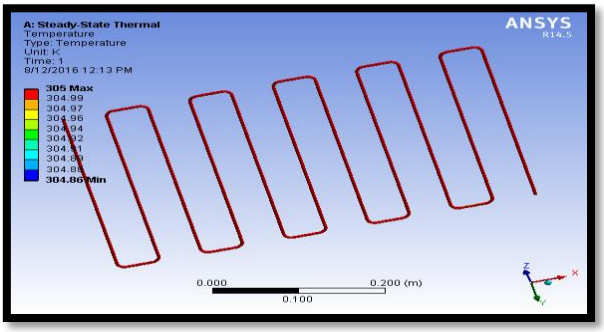
HEAT FLUX



PROPELENE



TEMPERATURE



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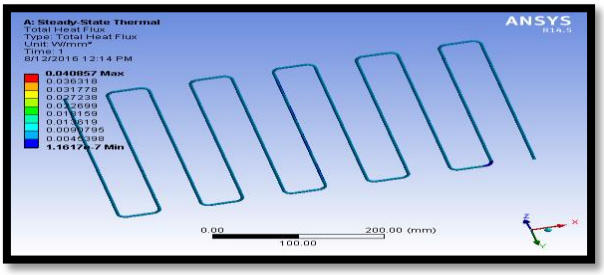
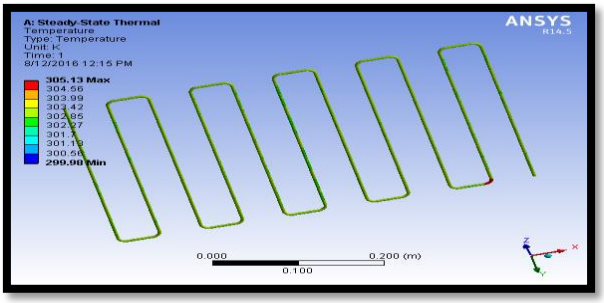
HEAT FLUX



R134A
TEMPERATURE



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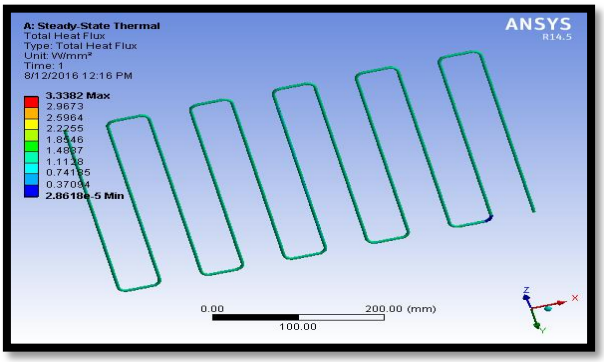
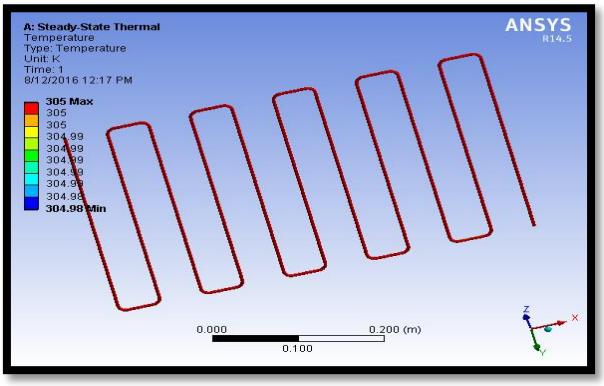


WATER
TEMPERATURE



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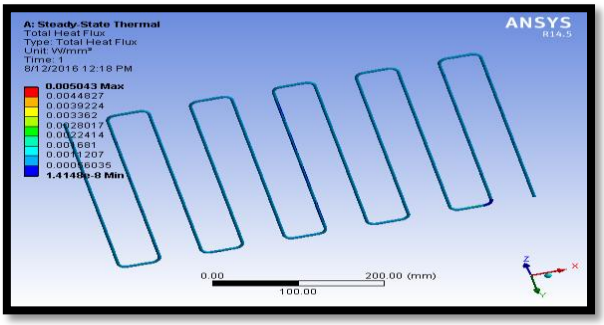
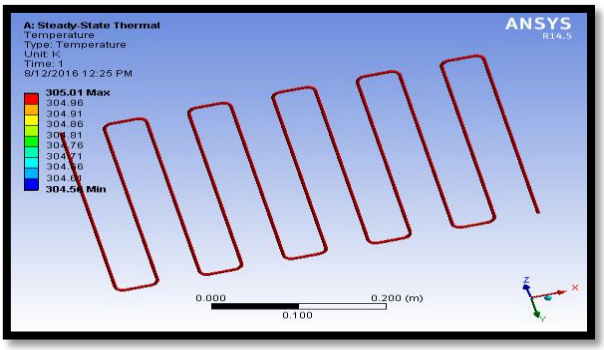


MATERIAL: - ALUMINUM
ETHYLENE GLYCOL
TEMPERATURE



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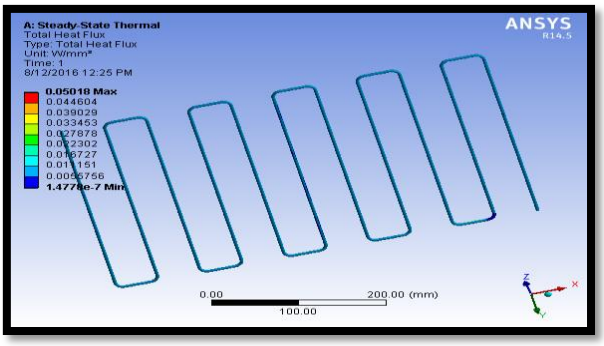
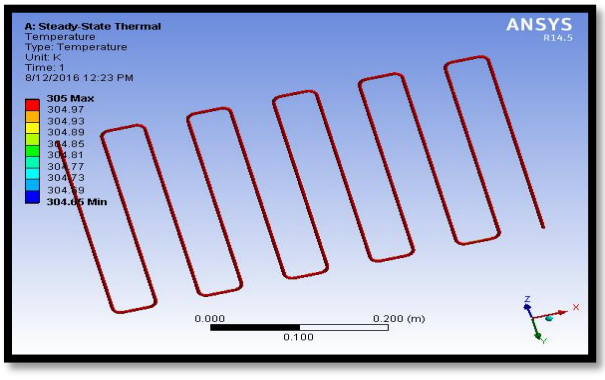


PROPYLENE
TEMPERATURE



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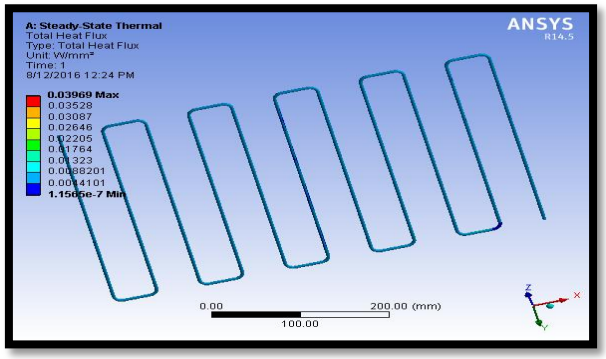
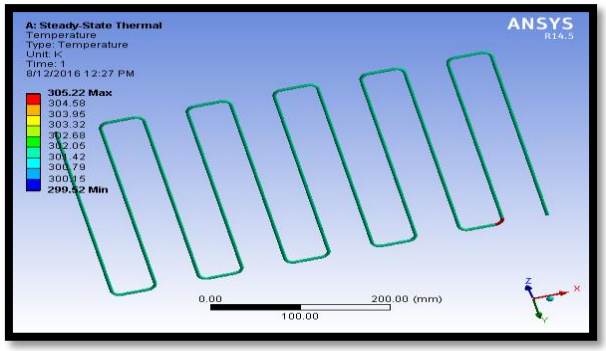


R134A
TEMPERATURE



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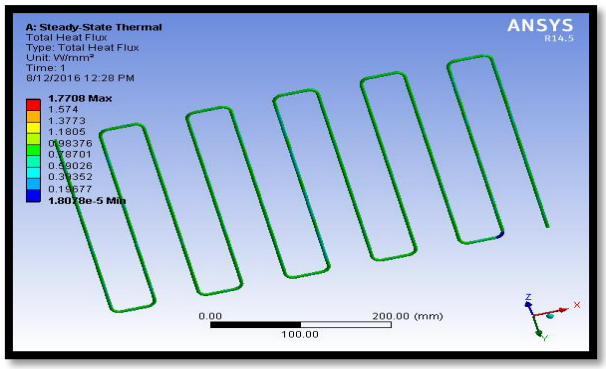
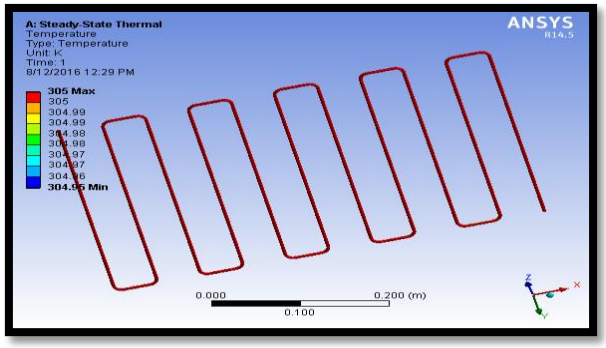
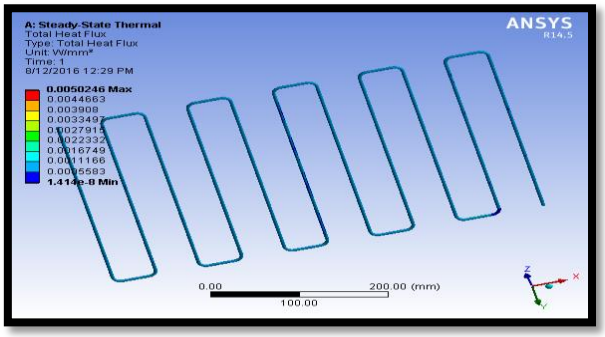


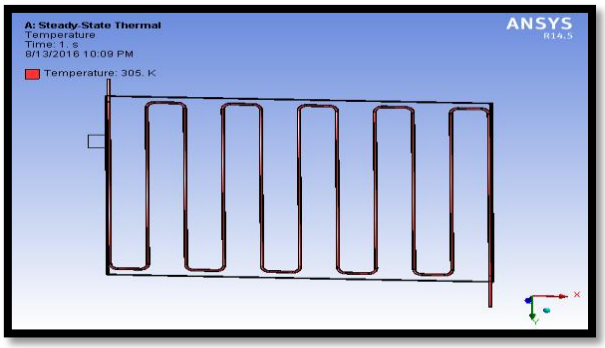
WATER
TEMPERATURE



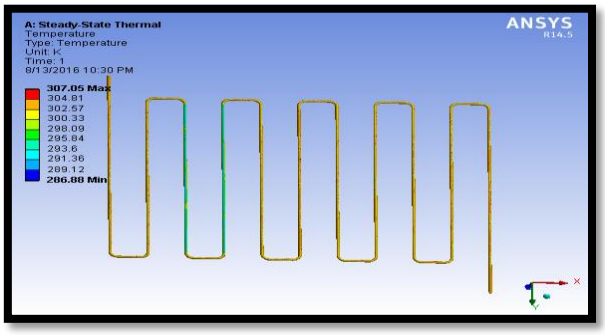
HEAT FLUX



CASE 2:- WITH PCM
MATERIAL - COPPER
TEMPERATURE



ETHYLENE GLYCOL
TEMPERATURE



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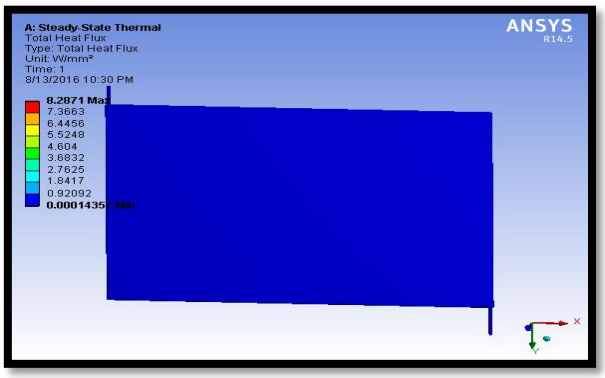

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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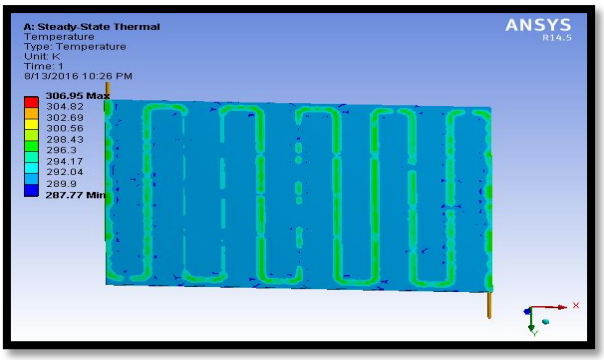
PROPYLENE
TEMPERATURE



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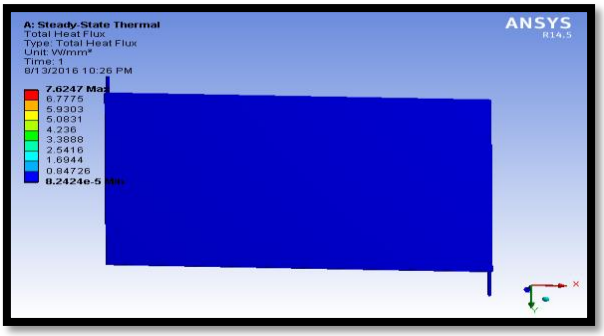
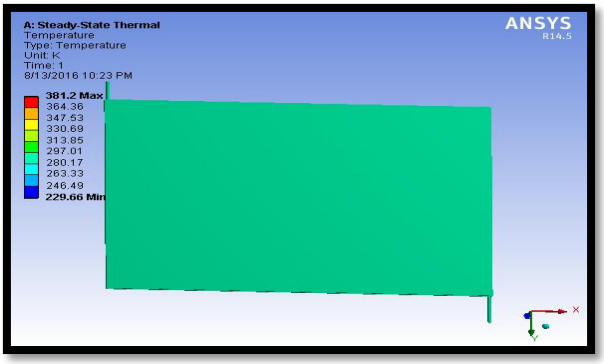


R134A
TEMPERATURE



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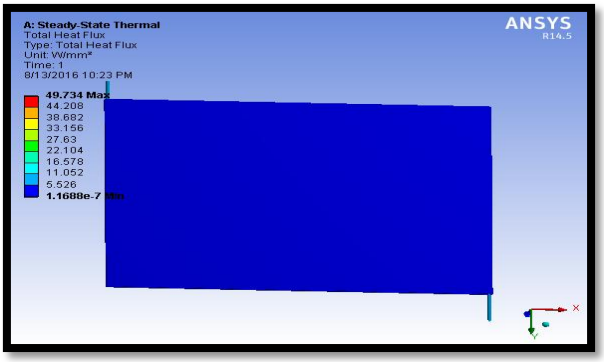
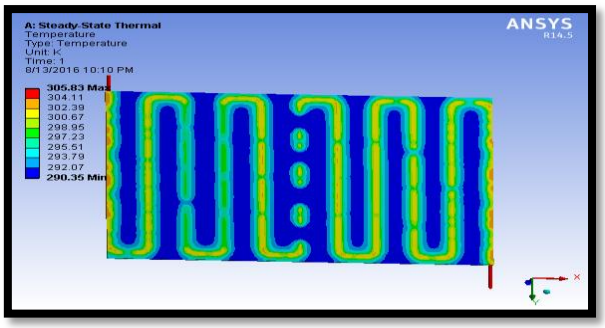


WATER
TEMPERATURE



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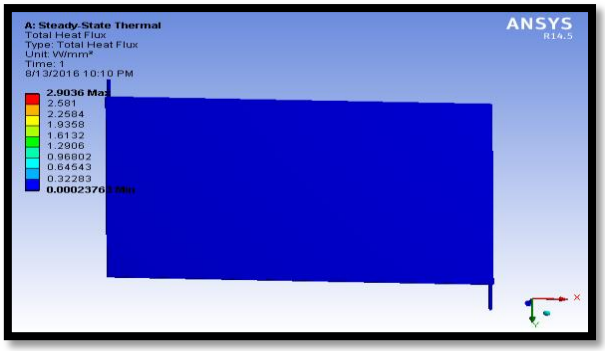
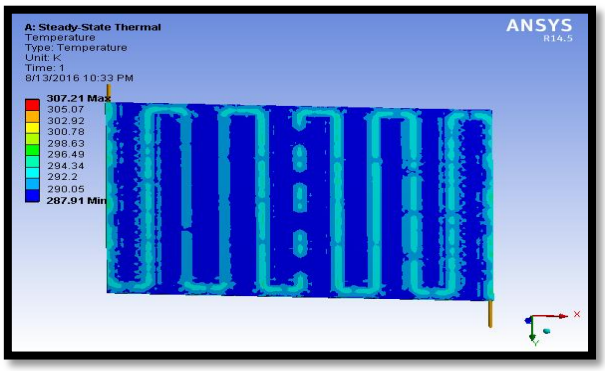


MATERIAL: - ALUMINUM
ETHYLENE GLYCOL
TEMPERATURE



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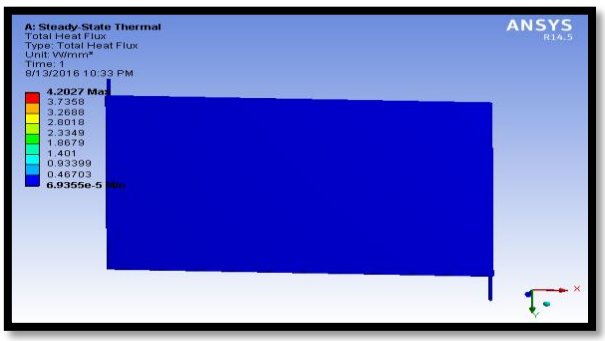

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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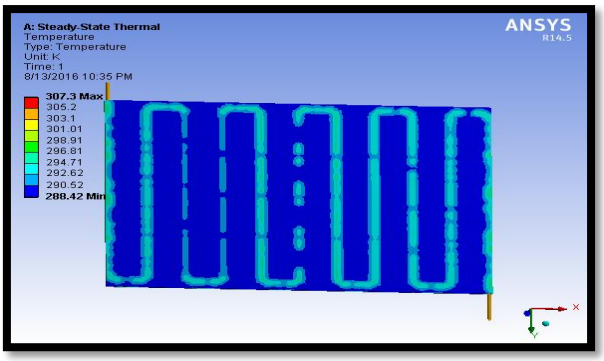
PROPYLENE TEMPERATURE



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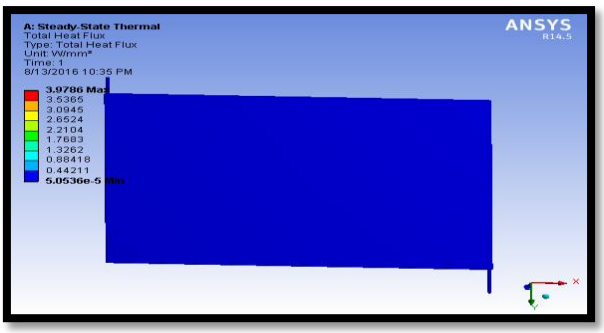
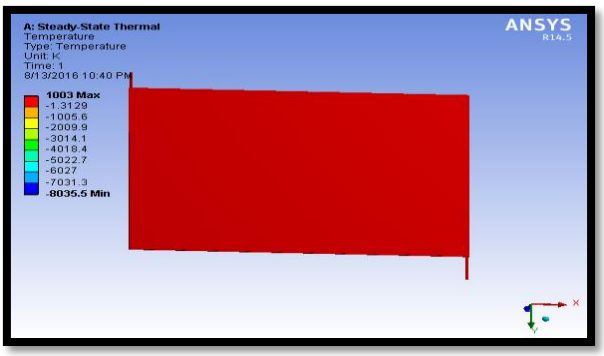
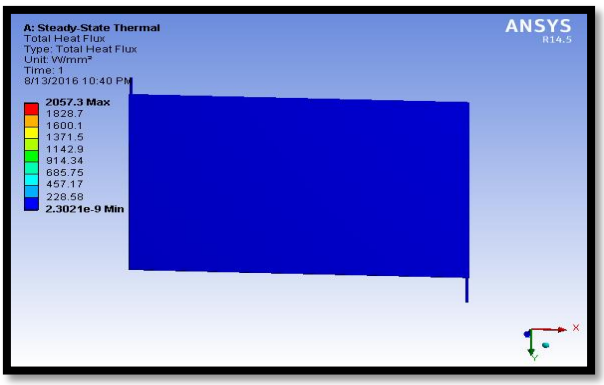


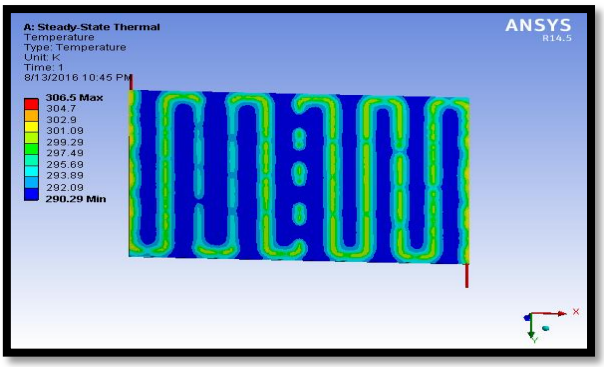
R134A TEMPERATURE



HEAT FLUX



WATER TEMPERATURE



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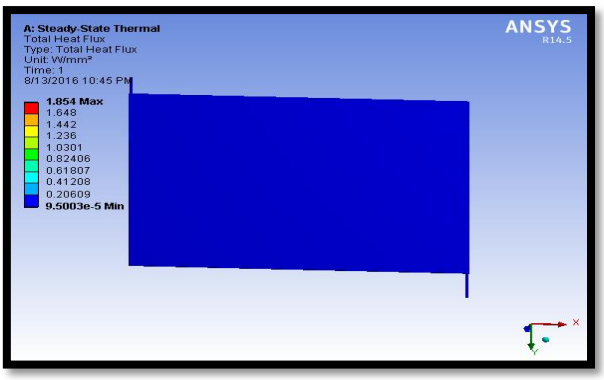

RESULTS TABLE WITHOUT P.C.M

Fluids	Copper			Aluminum		
	Temp (K)		Heat flux (W/m m^2)	Temp (K)		Heat flux (W/m m^2)
	Min	Max		Min	max	
Ethylene glycol	304.83	305	0.052053	304.56	305.01	0.050
Propylene	304.86	305	0.040857	304.65	305	0.0396
R134a	299.98	305.13	3.3382	299.52	305.22	1.7708
water	304.98	305	0.005043	304.95	305	0.0050246

ISSN No: 2348-4845
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WITH P.C.M

Fuids	Copper			Aluminum		
	Temp (K)		Heat flux (W/m m^2)	Temp (K)		Heat flux (W/m m^2)
	Min	Max		Min	max	
Ethylene glycol	286.88	307.05	8.2871	287.91	307.21	4.2027
Propylene	288.42	306.95	7.6247	288.42	307.3	3.9786
R134a	229.66	381.2	49.734	-8035.5	1003	205.73
water	290.35	305.83	2.9036	290.29	306.5	1.854

CONCLUSION

In this thesis, the thermal characteristics of evaporator in refrigerator are analyzed and compared for with pcm and without pcm at different refrigerants HFC – 134A, Ethylene glycol and propylene glycol and water. CFD analysis is done on the evaporator chamber to determine the heat transfer coefficients without pcm and with pcm. Thermal analysis is also done by varying two materials for the evaporator Copper and Aluminum. 3D modeling is done in Pro/Engineer and analysis is done in Ansys.

By observing CFD analysis results, placing the evaporator in the PCM chamber yields good results since the heat transfer coefficient and heat transfer rates are more than that without PCM chamber. The heat transfer heat transfer coefficient and heat transfer rates are important parameters to be considered in the refrigerator. By comparing the results between refrigerants, heat transfer coefficient is more when R134A is used and heat transfer rate is more when Ethylene Glycol is used.

By observing thermal analysis results, the heat flux values are more for the evaporator with PCM chamber since high heat transfer coefficients. Refrigerant R134A has more heat transfer rate.

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