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Computational Fluid Dynamics Analysis of Latent Heat Recovery Employed with Teg Module and Waste Heat Recovery from Automobile Radiator

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Abstract: Providing good and best solutions to everyday problems varies day by day with the evolving technologies. The solution pertaining to the problems associated with the exhaust gases from the automobile or other such equipment's revolves around only on the ways of reducing the pollution. Many designs and developments are also made in terms of alternative energies at low cost. One such ideology is to recover and reuse the energy that is exhibited out in the form of liquid or heat. Waste heat recovery will be a new energy source. Thermal fluid flow heat recovery system from Automobile radiator with internal and external tubes is one such option

While most of the state of art papers considers only the waste heat as energy source, this thesis discusses the usage of phase changing materials in the external fluid flow tubes in heating and cooling paths. Both the static and dynamic nature of the energy is used in the work. Design and development of heat energy recovery system from the air cooled radiator is made. The system is very challenging and it plays a major role in the works where the heat energy is recovered as electrical energy which paves way for an additional usage of Thermo Electric Generator (TEG).The system was analyzed for its better mechanical and electrical efficiency especially in terms of the storage. Experimentation is conducted for both the heat conservation process and reverse heat conservation. Thermal performance of heat recovery and storage techniques is introduced in this thesis. SCADA is used for simulating the process under different operating conditions. The model recovers the waste heat from the car radiator using Radiator Heating Pipes and Thermoelectric Generators (RHP-TEG) combination. It generates electricity from the waste heat recovered from the car radiator.. It has been observed that the efficiency of the conversion increases with the increasing temperature gradient in the TEG. It has been predicted from the theoretical have been consider CFD model.

I. INTRODUCTION

A. Energy Conservation System

The amount of energy consumed increases every year with the growth in the domains of the various industries. The burden of this demand falls on the environment and it should be reduced. According to(Lebduska 1978). The"Law Concerning the Rational Use-Of Energy" (Energy Conservation Law), as amended in 2008, obligated business and Indian operators participating in various business activities ranging from small to large scale should publish the reports about their energy consumption. This mainly applies to the automobile sectors(Houlihan 1998). Management methods for energy consumption by company operators are consequently becoming an issue for the retail industry, as well as energy conservation strategies at individual outlets. The Indian authorities promised a 7.1% reduction in greenhouse gasses from 2017 pertaining to the recommendations by the "Prathama green yochana system" which proves to be succeeded in Gujarat(NakazawaAsami *et al.* 1973). All the necessary steps are made in order to achieve the target specified above. This alsosatisfies the Energy conservation law.

The amended Energy Conservation Law was put into effect from April 2017(JeongMumma *et al.* 2003). This legislation demands certain actions such as submission of energy consumption reports by the industries with the duties executed by the respective company operators and franchise operators who involved in the activities done for managing the energy consumption. Roughly 115.5 billion India Rupees spent onconsumption of electrical power.

Various energy conservation strategies are implemented by the business owners in order to cut down the prices and abide by the actions suggested by the Government,(Maizza &Maizza 2001). In spite of theseefforts, the concentration was made on to enhance the performance of the individual facilities but there is a lack in the total management of energy consumption. In reality, proper measures as directed are not followed in many of the industries. This includes inappropriate maintenance of temperature in the

locations where centre equipment is installed. Human error also exaggerates the issue(Kalina 1983).
From the distribution socket industry, particularly, which includes convenience shops and which frequently involves the establishment of numerous socket, the capability to comprehend the energy intake status is lacking at individual outlets (Hasnain 1998, Yu &Chau 2009,Quoilin, Aumann *et al.* 2011). The methods employed for managing energy consumption by business operators are becoming a significant problem for the distribution business, along with energy conservation approaches for implementation at different outlets(Kalina 1983, SahaAkisawa *et al.* 2001). It's against the"Energy Conservation Controller" for attaining energy conservation in individual outlets and the"Energy Management Service", which offers energy management services for distribution outlet systems.

B. Need For Waste Heat Recovery System

Waste heat is a heat, which can be generated in a process by means of Fuel combustion or chemical reaction, and then ―dumped" into the surroundings although it could still be reused for a few useful and economic purpose (Zhang &Wang 1997, Bell 2008). The essential quality of heat isn't the quantity but instead its"value". Quantity of flue gases is created from Ovens, Kilns, Boilers and Furnaces. If some of the waste heat could beregained, a considerable number of primary fuels could be stored. The power can't be fully recovered. However, a lot of the heat could be recovered inwaste heat system and wastage can be minimized by adopting the stepsoutlined in the Thesis.

C. Benefits of Waste Heat Recovery

The benefits were described in terms of direct benefits and indirect benefits.
1) *Direct Benefits:* The major benefit of the waste heat recovery is the costeffectiveness of the system.
2) *Indirect Benefits:* Reduction in pollution: the reuse of heat results in reduction of pollution. If not reused, the gases exhausted will act as the major pollutant of the environment. Reduction in equipment sizes: Waste heat recovery lowers the fuel consumption, which leads to decrease in the flue fluidproduced.

This causes reduction in equipment sizes of all flue gas handling equipment's such as fans, stacks, ducts, burners, etc..
Reduction in auxiliary energy consumption: Reduction in energy sizes provides added benefits in the form of decrease in auxiliary energy intake like electricity for fans, pumps etc.

1) Domestic / Industry Waste Heat RecoveryDevices

Most of domestic and commercial industry process designed and developed the WHS based on the work byZhang 2000, Yang Yuan *et al.* 2003,Hsu Huang *et al.* 2011). This system is designed based on the review of the process flow sheets, and process flow diagrams and piping isometrics and electrical and electronics instrumentation with ducting cases.
It is necessary to evaluate the selected waste heat recovery system on the basis of financial analysis such as investment, depreciation, payback period, rate of return etc(Yu &Chau 2009, Hsu *et al.* 2011, Sprouse III&Depcik 2013). In addition the advice of experienced consultants and suppliers, decision must be done rationally. Next section gives a brief description of common heat recovery devices available commercially and its typical industrial applications.
a) Sources and uses of waste heat
b) Upset conditions occurring in the plant due to heat recovery
c) Availability of spac
d) Any other constraint, such as dew point occurring inequipments, etc.

After identifying source of waste heat and the possible use of it, the next step is to select suitable heat recovery system and equipment‘s to recoverand utilise the same (Yang 2005, WangZhang *et al.* 2011) It is necessary to evaluate the selected waste heat recovery system based on financial analysis such as investment, depreciation, payback period, rate of return etc. In addition, the advice of experienced consultants and suppliers must be obtained for rational decision. Next section gives a brief description of common heat recovery devices available commercially and its typical industrial applications.
Sipeng Zhu *et al.* (2014), Oomori &Ogino (1993) studied numerically the Thermodynamic analysis of an in-cylinder waste heat recovery system for internal combustion engines, superheated steam generated by motor waste heat is pumped into the pipe before the turbine to increase the boost pressure of the fresh atmosphere; intake valve shut timing is adjusted to control the amount of clean air as the original amount, and thus the higher pressure billed air expands from the intake stroke and transfers the strain energy straight to the crankshaft. In this method, the increased turbine output by the pre-turbine steam injection is finally retrieved in the

cylinder, which differs from the traditional Rankine cycle (HorstTegethoff *et al.* 2014, ShonKim *et al.* 2014)

The results reveal that the mass flow rate of the injected steam gets the biggest influence on the energy transfer processes followed by the temperature of the injected steam. With this in-cylinder waste heat recovery program, the fuel economy of a selected turbocharged diesel engine can be improved by 3.2% at the rated operating point when the injected mass flow ratio is set to be 0.1. The program is justified by comparing the simulation results with the developed renowned correlations. Simulations are subsequently conducted for concentric tube heat exchanger with different twisted tape configuration for optimum design (RinglerSeifert *et al.* 2009, JavaniDincer *et al.* 2012). The results show that the enhancement in the rate of heat transfer in annularly corrugated tube heat exchanger with jagged tapeis about 235.3percent and 67.26% respectively; when compared with the plaintube and annularly corrugated tube heat exchangers without jagged tapes.

According to optimum effects, for a 120 kW diesel generator, the use of corrugated tube with twisted tape concentric tube heat exchanger could save 2250 gal of fuel, $11,330 of gas cost yearly and expected payback of onemonth. In addition, saving in heating fuel also reduces in CO2 emission by 23 metric tons a year. During system integration, higher-grade extraction steam can be saved, leading to greater economic advantages. Results reveal that the net added power output can reach 9.00 MWe and using the proposed WHRS can yield net benefits around USD 2.60 million per year, which is much more than those of conventional WHRS. Energy destruction can be reduced from 34.1 MWth from the conventional WHRS into 285 MWth.

From the suggested WHRS (Talom &Beyene 2009, Pandiyarajan, Pandian *et al.* 2011)studied the performance evaluation of waste heat recovery using a dual loop Organic Rankine Cycle (ORC) method for diesel engine under different working conditions, the diesel engine-dual loop ORC joint system is introduced, and the effective thermal efficiency as well as the Brake Specific Fuel Consumption (BSFC) are chosen to evaluate the operating performances of the diesel engine-dual loop ORC joint system. The results demonstrate that the maximum Waste Heat Recovery Efficiency (WHRE) of this double loop ORC system is 5.4% under different operating conditions of the engine. At the motor rated condition, the dual loop ORC system accomplishes the maximum net power output at 27.85 kW.

When compared to the diesel motor, the thermal efficiency of the joint system can be increased by 13 percent. When the diesel engine is operating at the high load area, the BSFC could be decreased by a maximum 4%. Ye-Qiang Zhang *et al.*(2014) developed and experimentally studied anorganicRankine cycle system using single-screw expander for waste heat recovery from exhaust of diesel motor (ChenLundqvist *et al.* 2006, ShuLiang *et al.* 2013)An experimental system has also been assembled for this ORC system, and experiments were conducted for different expander torque along with petrol engine loads. Influences of expander torque and diesel engine heaps on the performances of ORC system were analyzed.

The results indicated that the highest of the power output is 10.38 kW and the largest ORC efficiency and total system efficiency are respectively 6.48% and 43.8%, which are achieved at 250 kW of diesel engine output(Wang Zhang *et al.* 2011, WangZhang *et al.* 2011). Meanwhile the biggest improvement of overall system efficiency is 1.53%. The maximums of quantity efficiency, adiabatic efficiency and complete efficacy of single-screw expander are 90.73%, 73.25% and 57.88%, respectively(He Zhang *et al.* 2011, Karthikeyan *et al.* 2013).They also analyzed the insulated diesel engine exhaust heat energy retrieval system used in thermoelectric power production. A maximum of 20.6% of waste heat available from the exhaust was recovered at full-load condition with the insulation of 400- 3mthickness (KumarHeister *et al.* 2013).

Tilmann Abbe Horst *et al.*(2013) developed a lively heat exchanger model for performance prediction and management system design of automotive waste heat recovery systems. Consequently, a dynamic model of the exhaust gas heat exchanger using the moving-boundary principle was developed. The model describes both design operation and the heat-up process of the part (CraneJackson *et al.* 2001, Liu Deng *et al.* 2015). For achieving high design accuracy in the resulting broad range of working conditions, new strategies for modeling wall temperature zone and distribution switching were developed. Simulations of stationary operating points as well as the response to normal disturbances of the machine's input factors are in good agreement with test bench measurements.

The model is utilized to develop a control system for dynamicoperation on the test seat. Further studies of these working attributes reveal varying dynamic behaviour depending on the heat flow speed from exhaust gas into working fluid as well as coupling of evaporation pressure and outlet steam temperature (ShonKim *et al.* 2014). Saiful Bari &ShekhHossain (2013) conducted an experimental analysis using water as the working fluid to estimate the exhaust waste heat accessible from a diesel engine having two accessible heat exchangers bought from the marketplace.

An additional power of 16 percent was found. As these heat exchangers weren't specifically designed for this application, efforts were subsequently made to enhance the overall functioning of the exhaust heat recovery system by optimizing the design of the heat exchangers.

The working fluid pressure and the orientation of heat exchangers were optimized. after optimization, the additional power increased from 16 percent to 23.7 percent(Kim 1991, ChuaChou *et al.* 2010). Bumroongsri *et al.*(2013) analyzed experimental heat transfer coefficients of waste heat recovery unit inthe detergent manufacturing process. It recovers waste heat from the exhaust gas of this procedure causing the reduction of heat loss.

Waste heat in the bronchial air is regained at the shell and coiled tube heat exchanger. The atmosphere flows in the other hand, and water flows in the tube. Four coiled tubes with different coil pitches were analyzed. The results reveal that the tube-side heat transfer coefficient increases as the coil pitch reduces. Loading ratio has an important effect on heat transfer coefficients. The growth of loading ratio leads to a lower value of the overall heat transfer coefficient. By 100 experiments, empirical correlations for the forecast of tube-side and shell side heat transfer coefficients have been proposed. The results indicate that the predicted heat transfer coefficients agree well with the experimental values.

Jiin-Yuh Jang & Ying-Chi Tsai (2013) analyzed to minimize the thermoelectric generator module spacing and spreader thickness employed in a waste heat recovery system, the optimization of TEG module spacing andits spreader thickness as used in a waste heat recovery system is researched and solved numerically using the finite difference method together with a simplified conjugate-gradient procedure. The predicted numerical data for the power vs. current (P--I) curve are in good agreement (within 8%) in the experimental information. (Frederiksen 2001). HuiXie& May Yang (2013) analyzed the dynamic behavior of Rankine cycle system for waste heat recovery of heavy duty diesel engines beneath driving cycle, four basic operating modes were defined, such as startup mode, turbine rotation mode, power mode and protection manner.

Later a RCS version was established and operating performances ofthis RCS under an authentic driving cycle were discussed. The results indicate that the on-road Rankine Cycle System Efficiency (RCS-E) is as low as 3.63 percent, which is less than half the design RCS-E (7.77%) in the rated operating point. Despite the inevitable vapor condition fluctuation, it is the working mode shifting during the driving cycle that contributes to the on-roadinefficiency. Accordingly, in order to maximize the RCS, it would be better toconsider whole consideration in reducing the functioning mode switching, while pursuing the maximum RCT-E. MA (Jang &Tsai 2013).

Guang-yu *et al.*(2012) studied analytically the Waste HeatRecovery and Utilization of China's Iron and Steel Industry, The present situation and status of retrieval and utilization of waste heat in the China'siron and steel industry is examined from several aspects such as the quality and the source process of waste heat, Based on these the potential and instructions are pointed out. Combining with the analysis of the basic principle utilizing energy scientifically, the style of the recovery and use of waste heat is given. It is concluded that it promote this scientifically and leads to rapid development of retrieval and utilization of waste heat from China's steel and iron sector (EndoKawajiri *et al.* 2007).

Dexin Wang *et al.* (2012) implemented and demonstrated the technology first in the gas-fired package boilers. The engineering was thereafter further grown to some two-stage design tailored to coal power plantflue gas software. The recovered water and heat can be used right to substitutepower plant boiler makeup water to improve its efficiency, and any residual recovered water may be used for Flue Gas Desulfurization (FGD) watercosmetics or other plant uses.

The thermoelectric devices are analyzed on a bench-scale thermoelectric heat recovery apparatus that simulates automotive exhaust. It isobserved that for higher exhaust gas flow rates, thermo electrical poweroutput increases from 2 to 3.8 W while total system efficiency decreases from0.95% to 0.6%.Degradation of the potency of the EGR-type heat exchangers within a period of driving can also be simulated by exposing the heat exchangers to diesel engine exhaust under thermophoretic states to forma deposit coating. As an example, EGR-type heat exchangers, power output and system efficiency is regarded as 5-10% lower for all conditions tested (Hussain Brigham *et al.* 2009, Hsu Huang *et al.* 2011).

Serrano *et al.*(2012) introduced a new system to examinealternative solutions for the issues related to the coupling between the WHR Rankine cycle and the thermal engine. These solutions are based on adapting among the turbochargers by removing its turbine and attempting to recover the energy from the Rankine cycle. At length, the telescope of this Rankine cycle supplies the recovered energy directly to the breaker of this turbocharger. Thus, in these designs the coupling is simpler as it involves onlytwo turbo machines that are supposed to share a comparable rotating rate. By the results of the global energy balance, these alternative designs produce slight benefits in gas consumption but in all cases these gains are lower in comparison to those attained with traditional layouts(SaidurRezaei *et al.* 2012).

SrinivasGarimella (2012) studied the low-grade waste heat recovery for simultaneous hot and chilled water generation. Heat recoveredby a gas flow at 120ºC was supplied to an absorption cycle to simultaneously generate chilled water and hot water for space conditioning and/or procedure heating. The system demands large components to allow heat market over quite small temperature differences, with the largest component being the waste heat driven desorbed.

Minor increases in heat supply temperature lead to substantial reductions in heat exchanger size(FritzBikas *et al.* 2011).

DaeHee Lee *et al.* (2010) studied experimentally the effects of carbon dioxide with respect to the efficiencies and emission reduction in the diesel engine exhaust heat recovery system. The co-generation concept used in the electric power is made by the generator linked to the diesel engine, and heat will be retrieved from the combustion exhaust gases and the motor from the fin-and-tube and shell-and-tube heat exchangers, it's found that at a water flow of 20 L/min along with a power generation output of 9 kW, the entire efficiency (thermal efficiency plus electric power generation efficiency) of the system reaches a maximum 94.4percent that's roughly 15-20% higher than thenormal petrol engine exhaust heat recovery procedure(IsodaNishitsuji *et al.* 1990).

Ismail Teke *et al.* (2010) developed new version for specifying the area and type of the most suitable waste heat recovery heat exchanger for maximum net gain. A non-dimensional E amount had been defined based on famous technical and financial parameters like the life-time, unit area cost of the heat exchanger, lower heating value of the gas, total heat transfer coefficient of heat exchanger, boiler efficiency, operation time each year, heatexchanger effectiveness, ratio of heat capacities, annual version of the temperature of fluids supplied to the heat exchanger and present worth factor. The non-dimensional E amounts were demonstrated in graphic forms as a function of NTU and ratio of heat capacities and corresponding heat V exchanger area giving maximum net profit can easily be acquired from such graphs. The best heat exchanger type and its place could be determined comparing net gains or efficacy of heat exchangers at NTU max.

D. Waste Heat Recovery From AutomobileRecovery System

In western countries the energy from condenser of Automobilerecovery systems are used for heating the room but this system can be used to produce hot water in tropical countries like India. An Automobile catalytic converter is essentially a vapor compression catalytic converter machine which takes heat from a low temperature source such as air or water and upgrades it to be used at a higher temperature. Unlike a conventional catalyticconverter machine, the heat produced at the Catalytic converter is utilized andnot wasted to the atmosphere.

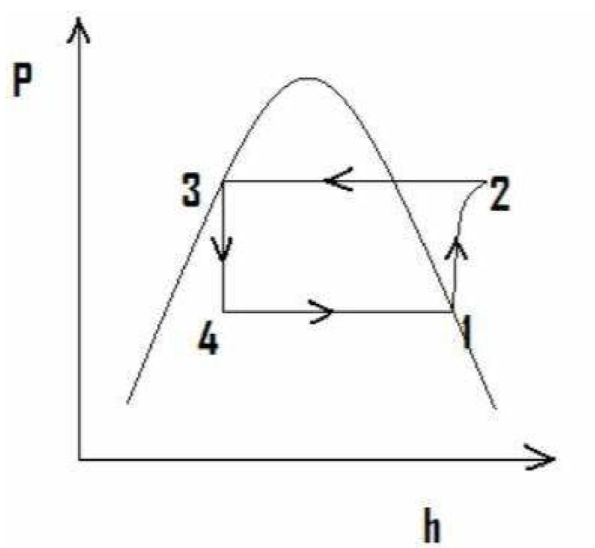

Figure 1.1Rankine cycle of the work

Figure 1.1 shows a simple vapor compression Ranklie cycle, together with the relevant pressure and temperature diagram. This illustrates the layout of a normal Rankine cycle with air cooled and heated. In the cycle shown, the low pressure and low temperature vapour refrigerant from the evaporator is drawn into the compressor through the suction valve.

1) Where it is compressed to a high pressure and high temperature. This high pressure and high temperature vapour automobile is discharged into the condenser through the delivery valve
2) The condenser (here it is water cooled condenser where the coolant is water) consists of coils of pipe lines where high pressure and high temperature vapour automobile is cooled and condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the coolant (water) thereby hot water is being generated. After condensation the refrigerant is sent to expansion valve.

3) Here the pressure and temperature are decreased. The automobile is finally sent to evaporator

The liquid-vapour refrigerant at low pressure and low temperature is evaporated and changed into vapour refrigerant at low pressure andtemperature. While evaporating, the liquid vaporrefrigerant absorbs its latent heat of vaporization from the room which is to be cooled. Thus the heat pump cum air conditioner cycle repeats and generates hot water from the air conditioner through waste heat recovery process.

E. Classification Of Automobile WasteRecovery System

Jadhao &Thombare (2013), a reduction in energy intake is possible by enhancing the performance of heat exchange systems and introducing different heat transfer enhancement techniques. From the middle of the 1950s, some efforts have been done on the variation in geometry of heat exchanger apparatus using different fin forms or various tube inserts or surface and the similar [1e7].WangDai *et al.* (2013), a number of the published investigations have concentrated on electrical or magnetic field application or vibrationtechniques [7.6e11].

Although an improvement in energy efficiency is possible from the topological and configuration points of perspective, much more is needed in the standpoint of the heat transfer fluid (Aghaali &Ångström (2015) in this paper enhancement in heat transfer is always in demand, since the operational rate of these devices is based on the cooling rate(MengWang *et al.* 2016).

New technology and innovative fluids with greater potential toenhance the flow and thermal characteristics (3.5 < Re < 280) along with a brand new convective heat transfer correlation for nanofluids inmicrochannels was also suggested(Matsubara 2002, LaGrandeurCrane *et al.* 2006)implemented 9.15 vol. % Al2O in water at a horizontal tube geometry and reasoned that in Pe amount of 2700 and 5700 around 37% promotion in heat transport coefficient in comparison to pure water may be occurred (KimPark *et al.* 2011) conducted a test for heating in flat tube at laminar flow of Al_2O_3 E water in 1 and 2 vol. % concentrations and concluded the interesting enhancement of 51 percent in heat transfer coefficient.

Nguyen *et al.*, Smith &Thornton (2009) performed their experiments atthe radiator type heat exchanger and at 6.8 vol.. In the paper, driven convection heat transport coefficients are noted for pure water and water/alumina Nano powder mixtures under fully turbulent conditions (Park Teng *et al.* 2011) The test section is made up of a normal automobileradiator, and the effects of the working requirements on its heat transport performance are examined. Additives to liquids are more noticeable. Recent advances in nanotechnology have allowed development of a new group of fluids termed nanofluids. Such fluids are liquid suspensions comprising particles that are significantly bigger than 100 nm, and possess a bulk solids thermal conductivity greater than the base liquids (Yaeger &Keller 1980). Nanofluids are shaped by suspending metallic or non-metallic oxide nanoparticles inconventional heat transport fluids. These so called Nano fluids display good thermal properties compared with Percent of nanoparticle for Reynolds number varying between 700 and 2050 (Armstead & Miers 2014). The Nusselt number for the nanofluid was discovered to be higher than that of the base fluid; and the heat transport coefficient increased with the increase in particle concentration. The ratio of the measured heat transfer coefficients increases with the Peclet number as well as nanoparticle concentrations.

Ewater; 20 nm at a millimeter-sized stainless steel test tube, exposed toconstant wall heat flux plus a low Reynolds number (Re < 268). The highest Nusselt number enhancement of this nanofluid of 8% in the concentration of 1vol. % was recorded.

Johnson Mollenhauer *et al.* (2010) conducted convective heat transfer experiments to get nanofluid(Samuel 2012)analyzed the flowbehavior of Nanofluids (Alewater) in a rectangular microchannel under laminar flow conditions. The Convective heat transport coefficient improved by over 32% for two 1.2 vol. Percent nanoparticle in the bottom fluids(Boretti 2012). The Nusselt number increased with an increasing Reynolds number (Wankhede &Krispin 2016).

Traditional fluids, such as refrigerants, water, engine oil, ethylene glycol, etc. have poor heat transfer functionality and therefore high compactness and efficacy of heat transport systems are necessary to attain the required heat transfer (Vaynberg Horn *et al.* 2006). Among the attempts for enhancement of heat transfer the list of fluids conventionally utilized for heat transfer and fluids containing particles around the micrometer scale. Nanofluids are the new window that was opened recently and it had been confirmed by several authors that these functioning fluid can improve heat transfer performance.

Zhang, Cleary *et al.* (2015) introduced an experimental evaluation of the convective turbulent heat transfer features of nanofluid (Al_2O_3 water) using 1e3 vol. %. The Nusselt number for the nanofluids increases with the increase of quantity concentration and Reynolds number. ChenGoswami *et al.* (2010) evaluated the convective heat transfer of nanofluids in the entrance region under laminar flow conditions. %) with Sodium Dodecyl Benzene Sulfonate (SDBS) as the dispersant, were tested under a constant heat flux boundary condition. For nanofluids containing 1.2 vol. %, the local heat transfer coefficient from the entrance region was found to be 41% higher than that of their foundation fluid at the same flow speed. In other work, (HatamiGanji *et al.* 2014)made an investigation of this laminar flow convective heat different radiators.

F. Maximum Waste Heat Recovery System

The following Table 1.1 provides temperatures of waste gases fromindustrial process equipment in the high temperature range. All of these are the results from gas fired procedures.

Table 1.1 Waste heat at high temperature range from various sources

Type of Device	Temperature ºC
Nickel refining furnace	1370-1650
Aluminium refining furnace	650-760
Zinc refining furnace	760-1100
Copper refining furnace	760-815
Steel heating furnaces	925-1050
Copper reverberatory furnace	900-1100
Open heart furnace	650-700
Cement kiln (Dry process)	620-730
Glass melting furnace	1000-1550
Hydrogen plants	650-1000
Solid waste incinerators	650-1000
Fume incinerators	650-1450

G. Medium Waste Heat Recovery System

The Table 1.2 gives the temperatures of waste gases from process equipment in the moderate temperature range. The majority of the waste heat in this temperature range comes from the exhaust of straight fired procedure components.

Table 1.2 Waste heat at medium temperature range from varioussources

Type of Device	Temperature ºC
Steam boiler exhausts	230-480
Gas turbine exhausts	370-540
Reciprocating engine exhaust	315-600
Reciprocating engine exhausts (turbo charged)	230-370
Heat treating furnaces	425-650
Drying and baking ovens	230-600
Catalytic crackers	425-650
Annealing furnace cooling systems	425-650

Source :Bureau of Energy Efficiency, New Delhi, India. Second edition(2005)

H. Low Waste Heat Recovery System

The Table 1.3 lists some heating sources in the low temperature range. Within this range it's usually not practical to extract energy in the origin, though steam production may not be completely excluded if there's a need for low-pressure steam.

Table 1.3 Waste heat at low temperature range from various sources

Type of Device	Temperature ^{o}C
Process steam condensate	55-88
Cooling water from Furnace doors	32-55
Bearings	32-88
Welding machines	32-88
Injection molding machines	32-88
Annealing furnaces	66-230
Forming dies	27-88
Air compressors	27-50
Pumps	27-88
Internal combustion engines	66-120
Air conditioning and refrigerationcondensers	32-43
Liquid still condensers	32-88
Drying, baking and curing ovens	93-230
Hot processed liquids	32-2321
Hot processed solids	93-232

Source :Bureau of Energy Efficiency, New Delhi, India. Second edition (2005) Low temperature waste heat may be useful in a supplementary method for preheating purposes. From the below table, it may be noted thatthe air conditioning systems are also one of the sources of possible recovery of waste heat energy. The following paragraphs will discuss the methods of recovering waste heat energy from atmosphere Components. This can beaccomplished by integrating heating pump with air preheating.

I. Radiator

Engine produces high amount of heat while running. This can raise the engine temperature to very high level and can damage or seize the engine components. (HatamiGanji *et al.* 2014, Wankhede &Krispin 2016).

Hence for the safety of engine components, it must be running at lower temperature, which is called engine working temperature. Engine cooling system keeps the engine running at its working temperature by removing excess heat. Coolant used here is the mixture of water and antifreeze which flows through the engine cooling system to absorb the excess heat and dissipate it through radiator. Engine coolant is a mixture of Antifreeze and Water(GoldmanBaker *et al.* 1987, VerdeCortés *et al.* 2010, RoweSmith *et al.* 2011). It is generally mixed in 30:70 to 50:50 ratios depending on the weather conditions in which the vehicle is used. 50% of Antifreeze is used in conditions where the temperature falls below -15^{o} Centigrade. 30% of Antifreeze is used in conditions where the temperature does not fall below -15^{o} Centigrade. Antifreeze is mixture of Glycol and Additives. It has anti rust properties to avoid rusting of engine passages. It hasvery low freezing temperature to avoid freezing in extreme cold conditions.

J. Components Of Radiator

Radiator is also known as heat exchanger, the purpose of which is to take out the heat from the engine. Here heat is transmitting through coolant from liquid medium to atmosphere. It consists of core, top and bottom tank. Core is designed with two sets of passageway, one set of tube as well as fin. Liquid coolant flows inside the fins as soon as air gets flow its outer surfaces. The heat presents in the engine is absorbed by the coolant and carried via the radiator then transferred to the atmosphere. The following Figure 1.2 showsthe components of the radiator.

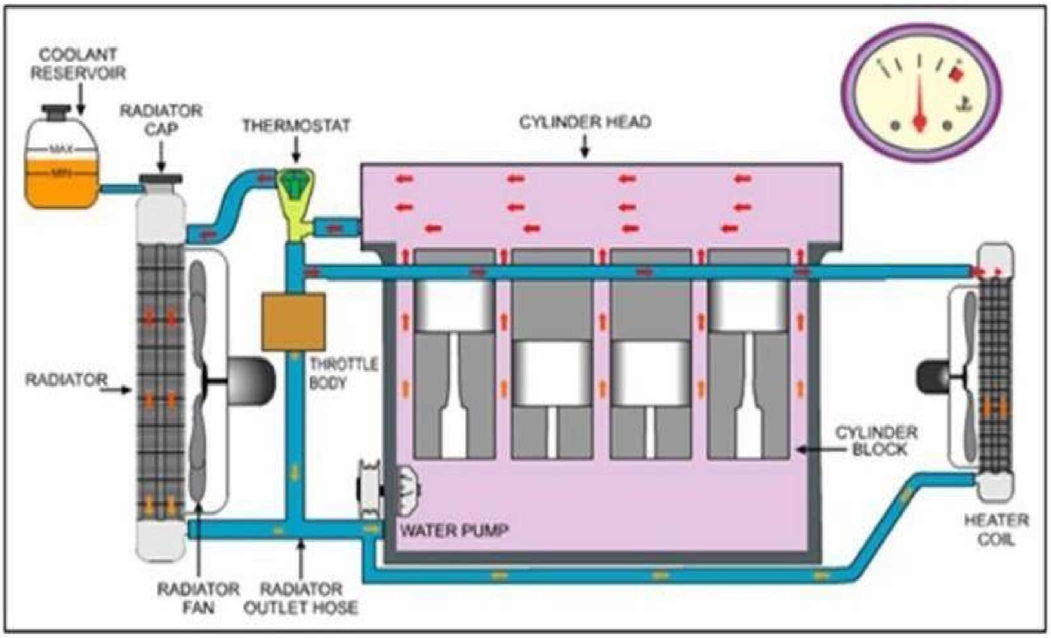

Figure 1.2 Flow diagram – RadiatorRADIATOR CAP

Tsopelas (1982), Bhogare &Kothawale (2013)radiator cap maintains a constant high pressure in the cooling system, which increases the boiling temperature of engine coolant. The increased temperature helps in easy dissipation of heat to atmosphere because of higher difference in radiatortemperature and ambient temperature. It contains two valves.
High pressure valve maintains the pressure in the system. It opensto release the coolant to coolant reservoir if pressure increases more than a limit. Low pressure valve or vacuum valve opens to allow the flow of coolant back to radiator when engine cools down.

K. Coolant Reservoir

Coolant reservoir stores the coolant which flows out from radiator cap when engine temperature and coolant pressure rises. It also allows the flow of coolant back to the radiator when engine cools down. This avoids the loss of coolant and frequent top ups.

L. Radiator Cooling Fan

Cooling fan maintains the flow of air through the radiator to dissipate the excess heat of engine to atmosphere. There are two types of cooling fans, mechanical fan and electrical fan. Mechanical fan is generally connected to engine crankshaft through a belt and set of pulleys.
Electrical fan has an electric motor which is controlled either by a fan switch installed on radiator tank or by ECM which turns it ON or OFF with the help of coolant temperature sensor.
RADIATOR HOSE
Hoses connect the components of cooling system that is top and bottom radiator tanks to the engine coolant passages. They also connect the heater coil to the system.

M. Water Pump

Water pump circulates the coolant by pushing it through engine passages and radiator. It is usually mounted on cylinder block and powered byengine through a belt.

N. Thermostat Valve

Thermostat valve allows the flow of coolant to radiator only when the working temperature is attained after starting the engine. This helpsengine to attain the working temperature quickly. It also avoids overcooling of engine and fuel wastage.

O. Radiator Cooling

Radiator cooling fins increases the total surface area of the metal body which provides cooling effect and hence, improves the efficiency to attain the maximum cooling effect. It also speeds up the transfer of heat energy.

P. Heat Conservation of Air Cooled Radiator

Automobile energy is totally free, non-polluting and abundant on Earth. It may provide approximately 10W/m^2 of Automobile energy on a Dynamic and Static conditions. Air Cooling radiator with and Thermoelectric Generating (TEG) cells are radiator outlet tube/inlet tube-based power generating cells which could convert auto energy to electric energy. In spite of the fact that the solar energy being cost free, these solar cells feature expensive semi-conducting materials and pose problems of low energy conversion efficiency (Scott 2010).

By concentrating the incoming radiation by using an Automobile concentrator, the Automobile energy intensity could be increased many times determined by the Automobile concentration ratio. The use of immersion in solar power generating systems may either increase the electrical power output or lower the required amount of solar cells for any given output energy. Automobile immersion is cost-cutting methods for solar-electricity production as smaller quantities of expensive Automobile cells are combined with an inexpensive solar concentrator to get a similar degree of power production.

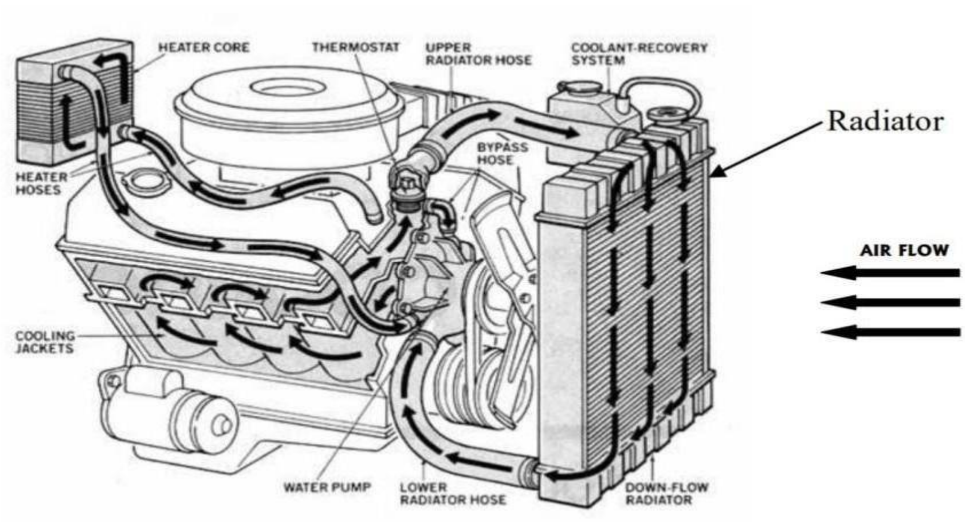

Figure 1.3 Heat Conservation of air cooled Radiator

Q. Statement of Problems

The Fresnel lens and parabolic trough are common Automobile concentrator types for Concentrated Thermoelectric Generator (CTEG) and concentrated Radiator air systems.

Bhogare &Kothawale (2013)the effective waste heat recovery is one of the present-day challenges in the Automobile industry and power engineering. The energy systems dedicated for waste heat conversion into electricity are usually characterized by low efficiency and are complicated in the multiple designs.

CFD has been applied to solve many thermodynamics and heat transfer problems. It includes investigations into the performance of heatexchangers. One such application was studied by Rustum&Soliman (2014), Bhogare &Kothawale (2013).

1) The researchers investigated an internally finned tube. In another study, plate heat exchangers were modeled in CFD and the hydrodynamics were studied. CFD was also used to characterize a cardioplegia heat exchanger.
2) Other types of exchangers that were modeled with CFD,includes a vertical mantle exchanger. Reliable results were found when compared with outdoor measurements only.
3) Therefore, an exchanger‘s configuration and material can easily be modified to investigate the design changes. The purpose of the work is to predict the flow behavior and temperature profile of a radiator with nanofluid

In the waste heat recovery from the Internal combustion chamber up to silencer can result in cell life degradation and minimum energy conversion and better efficiency and non-damaged products only allowed in these present systems. Most of the works has minimal energy conversion efficiency. Krauter Hanitsch& Wenham (1994)is the major work on Thermo electrical generator and PV cells.

R. Preparation Of Phase Change Material (PCM)

Phase change material thermal storage(PCMTS) also referred to as latent heat storage is one of the very promising thermal energy storage methods where a large amount of heat energy can be stored in a relatively compact mass of storage medium. The Phase Change Material (PCM) undergoes phase transition (melting and freezing) during heat absorption. The PCM also shows isothermal process during heat absorption that has received much attention in thermal control of buildings and thermal storage systems (KandasamyWang &Mujumdar 2007; SharmaTyagiChen &Buddhi 2009).

In building comfort applications, a high capacity thermal storage system can decrease electricity consumption by recycling heat stored during the day to be used in home heating during the evening. Alternatively, heat saved at night can offer daytime cooling. To integrate PCMTS to a passive cooling system for focusing solar cells programs (CTEG and CPV cells), the selection criteria of the PCM must incorporate reliability, compatibility, maintenance-free and higher cooling capacity. With these selected criteria, a fully passive and self-operated Automobile-based power generator can bemanufactured using the proposed passive cooling system. In an attempt to come up with cost-effective and compact storage technology, researchers in theglobe have been exploring the practicability of Solar systems as an alternative storage technology.

Solar systems use PCMs to keep renewable energy in the form of latent heat of fusion. PCMs are attractive because of their high energy-storage density at a constant temperature. As an example, the energy which can be kept by raising the temperature of 99 KG of potassium nitrate (KNO3) by 1K (sensible heat) can be stored in only one kilogram of the identical material by making the KNO3 experience phase change (latent heat). Thus, less storage material is needed when compared to SHTES which leads to reduction in the capital and construction costs (Robak *et al.* 2011a).

In CSP-LHTES plants, the working fluid (called the Heat Transfer Fluid (HTF) in this thesis) is pumped to charge and release renewable energy to and from the PCM respectively(Delavari &Hashemabadi 2014). As a result, the installation of LHTES systems into commercial large scale software has not yet been achieved. Since the operation of the PCMs is lower, several techniques has been developed including prolonged surfaces, multiple PCM's, thermal conductivity augmentation and micro-encapsulation of the PCM (Jegadheeswaran&Pohekar2009). Of all the techniques proposed to improve the operation of LHTES systems, utilizing heat pipes may be the optimal solution. This conclusion is based on an economic study of LHTES armed with bare heating pipes, in which the decrease in capital cost was foundto be 15% compared with this prevailing technique of electricity storage(Robak *et al.* 2011a).

S. Preparation Of Thermoelectric Generator(TEG)

KimWe *et al.* (2014),Thermoelectric Generator (TEG) theoretically may provide many advantages such as being highly reliable, without moving parts, and being environmentally friendly, in comparison with conventional electric power generators. Owing to these advantages, there have been considerable emphases on the development of the small TEGs for a variety of aerospace and military applications over the past decades.

More recently, there's a growing interest for waste heat recovery TEG, with various heat sources like combustion of solid waste, geothermal energy, power plants, along with other industrial heat-generating procedures. In the instance of TEG for waste heat recovery power generation, there have been many conceptual layouts of an energy conversion system which are possibly capable of getting application in this area (Sahin &Yilbas 2013, HeZhang *et al.* 2015).

These designs involve the consideration of their highest energy output and conversion efficiency with different thermoelectric heat exchanger. What's more, performance evaluations of these thermoelectric generators are carried out by modeling strategy. The results reveal that the majority of generators are promising devices for waste heat recovery. Even though the economic viability of a TEG may be improved significantly when employed for waste heat recovery, desirable TEG technology for waste heat recovery are those which could decrease the apparatus price and increase the conversion efficiency of a model. In the preceding analysis, the authors presented a numerical model to evaluate the operation of thermoelectric generator together with all the parallel-plate heating exchanger.

As the next step, the study is expanded to develop a low-cost, simple configuration TEG unit with commercially available Bi2Te3 based thermoelectric modules for an anticipated maximum energy production of approximately 150--200W degree. This analysis also aims at validating the previously published numerical version and providing some guidelines for themodel modifications. This job would further leads to the development of TEGfor its intended large-scale application in waste heat recovery.

T. Objective Of The Present Works

The Current research work Targets at Latent of waste heat out of Normal vapor compression Automobile radiator system.The objectives of theresearch are given below:

1) The power available in the nominal heat conduction of several energy conversion devices goes as waste, if not utilized correctly in this present circumstance.
2) This latent heat storage system is designed, fabricated and analyzed for high thermal energy storage with cylindrical tank formation released and implemented.
3) The major technical constraint that prevents effective implementation of waste heat recovery is the intermittent and time-consuming demand and availability of energy.
4) This method utilized thermos electric generator [TEG] electricity storage in various applications and the energy stored is evaluated and reported in this thesis.

U. Outline Of The Thesis

The outcomes of this study are presented in nine chapters. The chapters have the following content:

Chapter 2: Literature Reviews - gives a detailed literature review onapproaches of waste heat recovery, with emphasis on RHP-TEG systems. This chapter also presents the state-of-art of energy harvesting methods using automobile radiator-based Thermoelectric Generators (TEGs). These reviews provide a foundation for understanding the existing cooling difficulties and constraints in Automobile applications.

Chapter 3: Thermal Storage and phase Change Material -introduces a detailed review of thermal storage systems and PCM. This chapter gives a detailed description of the PCM classifications, thermal- physical properties, Most of thermal storage containments, thermal enhancement approaches and other background. Applicability of the PCM thermal storage for passive cooling and Heating in the Automobile radiator systems is also described.

Chapter 4: System Analysis and Mathematical Modelling – presents an overview of the proposed cooling and heating concept including description of the associated components. The Automobile radiator with instance of TEG system is integrated with PCM thermal storage for passive cooling and Heating of radiator system. The system analysis and mathematical modeling are presented in this chapter for predicting the thermal and electrical performance of the proposed Radiator with RHPTEG-PCM system under different fabricated levels.

Chapter 5: Experimental assessment of a concentrated thermoelectric generator using PCM thermal storage – presents detailed descriptions of experimental procedures, results and analysis of the Automobile radiator RHPTEG-PCMTS system. Experiments were conducted to study the maximum fabricated with concentration and power generation of the proposed RHP-TEG-PCMTS test rig.

Chapter 6: CFD Analysis of advanced numerical studies using FLUENT 6.3 simulation software was also conducted in order to visualize themelting behaviors and natural convection effects in the thermally enhanced PCM thermal storage systems.

Chapter 7: Result and discussion - Analysis of the computational fluid dynamic system with PCM storage and without storage is made and compared.

Chapter 8: Conclusions and Recommendations – presents major conclusions from the whole study and narrates the suggestions for future work.

II. LITERATURE SURVEY

A. Introduction

This Chapter presents previous work regarding the objectives of thestudy. The literature review starts with the definition of waste heat and its accessibility from the perspective of Indian industry. The present methods for recovering waste heat from industry are addressed in this area, and attention has been given to the passive heat transport method with Automobile radiator.The next section of the literature review discusses the various heating technologies and their recent development.

Past procedures for analysis and design of heat pipes have also been mentioned as they are related to the theoretical part of this study. The latter section of this chapter describes the working principles of the thermoelectric power generation method known as the "Seebeck effect". The section covers the conventional material for generating thermoelectric generators (TEG), the dimensionless parameter referred to as the figure of merit for assessing TEG efficiency and the present problems connected with TEG technology.

B. Waste Heat Recovery

The financial globalization has promoted the international flow of trade, investment, technology and financial capital, because of which, the globalization of the international shipping market was accelerated further. Nowadays the vast majority of prime movers (propulsion configuration) and additional plants of oceangoing boats are using petrol engines.,

(Kumar Heister *et al.* 2013). are made by High-pressure combustion engine remains the fundamental propeller for ships because of both the most inexpensive heavy petroleum and the maximum efficiency compared with all other heating engines. However, irreversibility in energy conversion is inevitable by the second law of thermodynamics.

(LeBlanc 2014). Said that While drifting in gas, diesel engines onboard have an efficiency of approximately 48 to 51 and the remaining portion of the input energy is discharged from the atmosphere concerning exhaust gas and jacket water. Much work presently in progress led to the improvement of the thermal efficiency by optimizing the setup of motor to accomplish a better fuel consumption. Also, much attention has beenmade on the progress combustion technology, such as HCCI (Jang &Tsai 2013) lean combustion , stratified combustion (Liu Deng *et al.* 2015)to achieve a greater overall efficiency and to reduce emission.

However, as these technologies have attained grown stage, it becomes harder and harder to get further improvement by using these methods. A valuable alternative approach to improving general energy efficiency is to catch and recover the"waste heat". Waste heat recoverysystem is among the best energy saving approaches to make a more efficient usage of fuels to attain environmental improvement. Contrary to the auto operating requirements, the motor of ship especially that of large tonnage shipruns at a constant rate for quite a while. It's easier to make use of stable waste heat on boats compared with that of car. Furthermore, it can provide both heatsupply (waste heat) and heating (sea water). To be able to protect the Earth's environment and climate and relieve the energy crisis, additional effort is made to design Green Ship in future. Though fresh combustion technology and after-treatment technology are getting matured, it is still difficult to satisfy the stringent emission rule. WHR will be an effective way to create more power on the groundsof exactly the same emission quality. It is just another reason why WHR technology brings much more attention of both energy and environment researchers. The merchant fleet all over the world represents almost 80 of all the vessels ordered each year. The two-stroke diesel engine possesses operational and economic benefits compared to other people. And its low spinning rate makes a reduced friction and greater efficacy feasible. What's more, it burns the cheapest residual fuel. The power retrieved in the motor is based on great extent upon the size of the principal engine and trade pattern (primary engine loading and ambient temperatures) of this ship. The engine size, operation route, loading environment andcondition ought to be taken into account before choosing an appropriate way to waste heat utilization. Before study on recovering waste heat from gasoline motor, the evaluation of energy balance should be carried out to figure out thepotential of WHR.

Scappin *et al.*(2018) evaluated the operation of marine two-stroke diesel motors by means of an energy balance (HeZhang *et al.* 2015)carried out an analysis of energy balance and utilized combined cycles to recoup energy from different waste heating sources in motor.

Weng & Huang (2013) Assessed a normal two-stroke diesel engine of MAN B&W Diesel and discovered that 25.5 of the released energy is wasted through the exhaust at ISO ambient reference conditions in 100 SMCR, and 16.5 and 5.6 in terms of the air cooler and coat water respectively. Assuming the ordinary operation in service in 85 SMCR1/458,344 kW in 280 days per year, 24 h every day, 31,726 t of heavy fuel will be lost through the exhaust gas, air cooler and coat water. If partial energy inside the waste heat could be converted into useful power, it might not just bring measurable advantages for improving fuel consumption but also reduces CO_2 and other harmful exhaust emissions correspondingly.

Though Striling cycle motors have shown their abilities to function with waste heat, the complex mechanical structure and its transient response period are the practical barriers that hinder the adoption and development of Striling motors according to (Aghaali &Ångström 2015). Hence, the heat-recovery possibilities taken into consideration in this work are turbocharger/power turbine, fresh water obtained by using MED or MSF desalination technology, electricity/power acquired from Rankine cycle, air-conditioning and ice-making acquired by utilizing sorption pipes, and combined WHR systems. All the technologies mentioned previously are cost- effective ways to extract energy from the waste heat.

C. Direct Heat Recovery System

The heat pipe is a system that can transfer heat efficiently over large distances in close to uniform temperature without including outside electrical energy. Despite its simple design; a heat pipe includes high thermal conductance and works without moving components. A basic notion of a heat pipe consists of a thin tube which has a wick structure lined onto the inner surface. A small amount of saturated water is inserted into the tube and acts asa working fluid. The heat pipe can be split into 3 sections that are an evaporator at the same end, a condenser at the other end and an adiabatic section in the centre (Figure 2.1).

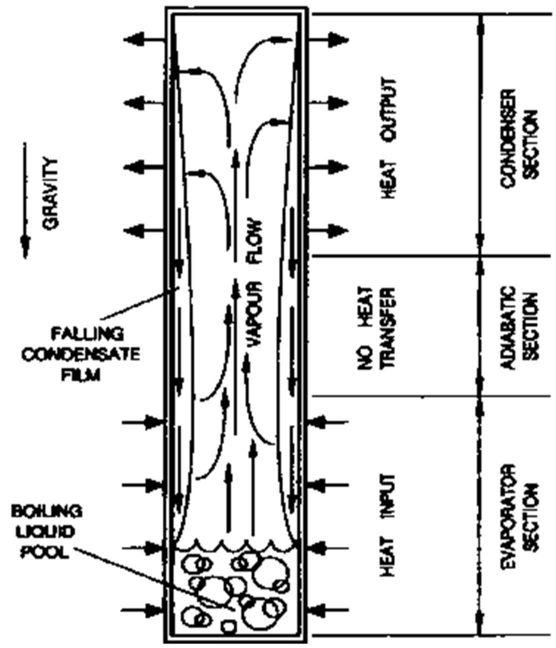

Figure 2.1 Heat pipe heat recovery system

The vapour flows and climbs to the cooler condenser effectively transferring the latent heat of vaporization. The vapour then condenses and modifies to the liquid phase. Because of the effect of gravity, liquid fluid will flow down through the back to the evaporator whilst the vapour flows always from the opposite direction through the core of the tube.
(Sprouse III & Depcik 2013) are drived that the Both heat pipes and thermosyphons shown in Figure 2.2 have the exact same working principle but, for a thermosyphon, condensate returns to the hot end bygravity whereas for a heat pipe by capillary action of a wick). Therefore for a heat pipe, the location of the evaporator is not restricted and may be placed anywhere, but to get a thermosyphon, it must be found below the condenser. The operating pressure and the type of fluid inside the heat pipe depend mainly on the temperature.
Usually, water can be used as working fluid for moderate temperature ranges, while other fluids are utilized for jelqing programs. The property of surface pressure should be considered when selecting the working fluid to be able to increase the capillary effect and to be compatible with wick substances. Other selection criterions are compound stability, easily availability, non-toxicity and cheapness. Heat from geothermal sources can beextracted using a heating pipe toaster and transformed to power. Nguyen *et al.*have introduced the basic concept of this system (Figure 2.2).

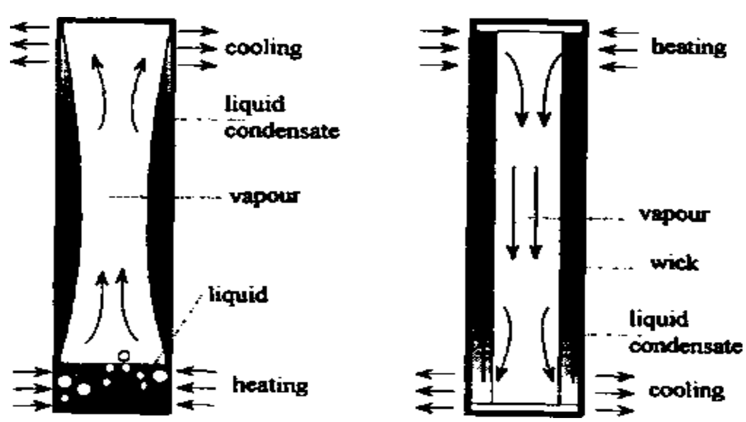

Figure 2.2 Thermo-syphon heat recovery systems

It consists of a closed vertical cylinder that was an evaporator, an insulated part along with a condenser. A turbine was put in the top end of this cylinder for generating electrical power. A plate split the high pressure area inthe evaporator and the low pressure region in the condenser. A nozzle converts the thermal energy into kinetic energy. The mechanical energy was converted to power via an electrical generator. Nguyen tested 4 distinctlayouts of heating pipe tanks. The last heat pipe layout was 0.5 m in diameter and 2.8 m in height and it produced 100 W of electricity with 10 kW heat input signal and running at 6000 rpm turbine speed. To improve the heating ducts performance, Akbarzadeh *et al.* introduced their latest turbine design comprising two"S" shaped pipes attached to a hub Figure 2.3.

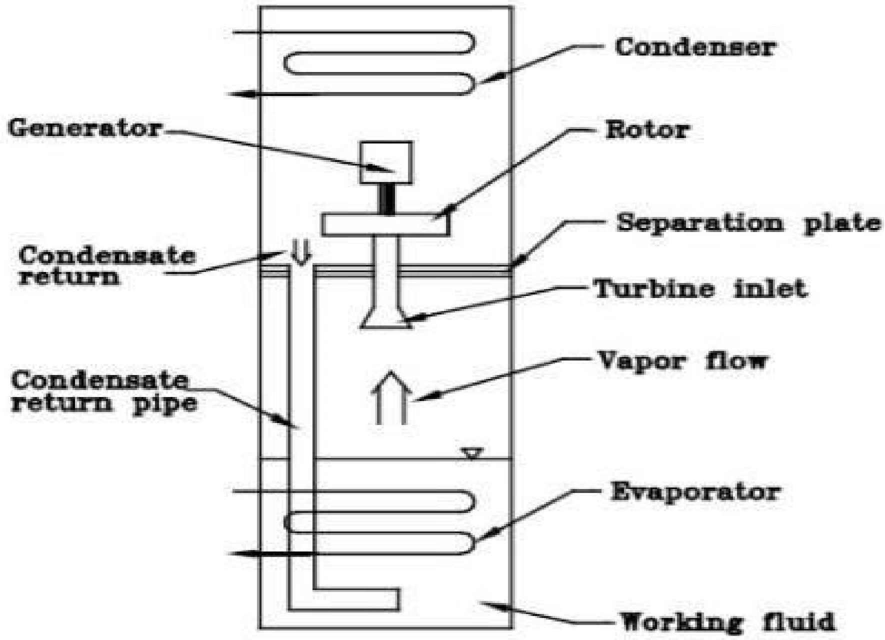

Figure 2.3 Condenser with heat pipe recovery system

Vapour flows vertically though the hub and changed its direction when entering the 2 pipes. The vapor created the telescope response torque as it exited at high speed through nozzles at the ends of the pipes. This turbine was anticipated to create 3 kW output power from 100 kW heat inputsignal.

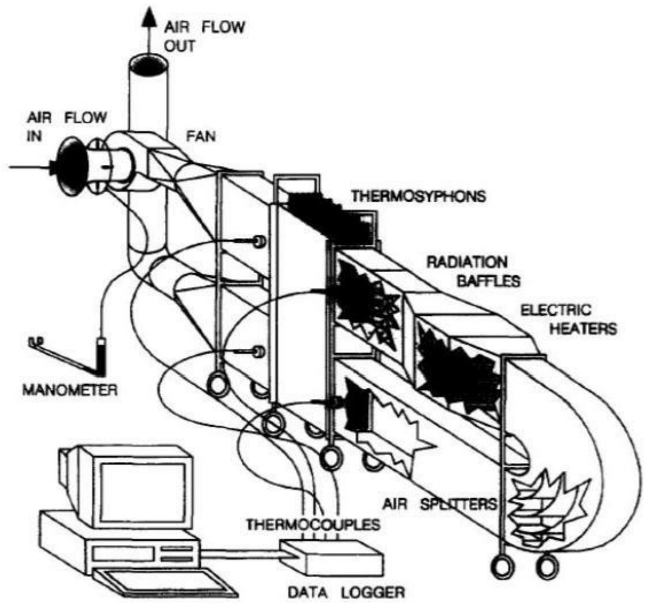

Figure 2.4 Duct pipe flow analysis recovered system

The model was made to work at 55°C evaporator temperature and 25°C condenser temperature according to a geothermal bore specification in Portland, Victoria. In a commercial scale case, a huge scale heating pipe extracted heat from a geothermal well in Kyushu, Japan according to Kusaba *et al.* (2002). The heat pipe was made of 150 millimeter diameter and 150 m span. The heat pipe system was equipped with a liquid feeding tube with a showering nozzle. It had been tested in a geothermal well of 70-150 m thickness. The system expressed approximately 90kW of heat in 80°C working fluid temperature. A computer simulation was developed to forecast the output power available from the heat extraction by contemplating a turbine to be installed on the top of the heating pipe. The prediction showed that the 0.8 m diameter telescope could generate roughly 7.8 kW of electrical power at 3000 rpm.

D. Techniques Handling Heat Recovery System

A Thermoelectric power Generator (TEG) is a device that can convert thermal energy into electricity. It is a solid state heating that contains no moving parts, no vibration and no noise, is light in weight and very reliable. To generate electrical power, the TEG should be attached between a heat source and a heat sink. Due to the temperature gradient made between the heat source and the heat sink, heat will flow throughout the module and also be rejected to the surroundings through the heat sink.

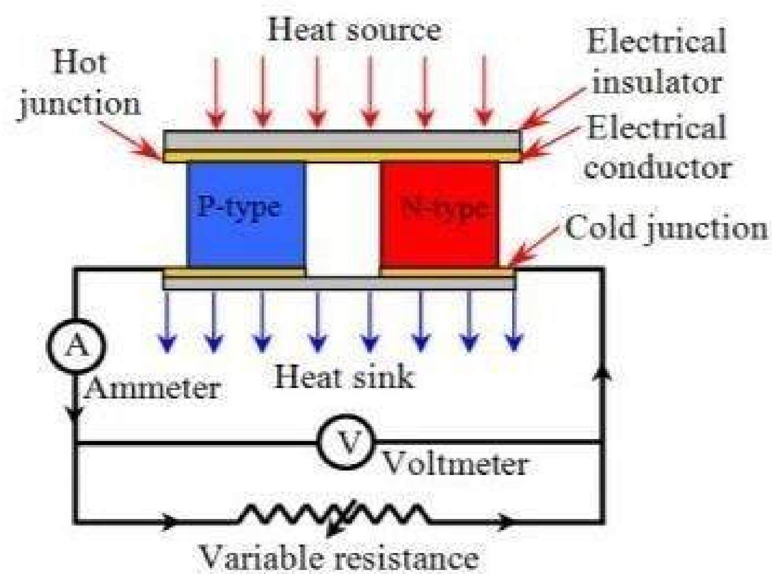

Figure 2.5 Thermo electric generator

If the temperature gradient is preserved, electric power will be continuously produced. The thermoelectric module operation relies on the Seebeck effect as shown in the Figure 2.5.The found electromotive force or potential difference (voltage) is produced by means of a circuit created from two distinct cables if one of those junctions was warmed. In a thermoelectric module, when two dissimilar conductor are connected and the two junctions are maintained at temperature and at which >, an open circuit electromotive force or potential difference (voltage) is developed between this junctions. The electrical voltage is proportional to the temperature difference and is supplied by:

E. Review of Thermoelectric Power Generation

The materials to generate a thermoelectric (TE) cell made from a n-type and p-type couple. A figure of merit, ZT expresses the efficacy of the TEmaterial.

Rowe *et al.* (2013) has categorized thermoelectric materials into established materials and new materials. Today, the most popular available thermoelectric materials are Bismuth Telluride (Bi_2Te_3) - based alloys and PbTe-based alloys that they have ZT values near unity.

Bell (2008) reported that a higher TEG efficiency can be achieved if the ZT value is maximized and the temperature differential between the warm and the cold sides of the TEG is preserved as large as you can. The major challenge of thermoelectric power generation is its own low heat-to-electricityconversion efficacy which typically near to 5 percent.

Although the TEG cannot be used widely due to this limitation, there are many businesses that use TEG for many applications includingcooling/heating car seats, laser diode coolers, DNA synthesizers and low- voltage electrical generators. The declaration for domestic product get, more sustainable energy resources is an ever-growing worldwide concern because of escalating energy costs and global warming associated with fossil fuel sources. Many advantages of this energy-conversion phenomenon includesolid-state operation, the absence of toxic residuals, vast scalability, maintenance-free operation vis-à-vis the absence of moving parts or chemicalresponses, and a very long life span of dependable operation.

Conversely, solid-state thermoelectric devices may also change electrical energy to thermal energy for cooling or heating using the Peltier effect. When compared with traditional heating and cooling mechanisms, solid-state thermoelectric energy converters have the benefit of simplicity; they produce no more vibrations and are highly scalable.

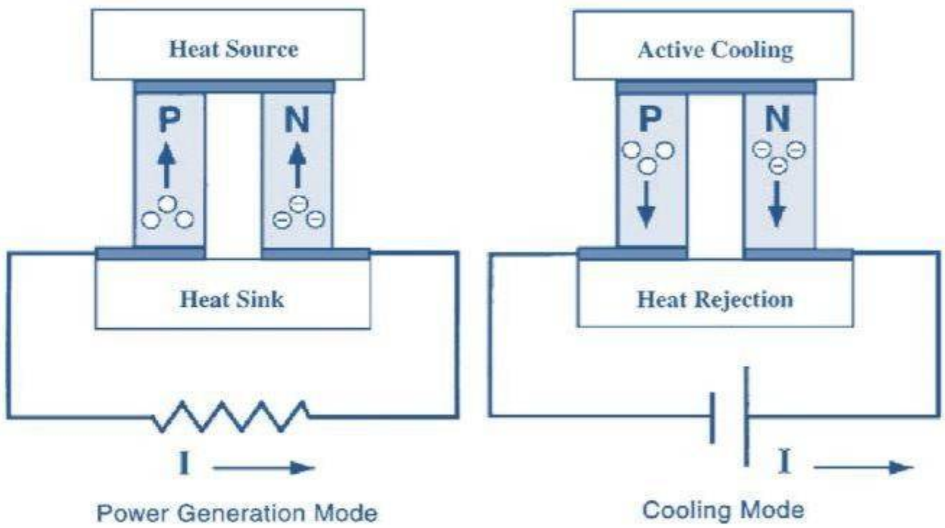

Figure 2.6 Thermoelectric Generator in heat source with Hot /Coolingmode

Furthermore, because TE devices utilize no refrigerants or working fluids, they might be expected to create negligible direct emissions of greenhouse gases over their lifetimes. However, because of their low efficacy,present TE materials have found limited commercial application. A brief perusal of these possibilities is illustrated in Figure 2.6 in which the different scales of energy generation which are represented are related to different applications. The problem that remains is the efficiency of today's thermelectric material is insufficient to compete with traditional powergeneration and refrigeration.

In addition, the growing need for alternative power resources is driving an increasing interest in developing a new production of thermoelectric materials. To become competitive with present works thermoelectric materials need to improve in efficiency by a factor of three on the present values. Thus, this review discusses fundamental understanding of thermoelectric materials, their applications and an overview of the parameters that influence their functionality.

F. Review Of Phase Change Material

Materials to be used for phase change thermal energy storage needsto have a large latent heating and high thermal conductivity. They ought to have a melting temperature lying in the practical array of operation, melt congruently with minimal subcooling and be chemically stable, low in cost, nontoxic and non-corrosive. Materials which were studied during the last 40 years are hydrated salts, paraffin waxes, fatty acids and eutectics of organic and non-organic compounds.

Based on the software, the PCMs must be chosen based on their melting temperature. Materials that melt below 15 ◦C have been used for preserving coolness in ac applications, while materials that melt over 90◦C have been used for absorption refrigeration. All other substances that melt between both of these temperatures can be implemented in solar heating system and for heating load leveling applications. These materials represent the category of substances that has been examined most. Comprehensive lists of most possible substances that could possibly be used for latent heating.

Lorsch *et al.* (2015), Lane *et al.* (2009) and Humphries and Griggs*et al.*(2018)who have reported a large number of potential candidates for latent heat storage covering a wide range of temperatures. Industrial paraffin waxes are inexpensive with average thermal storage densities (200 kJ/kg or 150 MJ/m^3) plus a broad range of melting temperatures (Figure2.1a).

Hasan *et al.*(2015) has conducted an experimental investigation ofpalmitic acid as a PCM for energy storage. The parametric study of phase shift transition included transition period, temperature range and propagation of this sound liquid interface, in addition to the warmth flow rate characteristics of the used circular tube storage system.

Dimaano&Escoto (2016) have evaluated a combination of capric and lauric fatty acids for such storage. The melting point of the mixture was about 14 C and its latent heat of melting ranges between 113 and 133 kJ/kg, which depends on the composition. Some materials have only been used to examine the performance of the storage units and therefore are unlikely to be applied in practice. Examples of which are dimethyl-sulfoxide, which has a melting point of 16.5ºC with a latent heat of only 86 kJ/kg , and maleic anhydride, thathas a melting temperature of 52ºC with a latent heat of 145 kJ/kg. Glauber salt (Na_2SO_4 Æ H_2O), which comprises 44 percent Na_2SO_4 and 56% H_2O by weight has been studied as early as 1952. It's melting temperature is approximately 32.4 C with a high latent heat of 254 kJ/kg (377 MJ/m^3) and is one of the least expensive materials that may be used for thermal energy storage. However, the problems of phase segregation and subcooling have restricted its application.

Biswas *et al.*(2019) has suggested the use of the additional water principle to prevent formation of the heavy anhydrous salt. Although this makes the system secure with biking, it reduces the storage density and requires the system to be operated with a large temperature swing. The usage of a thickening agent, such as Bentonite clay, with the Glauber salt was proposed to overcome the problem of phase segregation. Sadly, this will cut the rates of crystallization and heat transport into the salt because of the lower thermal conductivity of the mixture. Borax has been suggested by Telkes*et al.* (2008) as a nucleating agent to minimize sub cooling. But this required athickening agent to avoid settling of their high density borax. The majority of the other hydrated salts share exactly the same issues. There are many advantages of microencapsulated PCMs, like increasing heat transfer area, reducing PCMs reactivity towards the outside environment and controlling the fluctuations in the storage material volume as phase change happens. Lane has recognized over 200 potential phase change heat storage materials melting from 10 to 90ºC for use for encapsulation. Microencapsulation of $CaCl_2$ Æ $6H_2O$ in polyester resin was especially successful, and the advancements of wall and floor panels were analyzed.

Macroencapsulation of $CaCl_2$ Æ $6H_2O$ in plastic film containers seems promising for heating systems with air as the heat transfer medium. Heevaluated the technical and economic feasibility of utilizing encapsulated PCMs for thermal energy storage in solar powered residential heating applications and has developed way of encapsulating a group of promising phase change heat storage materials in plastic or metal containers. After considering a number of cooling and heating systems employing phase change heat storage, a forced hot air, central heating design with $CaCl_2$ Æ $6H_2O$ encapsulated in plastic pipes was accommodated.

The encapsulation of PCMs into the micropores of an ordered polymer film was researched by Stark *et al.* (2003) Paraffin wax and high density polyethylene wax have been infiltrated successfully to extruded movies of the ordered polymer by a solvent exchange technique to yield microcomposites using PCM degrees of this sequence of 40 volume percent. These microcomposite films show excellent mechanical stability under cyclic freeze--thaw conditions.

Royon *et al.*(2000) have developed a new material for storage. The final substance remains well shaped, requiring no support as well as coating, therefore it can be used directly. Nonetheless, the potential usage of microencapsulated PCMs in various thermal management software is limited to some degree by their cost.

Laterly Hong &Xin-shi(2001) have employed a compound phase change material, which is made up of paraffin as a dispersed phase change material along with a High Density Polyethylene (HDPE) as a supportive material. This newly created phase change material is very acceptable for application in direct contact heat exchangers. The 75% paraffin and 25 percent HDPE mix supplied a phase change material that has a latent heat of 157 kJ/kg compared to 199 kJ/kg for its paraffin used and using a transitiontemperature of roughly 57ºC, which is near that of paraffin. Ammonium alum and ammonium nitrate in the weight ratio of 1:1 forms a eutectic that melts at 53ºC and crystallizes at 48 C. Its enthalpy, as measured by drop calorimetry, was discovered to become 287 kJ/kg in the temperature assortment of 25— 67ºC, that is 1.67 times greater than that of water (172.2 kJ/kg) and 8.75 timesgreater than that of stone (32.8 kJ/kg).. But by adding 5% attapulgite clay into this eutectic mixture, phase separation was prevented.

G. Summary

This chapter has introduced and reviewed the present technologies for heat transfer enhancement in radiator waste heat recovery[RWHR] systems. RWHR systems have a significant problem of low thermal conductivity. Therefore, RWHR systems still haven't been executed in high solar concentrating applications. Much attention has been dedicated to incorporating Radiator due to their exceptional thermal conductivity to solve this issue.

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The present study focused on raising the overall thermal conductance of PCMs utilized in RWHR units through using HPs.In addition, a preliminary system sizing and financial evaluation has been conducted.

The following chapters presents a detailed descriptions such as numerical modelling and experimental validation of three new methods forimproving the operation of RWHR systems using different radiator profiles

III. THERMAL STORAGE AND PHASECHANGE MATERIAL

A. *Introduction*

In Automobile air cooling industry that are equipped withRWHTEG systems, the heat transfer fluids flow to control and discharge the renewable energy to and from the PCM respectively. On the other hand, the heat transfer speeds between the heat transfer and the PCM are restricted by the low thermal conductivity of the PCM. Inorder to reduce the thermalresistance of the PCMs, Shabgard *et al.* (2010) indicated to stud the HTF tubes using bare HPs.

The advantages that could be gained by using HPs along with fins (finned HPs) in high-temperature LHTES systems have not been studied. The combo of both HPs and fins has got the potential to enhance the operation anddecrease the capital cost, this is stated depending on the fact that the HPs outperform fins in terms of heat transfer (Robak *et al.* 2011b), however fins are predicted to be cost-competitive especially contrasting with high- temperature HPs as shown Figure 3.1.

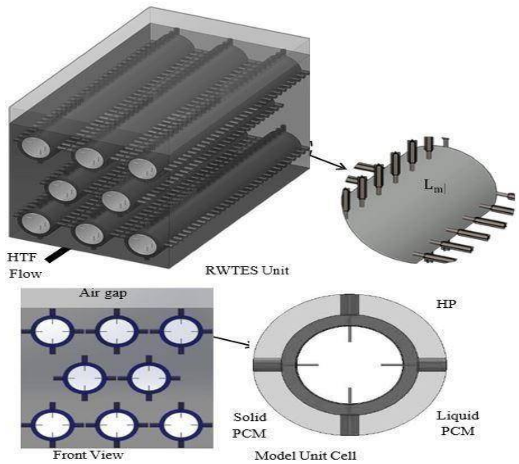

Figure 3.1 Latent heat stored energy system

The target of this chapter was to develop a numerical model to investigate the effect of incorporating finned HPs into some high-temperature RWHTEG unit. The model was designed with a 2-D control volume method where the thermal resistances of the HPs are formulated as a mathematical model that represents the physical problem. In addition, an experimental investigation was conducted to ensure the adaptability of the simulation. The shell and tube configuration is quite typical in heating systems. It is the most intensely researched configuration in RWHTES systems (Agyenim *et al.*2010). This may be attributed by two factors:

1) That the huge majority of engineering methods use cylindrical pipes
2) Shell and tube systems have minimal heat losses. As a result, the shell and tube configuration was adopted by all of the previously mentioned studies of high-temperature LHTES systems. The design considered in this chapter is the one introduced by Shabgard *et al.* (2010).
3) The device consists of a range of tubes, which carry the HTF, inserted in an insulated shell full of PCM. At the top ofthe shell, an air gap has been left to account for the growthof the PCM during melting.

B. *Issues of Latent Heat Storaged Systems*

Storage materials - This is referred to as a change in condition, or"Stage". Originally, these solid--liquid PCMs perform like conventional storage substances, their temperature rises as they absorb heat. Unlike conventional (sensible) storage materials, PCM absorbs and release heat in a nearly constant temperatures. They store 5-14 times more heat per unit volume compared to sensible storage materials like water, masonry, or stone. A large number of PCMs are proven to melt with a heat of fusion in any required range. These substances exhibit certain desirable thermodynamic, kinetic and chemical properties which makes them employable.

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Moreover, economic considerations and effortless accessibility of these materials has to be kept in mind. The PCM to be utilized at the design ofthermal-storage systems should exhibit desirable thermo physical, kinetics and chemical properties that are as follows (ZhangCleary *et al.* 2015): Solar water heater is getting popularity (HatamiGanji *et al.* 2014) since they are relatively cheap and simple to manufacture and maintain. ShonKim *et al.* (2014)analyzed a built-in storage type water heater containing a coating of PCM filled at the base.

During the hours when the sun exhibits much heat, the water gets heated up and transports the heat to the PCM below it. The PCM assembles energy in the form of latent heat and melts. Throughout sunshine hours, the hot water is removed and is substituted by cold water, which increases energy from the PCM. The energy is discharged by the PCM when there is a phase change from liquid to solid. This type of system might not be successful because of the poor heat transport between PCM and water. A cylindrical storage device at the closed loop with a flat plate collector has been studied byBansal&Buddhi(2008)with its charging and charging mode. A comparative study of solar energy storage systems based on the latent heat and sensible heating technique has been carried out to preserve the solar heated hot water during night time by Chaurasia *et al.* (2009).

For this purpose, two indistinguishable storage components were utilized. One storage unit comprising 17.5 kg paraffin wax (m.p. roughly 54 8C) as the storage substance is packed in a heat exchanger made up of aluminum tubes and another unit simply comprises of water as a storage substance in a GI tank. Both components were separately charged during the afternoon with the support of flat plate solar collectors having same absorbingarea. This study has revealed that the latent heat storage system relatively yields more hot water over the following day morning in comparison with thoughtful storage system. A comparison has been made between different sized latent heat storage tanks and sensible heating at a water tank using different degree of stratification (Isoda Nishitsuji *et al.* 1990). The storage vessel consists of a number of closed cylindrical pipes full of phase changing materials (Figure 3.2).

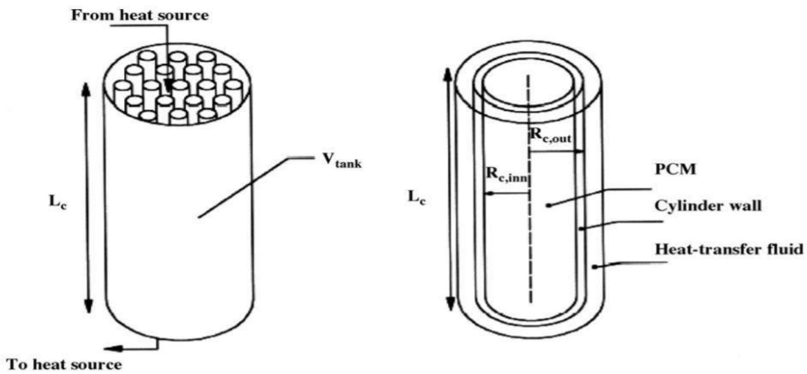

Figure 3.2 PCM storage system in heat transfer fluids

These pipes were surrounded by heat transport fluid. Bajnoczy*etal.* studied the two-grade heat storage system (60-30 8C and 30-20 8C) based on calcium chloride hexahydrate and calcium chloride tetra hydrate. Authors also studied the phenomenon with the various storage capacities during the cycles and possible utilization of a solar energy storage platform for national water-heating system. CaCl26H2O was utilized as phase change material. A comparison is also made with different storage systems made with PCM, Water and stone. Whenever solar energy is available, it is collected and transferred into the power storage tank that is full of 1500 kg encapsulated Phase Change Material (PCM). It consists of a boat packed from the horizontal direction with cylindrical tubes. The power storage material (CaCl26H2O) is within the tubes (the tube container is made up of PVC plastic) and heats transfer fluid (water) flow parallel to them.

A solar collector with storage for water heating having salt hydrate as a phase change material is also studied. The results of parametric studies on the impact of this transition temperature and of the depth coating of the salt- hydrate PCM on the thermal performance of the charging procedure has also been presented. Sharma *et al.*(2004) designed, developed and evaluated the performance of a latent heating device during the day and morning hours, employing a box type solar collector. Paraffin wax (m.p. 54 8C) was used as alatent heating material and also found that the functioning of the latent heatingunit in the machine was quite great to find the warm water at the desirable temperature range. Inside this collector, the absorber plate--container unitplays the role of absorbing the solar energy and saving PCM. The solar energy was saved in paraffin wax, which was used as a PCM, and was discharged to cold water flowing in pipes situated within the wax. The collector's effective area was assumed to be 1 m2 and its total volume was divided into five businesses.

The experimental device was developed to simulate among thecollector's industries, with an apparatus-absorber effective place of 0.2 m^2. Outdoor experiments were carried out to demonstrate the applicability ofutilizing a streamlined solar collector for water heatingsystem. The time-wise temperatures of this PCM were recorded through the procedures of charging and discharging. The solar intensity was recorded throughout the charging process. Experiments were conducted for various water flow rates of 8.3-- 21.7 kg/h. The impact of this water flow speed on the helpful heat gain was analyzed. The heat transfer coefficients were computed for the charging process. The propagation of this melting and freezing front was also studied during the charging and discharging procedures. The experimental results showed that during the charging process, the average heat transfer coefficient increases sharply with the increase in the molten layer thickness. During the discharge process, the useful heat gain was found to rise with the increase in the water mass flow rate.

Cabeza *et al.*(2006) assembled solar pilot plant at the University of Lleida to test the PCMbehavior in actual conditions, which could work continuously with a solar system, or could also work with an electric heater. The PCM module geometry adopted uses several cylinders at the top of the water tank. Several experiments with two, four and six PCM modules were carried out in the real installation. A granular PCM graphite chemical of roughly 90 vol. % of sodium acetate trihydrate and 10 vol. Percent graphite was selected as the PCM for the experiments presented here. Writer concluded that the addition of a PCM module in water tanks is a reallypromising technology. It might allow to have warm water for longer periodsof time even without outside energy supply, or to utilize smaller tanks for the identical function.

Suat *et al.*(2007) introduced a traditional open-loop passive solar water-heating system with sodium thiosulfate pentahydrate as phase change material (PCM). Experimental investigations were made. A comparative study in terms of enhancement in solar thermal energy functioning is made with the conventional system with no PCM. Heat storage functions of the exact same solar water-heating system with other salt hydrates PCMs like zinc nitrate hexahydrate, disodium hydrogen phosphate dodecahydrate, calcium chloride hexahydrate and sodium sulfatedecahydrate (Glauber's salt) were analyzed theoretically using meteorological data and thermo physical properties of PCMs with few assumptions. It was observed that the storage period of hot water, the generated hot water mass and complete heat accumulated in the solar waterheating system with the heating storage tank blended with PCM were roughly 2.59 to 3.45 days of that at the traditional solar water-heating system. It was also revealed that the hydrated salts of the highest solar thermal energy storage functionality in PCMs used in theoretical evaluation were disodium hydrogen phosphate dodecahydrate and sodium sulfatedecahydrate, they are depicted in Figure 3.3.

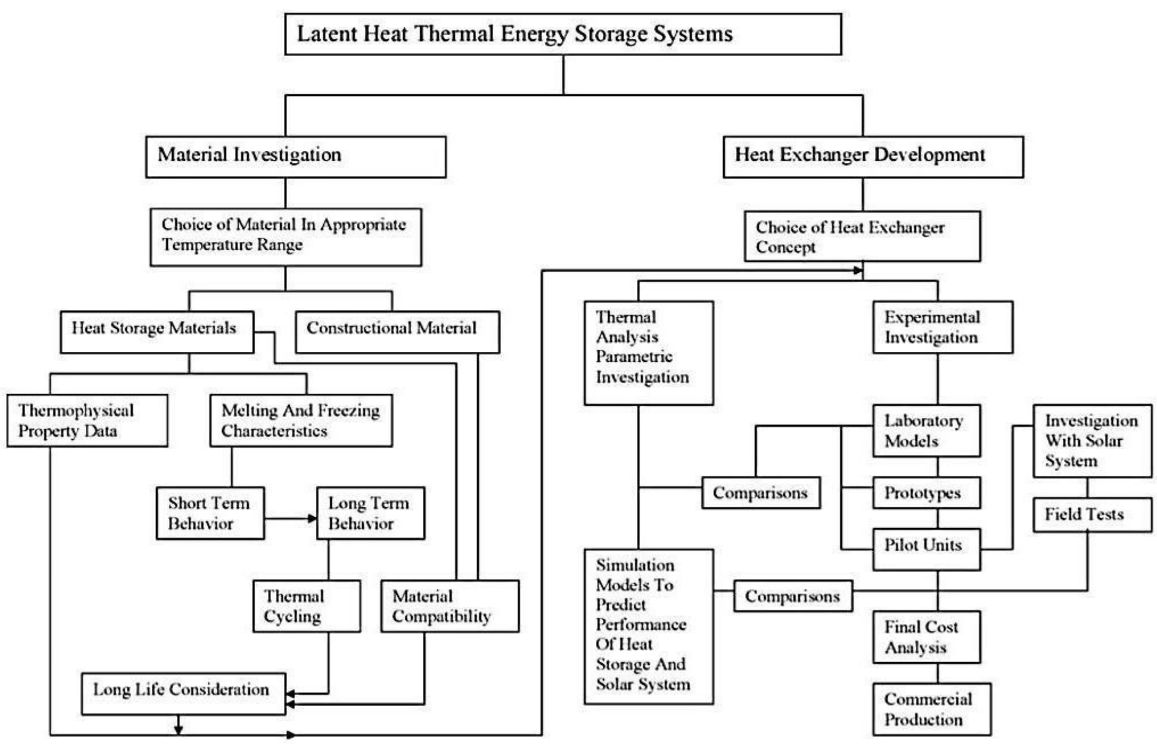

Figure 3.3 Latent heat storage system

C. *Numerical Modeling*

The problem of forecasting the behaviour of phase-change systems is difficult due to its inherent non-linear nature at transferring interfaces, for which displacement rate is controlled by the latent to maintain a reasonable representation of the physiological processes which is a part of the melting process.Version grid density must be large enough to smoothly cover the sound liquid port. But this high density is not required elsewhere in thenumerical modeling. Therefore, it is natural to accommodate the grid to the local physical conditions to improve the computational efficiency. There aretwo major approaches used to get this done.

One uses a local mesh refinement method, i.e. h-method.In this case, the model begins with a uniform grid and, at every iteration, grid points are added or removed to match the required accuracy. This is the most commonly used commercial method. The most important trouble with this process is to maintain the structures, since the topology and the amount of grid points will be changing at each step. To prevent this issue, the r-method(r stand for relocation), also known as the moving mesh method, starts with a uniform mesh and then moves the mesh points, keeping the net topology and amount of mesh points fixed since the solution evolves. Grid deformation is usually done by monitoring a rapid variation ofeither the solution or one of its higher order derivatives. This technique was used with phase-change problems as described in Lacroix&Voller(2001). They performed a study which compares the methods for simulation of a phase-change version in a rectangular cavity. They concluded that the grid must be finer for a substance with an exceptional melting temperature while the limiting factor in moving mesh is the need to use a coordinate generator during every time of increment. Comparison between moving and fixed grid is carried out by Viswanath(2002) and Bertrand *et al.* (2003).

Ithas also been discovered that front-tracking methods are better adapted to the problem than the fixed-grid procedures. The fronttrackingapproaches would nevertheless fail to simulate scenarios where the transition from the liquid into the solid phase is not a macroscopic surface, and enthalpymethods are to be utilized in many solidification issues where a solid--liquid interfacial region exists between both stages.

D. *Mathematical Modeling*

In the adopted design, renewable energy is exchanged between the HTF and the PCM through either the HPs or the HTF tube wall. Consequently, there will be a region of solidification related to each path. A numerical model was created to simulate the pure conduction heat transport processes related to those 2 regions of solidification where every area isconsidered independent of other. The calculation is terminated if these two regions merge. The control volume system depending upon the effective heat capacity method was used to address the energy equation for the solid PCM, the liquid PCM, the mushy zone, and the fin regions as a single domain. The thermal resistances related to the HTF tube and the HPs were integrated into the boundary states of the PCM domain.

E. *Experimental Design*

The fins are stored vertical so as to never dampen the natural convection currents that occurs throughout the charging process, whereas the HPs are kept horizontal in order to move the identical heat during the charging and discharging procedures. Figure 3.4 displays the suggested design. A unit variation cell of span within this fresh heat enhancement designof an LHTES unit, the HTF stations aren't penetrated by any HP that differs inthe design introduced by Shabgard *et al.* (2010). Studding HPs to HTFstations is complicated in manufacture and possesses risks of structural failure(leakage) due to persistent heating and cooling system under acute illness. To prevent such unwanted risks, the suggested heat enhancement procedure is to put HPs in suspension structures.

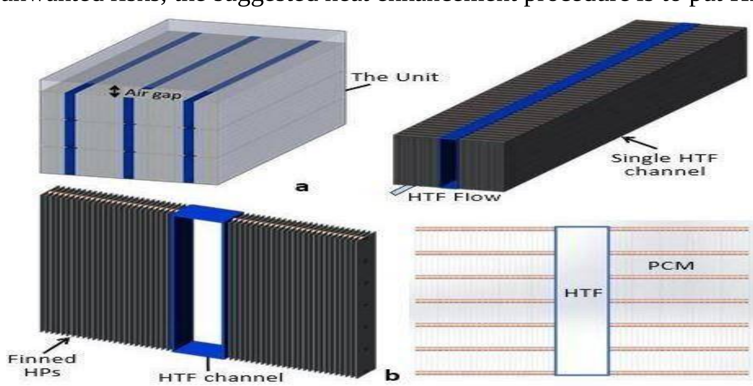

Figure 3.4 Latent heat storage in Fin flow radiator

IV. COMPUTATIONAL FLUID DYNAMICS ANALYSIS

The manufacturers of automobiles especially energy efficient cars needs a thorough optimization process in designing the engine parts in specific the radiators. Radiators are set up in automobiles to eliminate heat from the under hood which include engine cooling and heat removal through air-conditioning procedure. Using higher output with closely packed beneath hood packaging, the accession of new emission control elements and the need for aerodynamic front end styling using thinner openings are diminishing the space available for flow of under-hood cooling air.

These circumstances demand a better understanding of the complex cooling fluid flow characteristics and consequent thermal performance of the radiator. About 30% of the renewable energy generated due to combustion of fuel is dissipated into the coolant that circulates from the engine-cooling coat. The hot coolant coming from engine cooling coat is to be chilled in a radiator and then circulated in the coat. In an automobile, energy dissipated from the motor is not properly used but lost to the air. The engine performance, safety and engine life is very much dependent on the effective engine cooling. CFD Analysis of the radiator for a whole is seldom reported in the literature.However, the technical details regarding fin-tube heat exchangers are available in bits and pieces since individual analysis are carried out unnaturally or numerically.

Hilde Van Der Vyer *et al.* (2001) conducted a CFD simulation of 3 dimensional tube-in-tube heat exchanger utilizing Star-CD CFD software and made a validation test together with the experimental work. The writers were fairly powerful to simulate the heat transfer characteristics of the tube-in-tube heat exchanger. Though this work isn't directly related to the proposed analysis, this was used as the base for the procedures of CFD code identification of a heat exchanger.

Witry*et al.*(2012) carried out CFD investigation of fluid flow and heat transfer in patterned roll bonded aluminum radiator, where FLUENT's segregated implicit 3-D constant jelqing with incompressible heat transport can be used as the tool. In this analysis, unwanted airflow pattern and tube side water leak pattern are studied. The writers presented the variant of overall heat transfer coefficients across the radiator ranging from 75 to 560 W/m^2-K. This study established the capability of FLUENT code to handle such issues. Chen *et al.* (2013) made an experimental evaluation of the heat transfer characteristics of a tube-and-fin radiator in vehicles using an experimental optimization design technique on a wind tunnel test rig of the radiator.

The authors have developed the regression equations of heat dissipation rate and air pressure fall. The impacts of the air speed, inlet coolant temperature and volume flow rate of coolant on heating dissipation speed, coolant pressure drop and air pressure drop have been discussed in detail by means of the numerical investigations. The results printed in this paper provide a basis for the theoretical analysis of heating performances and structural refinement of this tube-and-fin radiator.

Coupling of CFD and shape optimization for brand new design, a paper by Sridhar Maddipatla, forms the benchmark for the present work. This paper presents a system to design auto radiator by coupling CFD with a shape optimization algorithm onto a simplified 2D version. It comprises automated mesh generation using Gambit, CFD analysis using Fluent and an in-house C- code implementing a numerical shape optimization algorithm is also been discussed. The entire leak simulations reported in this paper was conducted using the classical simple algorithm with a k-ε tumultuous version and second order upwind scheme. The analysis is aimed to examine the fluid flow characteristics in a commercially available radiator and understand the flow phenomenon to establish much better layout. It entails calculating the total pressure drop and mass flow rate distribution of the coolant and air in and around the only tube arrangement of an automotive radiator. The fluid flow simulator is conducted using commercial software FLUENT.

A. *Simulation Design Experimentation*

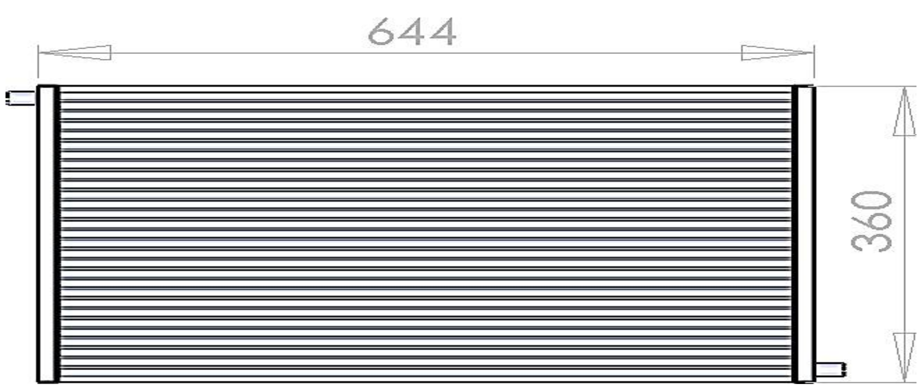

Figure 4.1 Radiator model in full dimensions (Solidworks)

The Numerical experimentation of the work carried out includes reverse engineering of a commercial automotive radiator to the essential liquid domain, discretizing the fluid domain, simulation of the fluid flow and heat transport at steady state and post processing the results and drawing appropriate conclusions. The radiator of a commercially present vehicle is selected for the research to bring from the practicality into the study.

The specifics of the geometry of the radiator had been obtained by the process of reverse engineering.

Due to the structural and complexity and functioning requirement variability of the radiator, it is extremely hard to analyze its heat performance correctly by means of experimentally research.

Table 4.1 Velocity Validation Analysis Car

S. No.	Velocity of Car Kmph	Velocity of Car m/s	Engine Temperature Tube Side Inlet	Tube Side Outlet Temperature (Experimental)	Shell Side inlet Temperature	Shell Side Outlet temperature (Expert mental)
1	30	8.333333333	95	87.12	35	60.52
2	40	11.11111111	95	86.92	35	62.15
3	50	13.88888889	95	86.52	35	63.52
4	60	16.66666667	95	86.14	35	63.89
5	70	19.4444444	95	85.95	35	64.52
6	80	22.22222222	95	85.14	35	65.27
7	90	25	95	84.96	35	66.29
8	100	27.77777778	95	84.52	35	68.26

So, the existing research about the warmth performance of radiatorswas mainly focused on experimental studies in recent years.In this research, experiments were carried out by using engine capacity of 1.5L for Proton Wira (4 cylinders) for evaluating the working performance of different varieties of radiator (capacity for 1.5 L) which are used for passenger automobiles. Figure 6.1 show the schematics of engine radiator performance evaluation and its detector arrangement.

B. Generating The Model

Introduction to Solid Works

Most of advanced features, such as extrusions, sweeps, cuts, holes, slots can be used to produce a part in the conceptual sketch through strong feature-based modeling, in addition to constructing and modifying parts through direct and intuitive graphical manipulation. Basic entities, and dimension and constrain can be employed in the geometry. The initial part of the modeling is to design a 2Dconceptual layout, create precise geometry followed by other rounds.

Finally, Part Modeling Help supplies procedures for modifying part in and procedures that are to be known before building a component. Part Modeling Help introduces one to the terminology, basic design concepts, one can learn how to construct a 3D parametric component out of a 2D sketch.

C. Three-Dimensional Modeling

It is observed that modeling the water flow in various cross sections and researching it would surely be a basis for non-uniform flow analysis. Solid works Component enables to design versions as solids in an innovative three-dimensional solid modeling environment. Strong models are geometric models that provide properties like volume, surface area, and inertia.

Solid works provides a progressive environment in which models can be created and altered through graphical manipulations. The design process of the project is pushed by selecting an item (geometry) and then choosing a tool to apply on the object. This object-action work flow provides increased control over the design of the models while allowing expressing the creativity of the designer.

The user interface Offers support for this design process The Strongworks innovative modeling environment streamlines the design process to concentrate on product development and push the designs to new levels of imagination. The context sensitive user interface guides throughout the designprocess.

Once you choose an item and an act, Solid works interprets the present modeling context and presents requirements and optional items to finish the task. This information is shown in a non obtrusive user interface known as the dashboard which enhances the capacity to directly work with the models by assessing the activities and guide throughout the design process.

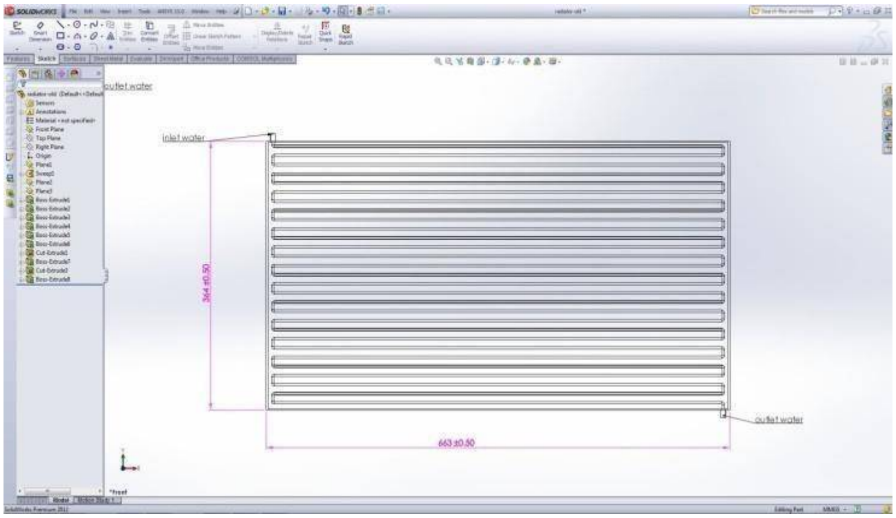

Figure 4.2 Internal and external heated pipe without PCM model

D. Importing The Datas Into Ansys Work BenchProcedure

When the analysis process is completed the data is stored in the work bench. Then it may be looked at in ansys workbench product launcher as a URL to ansys product launcher. Thus the result can be generated in the overall post chip using the ansys product launcher. Within this instant, the size of the true part model has been quantified to design a modeling approach that the related journal from the drawings utilizing off line eproces. Using thisprocedure, the actual part model can be imported in CAD modeling as *.prt file. Hence the imported *.prt document can be viewed by the modeling program i.e solid works variant 2018. We can generate the plot outcome, result fluid and summarize the thermal pressure values, radiator heated pipe analysis and hence the heat transfer values can easily be assigned. Hence the water flow heat stress canbe calculated. Finally the calculated output signal results from ansys workbench can be contrasted with the three dimensional discretization model done using FEA.

In strong functions, the 3D dimension of this imported part model has been converted to *.parasolid file. Now we can have the ability to set the actual dimension, appearances for the converted design file. After setting the need data in solid works, the file could be flashed to the investigation software i.e., ANSYS WORKBENCH. This component model may be imported into ansys as .IGES document with the intention of analyzing using works. Thus the IGES file was erased in ansys work bench.

E. Discretization of The Fluid Domain

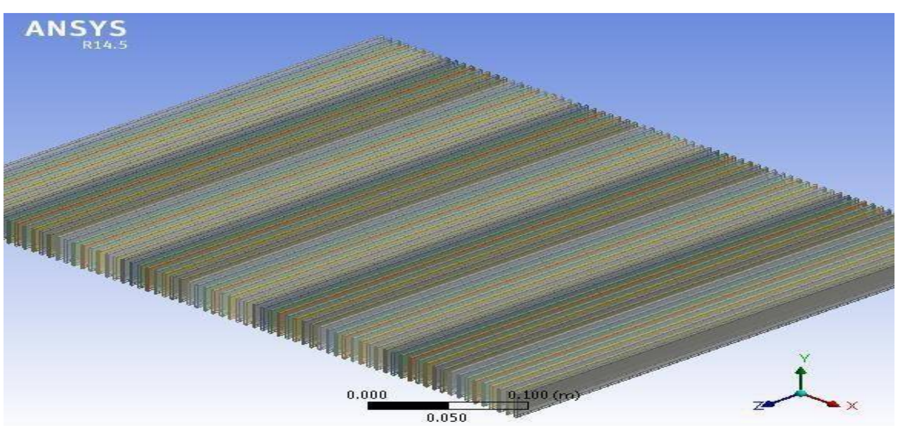

Figure 4.3Radiator with modeling analysis used in CFD

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The input and boundary conditions are selected from the analysis of Changhua Lin and Jeffrey Saunders, in which the effect of varied air and coolant inlet Temperatures on the particular dissipation are discussed. The air compressor speed (Vai) is preferred to be 4.4m/s atmosphere at ambient temperatures. With reference to the specifications of this coolant pump utilized for the chosen vehicle, coolant inlet speed (Vci) is 0.0063 kg/s in each tube. The properties of blood and air were characterized for regular conditionsand kept constant during the analysis.

The segregated solver has been used for incompressible and mildly compressible flows by most investigators and has been shown to depictresults with better precision. It solves the energy and flow equations.

The continuity, energy and momentum equations (equations not revealed in this work for their generality) of fluid flow are resolved in the process of obtaining temperature profiles.

The segregated approach solves for a single variable field (e.g., pressure, p) by contemplating all cells precisely at the exact same time. It thensolves the coming variable field by considering all cells at precisely the exact same time, and so on. This strategy is well documented in literature and commonly adopted by the scientists in complicated problems like conjugate heat transfer coped in this work.

Robustness, economy, and reasonable precision for a broad range of turbulent flows and heat transfer simulations are the reasons for choosing this particular model. The geometric similarity between the rows of tube and fin helps us in restricting the computational domain to one tube and adjacent fin arrangement as shown in Figure 6.3.

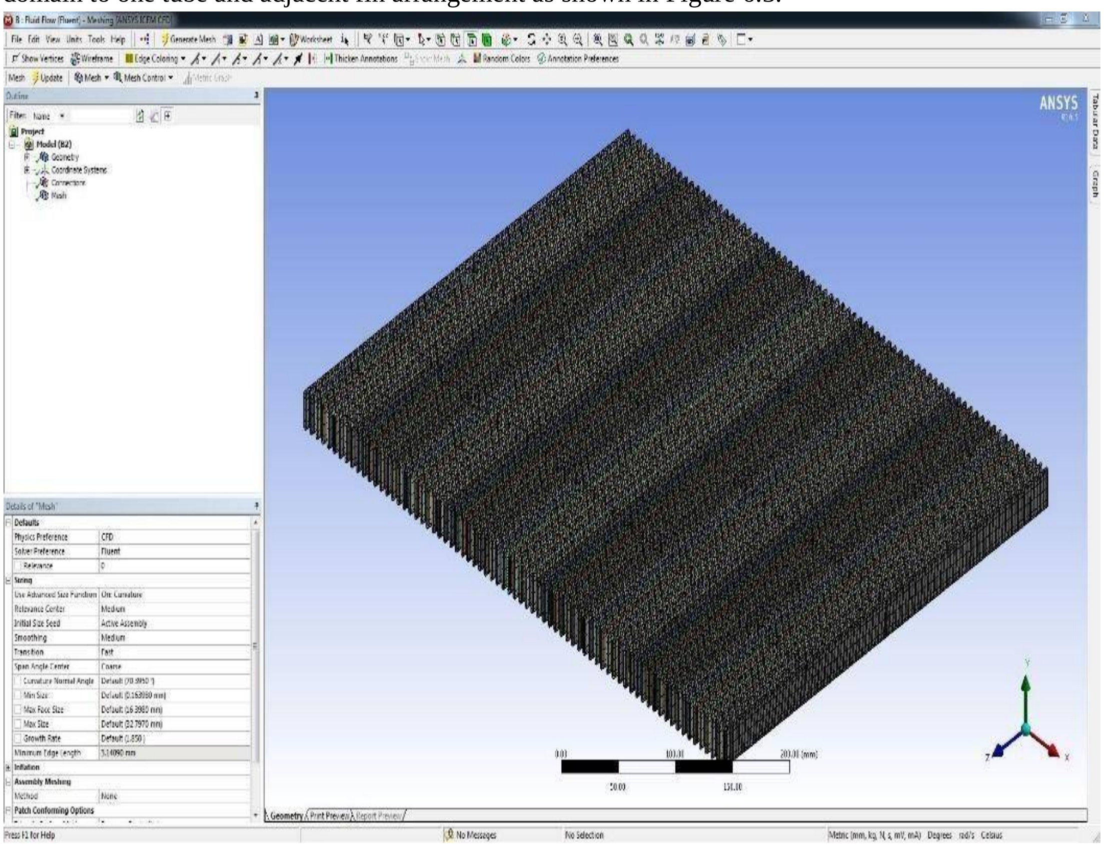

Figure 4.4 Discretization model –CFD

Therefore, the liquid domain is created for a single fin and tube assembly and numerical analysis is performed. The fluid domain includes the airflow quantity and the blood flow quantity.

The problem is solved as a conjugate heat transfer requiring the depth of the tube and fin must also be mimicked. The surfaces from the air realm, coolant domain, tube thickness and fin depth are discretized withvarying mesh density in accordance to the physics of fluid flow and heat transport.

Denser net size is used at significant volumes in the fluid flow and heat transport domain. The grid liberty study of this simulation is carried out to arrive at the minimum number of components required to keep the essential stability and accuracy in the computation. The finalized element count and theassociated aspects are listed.

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The meshed geometry for a single tube and fin is subsequently extended to the entire 32 fin assembly of the radiator as shown in Figure 6.4. The physics of conjugate heat transfer in radiator is simplified with the following technically valid assumptions.

1) Fluid flow speed is uniformly distributed through the core inevery pass on every fluid side. No flow leakages happen in any flow. The flow condition is characterized by the bulk speed at any cross section.
2) No phase change occurs in fluid streams.
3) Properties of the fluids and the wall, such as specific heat, thermal conductivity, and density are just determined by temperature.
4) Velocity and temperature in the entry of the radiator center for air and coolant is uniform.
5) No inner source is present for thermal-energy generation

V. RESULTS AND DISCUSSION

A. Computational Fluid Dynamics Discussion

The simulation results obtained reveal reasonable variation in the temperature and pressure as depicted in the Figure 7.6. A fall in temperature of the coolant from 371.6 K into 365.6 K and a rise in the temperature of the air from 301.1 K to 310.6 K are observed in those plots. The effectivenessof the heat exchanger is calculated to be 80%. The fall in the strain is 52.3Pa.

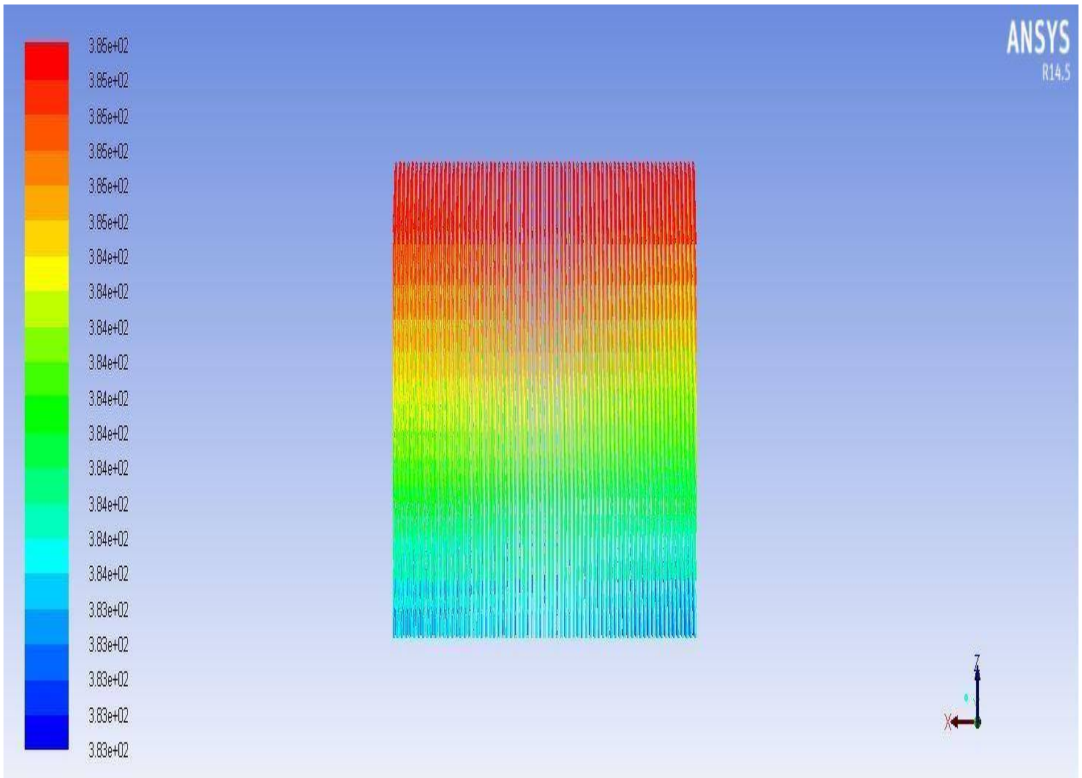

Figure 5.1 Computational fluid dynamic systems in RHT-TEG withPCM model

The energy transfer unit weight from the coolant domain is 303.6449 kJ/kg and of atmosphere is 37.1 kJ/kg signaling the compactness of this heat exchanger. This is an indirect indicator of slow response of the radiator at the initial phases of the fin. This suggests the need for a deeper study in this region from the direction of enhancing the initial thermal slackness.

This trend is likely in any usual radiator performance. The pressure contours of atmosphere and coolant along their instructions of circulation that of the atmosphere across the path of airflow and temperature contours of coolant and air together their directions of flow add to the data base comprehension towards a greater design of radiator.

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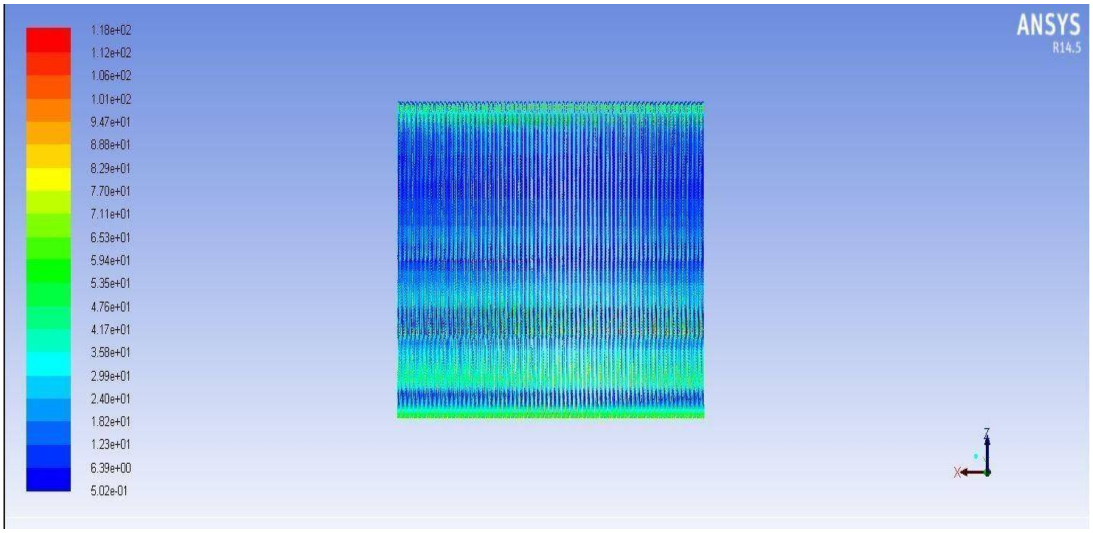

Figure 5.2 Computational fluid dynamic systems in RHT-TEG withoutPCM model

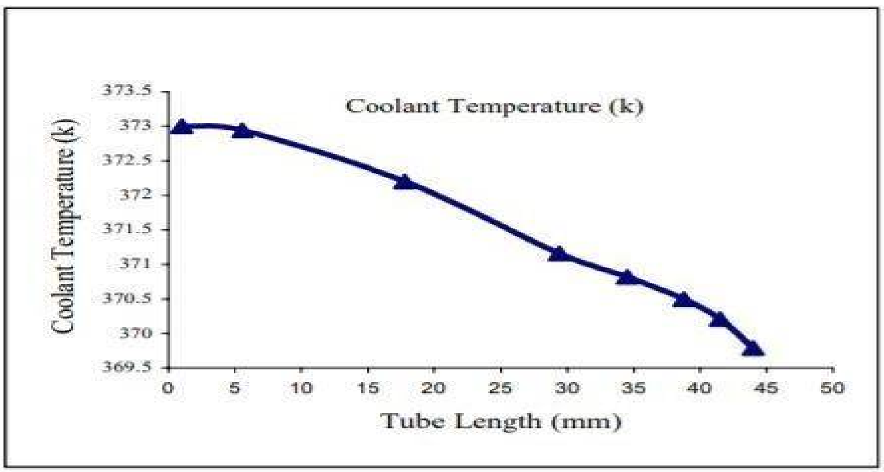

Figure 5.3 Coolant temperature Vs Tube conduction length

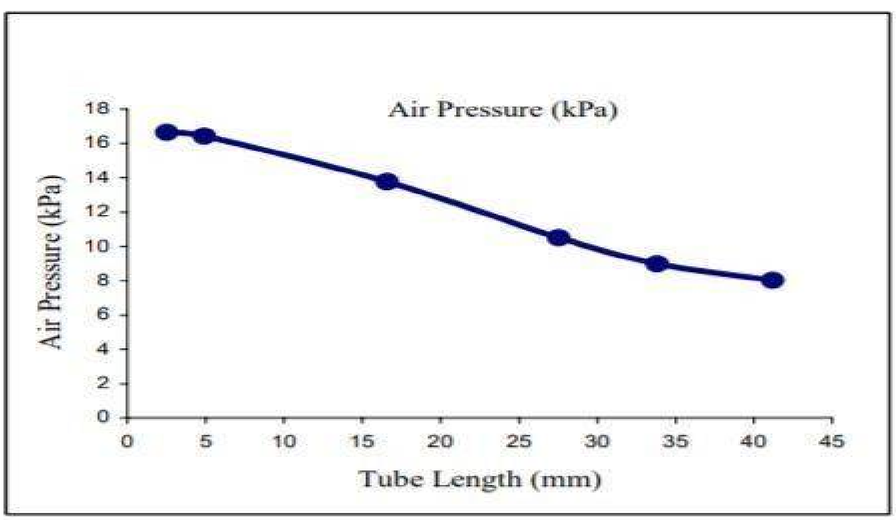

Figure 5.4 Air pressure Vs Tube conduction length

The radiator's functioning is usually expressed in terms of effectiveness and compactness. Effectiveness is the measure of heat transport speed of the system, given by ε = (actual heat transfer)/(maximum heat transport potential), The effectiveness of this system is regarded as 81% from the computational analysis, which reflects the average performance of the radiator as a heat exchanger. Compactness of the machine is the energy transport that happens per unit weight. The following figure represents the effectiveness.

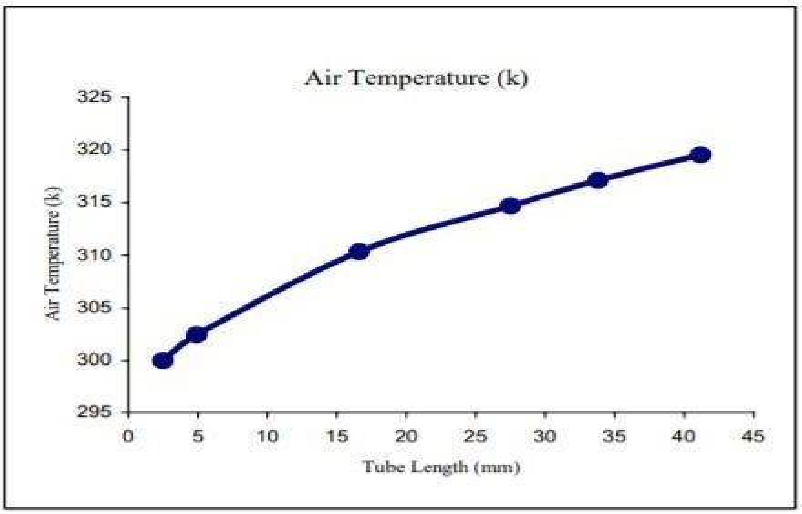

Figure 5.5 Air temperature Vs Tube conduction length

The effective thermal conductivities of several samples of RHP- TEG with PCM mixtures were measured. Especially, mixtures containing 1%,2% and 3% in quantity of RHP were used. Nine embedded thermocouples were used to assess the temperature profile of each sample in addition to the temperatures of the water inlet and outlet, the warm plate along with the cold plate. When stable conditions were achieved, the temperature drop, ΔT, across the MHP- PCM mixture was recorded. Since the apparatus was well insulated, one-dimensional heat conduction throughout the RHP-PCM with- out mixture can be assumed. Therefore, the complete heat transfer rate through each sample was assumed to be equal to the electric power drawn by the electrical heater cartridges, Where ―W‖ is the electrical power provided to the hot plate, a is the distance between any two thermocouples, ΔT is the temperature drop across the length a, and also A is the cross section area.
The geometry along with the input of the model was amended in accordance with the PCM and the HPs clarified in. Figure 7.11 shows the experimental measurements and the numerical forecasts. The numerical predictions are a bit greater compared to experimental measurements, which might have resulted from the thermal contact resistance between the PCM andthe HPs not being quantified in the present version. However, the numerical predictions are comparable with the experimental measurements.

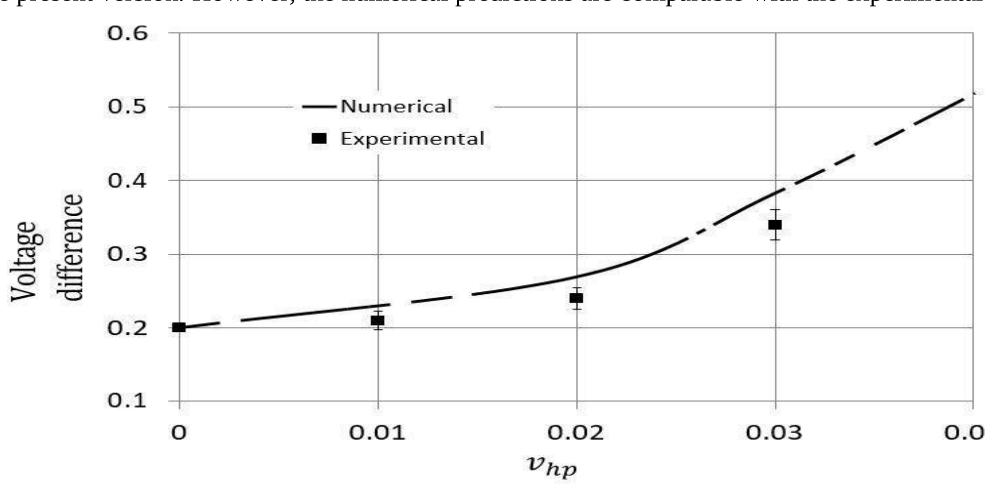

Figure 5.6 Comparison – Voltage difference Numerical Vs experimental

B. Summary

The fluid flow and heat transfer analysis of one tube-fin arrangement of an automotive radiator has been successfully performed using numerical simulation built with commercial software FLUENT. The variations in the pressure, temperature and speed in the direction of coolant flow and airflow are presented and analyzed.

The air that absorbs the heat as a result of forced convection increases with the increase in temperature by 9.5 K. The study forms a foundation for its fluid flow analysis of an automotive radiator. Together with the computational time and resources available, the results obtained were found to be satisfactory. But a continuing study in a variety of facets towardsa better layout of the radiator is suggested as shown below.

1) Optimizing the worth of the flow rates and also the measurements of the radiator for a given power rating of the automobile, by generating CFD codes.
2) To account for the version of the inlet conditions with time as in technical instances, transient analysis can be done.

VI. CONCLUSION AND FUTURE SCOPE

A. Conclusion

This research study investigates a new way of recovering waste heat out of car radiator and power utilizing an internal combustion unit blend of radiator heating pipes and thermoelectric generators (RHP-TEG). The RHP-TEG system is made up of Bismuth Telluride (Bi_2Te_3) based thermoelectric generators (TEGs), which can be sandwiched between 2 air cooled radiator heating pipes to accomplish a temperature gradient throughoutthe TEG to get thermoelectricity generation.

This system is unique as it may simultaneously recover waste heat and create electricity utilizing a completely passive method with no moving components in auto systems. A detail manufacturing model was created to offer a preliminary performance quote for this system before beginning more thorough laboratory work.

The analytic model was derived with the energy balance equation along with the thermal resistance procedure. It was discovered from the experiment that the thermal resistance of this TEG diverse with all the heat input. The TEG thermal resistance revealed a little change (standard deviationof 0.03°C/W) using the rising heat input on the heating ion assortment of 120 W. As an average, a normal value of 0.8 °C/W has been considered inthis study. It was also discovered that the TEG thermal-to-electric energy conversion efficiency increased with increasing temperature gradientthroughout the TEG.

The parameters gathered for this experiment were used from the theoretical design to ascertain the optimum configurations of this potential full-scale RHPTEG system. The simulation results of this theoretical model have revealed that the electrical and thermal operation of the RHP-TEGsystem diminished with increasing mass flow.

The simulation results indicated that the optimal mass flow rate should be roughly 0.03 kg/s (or air face velocity of 0.9 m/s) for generating themost electrical and thermal operation of the system. It was noticed in the simulation effect that decreasing the mass flow rate less than 0.03 kg/s can create the temperature of the RHP-TEG to rise within the TEG temperature limit of 125°C.

Additionally, a rise in the amount of radiator leak heating pipe row installed into the machine could raise the quantity of heat transfer speed and the electric power output. Based on these outcomes, it had been proposed that the potential full-scale RHP-TEG system ought to be set up with concurrent flows of their RHP-TEG modules. Under those thermal conditions, the theoretical model predicted that the RHP-TEG method could possibly create approximately 10 W of electric power and the speed of heat recovery could be 1.6 kW utilizing 2 kW of heating energy input. The experimental information obtained from this testing has been utilized to confirm the theoretical model. The simple notion of theexperimental rig consisted of a TEG connection between two heating pipes that they function as an evaporator (heating pipe 1-outlet) and a condenser (heat pipe two inlet). These procedures made a temperature gradient throughout the TEG and create power. The system configuration has been anticipated to grow the recovery ratio of waste heating since the warmth discharged from the condenser preheats the incoming air and thus raises the warmth of air flow within the evaporator. In the true experimentation, eight rows of those HP-TEG modules were set up between those ducts.

The modules were organized in series to the management of air flow. A 120 millimeter gap split each module. On account of this high temperature increase across the TEG temperature limitation, the cheapest air face velocity was confined to 1.1 m/s. The temperature limitation of the TEG was put from the producer at 125°C. During this limitation, the solder substance of this TEG could be ruined with potential loss of functionality. It was discovered from the experimental results that the heat transfer speed of this RHP-TEG system decreased with a rise of air flow speed. The decrease in the heat transport rate happened due to the fall of the temperature gradient between the warm and the cold ducts. This deviation was imputed to the heat reduction though the machine wall in the real experiments.

For the theoretical design, heat reduction didn't happen because the walls have been considered adiabatic. The heat recovery operation of the RHP-TEG system has been evaluated by the radiator efficacy. It has been revealed that the potency of the system rose from 28 percent to 37 percent when the air flow has been diminished to the minimum speed moderatedriving conditions. In a minimal air face velocity, the temperature difference between the warm and the cold atmosphere improved, leading to the gain of the system efficacy. Like the speed of heat transport instance, the energy output rose when the air flow speed was decreased to the bottom air mill atmosphere.

The maximum electric power generated was roughly 7 W. Experiments on the projected system have shown the use of entirely passive devices (heat pipes and TEGs) for heat recovery and electricity production is an efficient way of reusing waste energy.

This is only because it provides many benefits when compared to the concurrent flow heat settings. A counter flow setup of a RHP-TEG was also designed to replicate the functional situation of this heat exchanger in business. The counter flow heat exchanger of this RHP-TEG has two differentair ducts. Both of these ducts were thermally linked utilizing the RHPTEG modules. The condenser part of these RHP-TEG modules was set up in the cold duct that transported cold air in the environment. The evaporator part of this RHP-TEG was put from the hot duct that carried hot atmosphere. Air example supplied fresh air to the duct and has been installed in the entry of every duct. The ambient air entering the hot duct was warmed with a 2 kW electric heater prior to flowing through the evaporator part of this RHP-TEG.

A theoretical model was developed to forecast the operation of the counter-flow system. This version also managed to predict the electrical and thermal performance output of this RHP-TEG such as the speed of heattransport, the efficacy of the heat exchanger and the energy output. To rate thesystem, the consequence of altering the air face velocity of the chilly side,was analyzed in this experiment. By comparison, the air face velocity of the other hand, *h* was reduced at 1.1 m/s and has been kept at the level for the whole experiment.

The potency of the counter circulation RHP-TEG improved with increasing. The efficacy increased due to the growth of the temperature gap ofatmosphere in the hot side. The heat recovery speed of this counter circulationRHP-TEG also increased with increasing.

The gap was 4.5%. On the other hand, the theoretical model called a greater power output than quantified with a deviation less than 26 percent.

The experimental electricity output was less when compared to the theoretical outcome due to the heat reduction which occurred through the heattransfer procedure. The heat reduction reduced the popular of their TEGsurfaces and diminished the thermal-to-electric conversion efficacy. It may bereasoned that the efficacy of the counter circulation RHP-TEG heat exchangerand its own power performance improved with increasing air speed which reverses with all the Utype RHP-TEG heat exchanger.

The U-type RHP-TEG heat exchanger operation was better when working at low air speed. The flue gas in 270°C from the chief oven has been recovered to be used in a proving procedure. The recovered energy warmed incoming air to 38°C until it entered the toaster. The analysis was conducted by implementing the real data to the theoretical version of this RHPTEG.

The functioning of the RHP-TEG system at the bakery was optimized by changing several input factors. The best configuration of these input parameters such as the amount of heating pipes, the amount of warmth pipe/rows and the amount of thermoelectric units/row has been researched. The bakery heat recovery method has been discovered to offer optimumperformance as it utilized 2 rows of RHP-TEG modules. Each row of this RHP-TEG consisted of two heat pipes in both condenser and evaporation sections.

B. *Future Scope*

1) Future research would focus on the promising RHP-TEG using PCM configurations investigated in this research. In other words, using different fin substances may lead to more improvements beyond the results reported in this research; for example the fins can be made of graphite transparency that offers high thermal conductivity, low density and decent corrosion resistance against nitrate and nitrite salts. Furthermore, extending the study to distinct RHP-TEG usingPCM working fluids, PCMs and wall materials, maydiminish. In addition, quantifying the importance of the fins as well as the effects of the convection currents during melting are justified.
2) The numerical models developed in this work may be extended to estimate the ramifications of PCM volume shift during freezing and melting cycles. In addition, and if more time and funding needed was allowed, a prototype RHP- TEG unit could have aided the research, also provided valuable real information on the thermal performance ofsuch units under repetitive melting and freezing cycles.
3) The proposed RHP-TEG units were sized based on a preliminary optimization. Thus, a comprehensive optimization strategy to fortify the sustainable performance of these units is highly recommended, and it will be the topicof future study.

4) An investigation on the possible benefits of using the proposed heating technique in other engineering programs ishighly recommended, and it'll be the topic of future research.
5) On the other hand, the purchase price of the proposed RHPs is anticipated to be relatively high as new technology are often initially very expensive, but the costs tend to diminish considerably when these technology become completely established.

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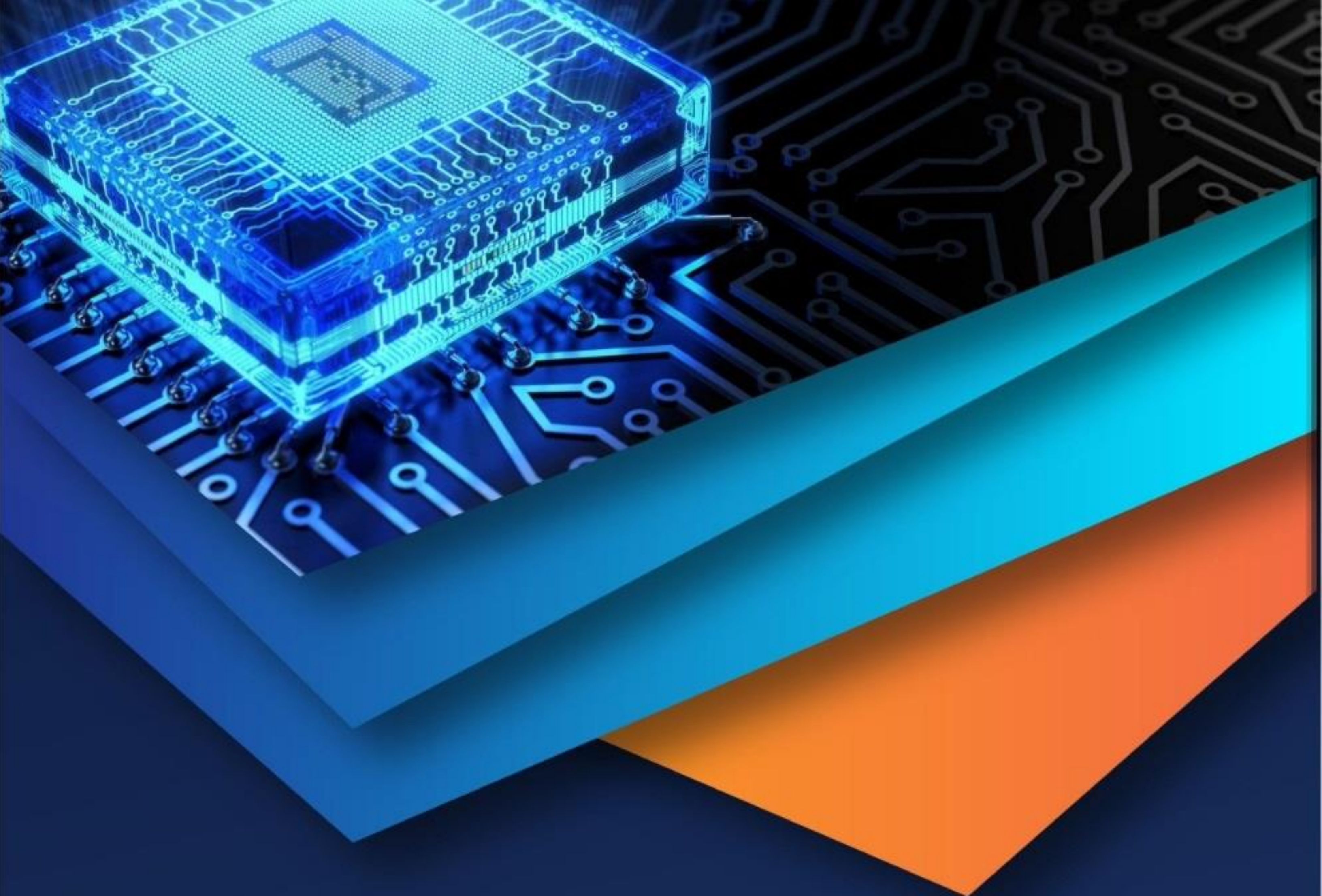

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