

# Heat Transfer Enhancement of Water Cooled Chiller by using Nanofluid

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**Abstract** - Today's technology requires high performance device to save energy. Majority applications use water as a base fluid which has limitations to transfer heat from one medium to another. Introducing suspending nano particles (Nano fluids) in the heat transfer fluids such as water, oil, diesel, ethylene glycol etc. is emerging technology. Recent research work shows that Nano fluids have higher thermal conductivities compared to the base fluids. Aim of this review is to summarize the recent developments in research on the stability of Nano fluids, improvement of thermal conductivity and viscosity of nano fluid suspension.

**Key Words:** Nanoparticles, Properties, heat transfer enhancement, Heat exchanger...

## 1. INTRODUCTION

Traditional heat transfer fluids, such as water, oil, and ethylene glycol mixture are inherently poor heat transfer rate. There is a strong need to develop advanced heat transfer fluids, with significantly higher thermal conductivities and improved heat transfer characteristics than are presently available. Despite considerable previous research and development focusing on industrial heat transfer requirements, major improvements in heat transfer capabilities have been held back because of a fundamental limit in the thermal conductivity of conventional fluids.

It is well known that metals in solid form have thermal conductivities that are higher than those of fluids by orders of magnitude. For example, the thermal conductivity of copper at room temperature is about 700 times greater than that of water and about 3000 times greater than that of engine oil. Even oxides such as alumina (Al<sub>2</sub>O<sub>3</sub>), which are good thermal insulators compared to metals such as copper, have thermal conductivities more than an order-of-magnitude larger than water. Therefore, fluids containing suspended solid particles are expected to display significantly enhanced thermal conductivities relative to those of conventional heat transfer fluids [13]. In fact, numerous, theoretical and experimental studies of the effective thermal conductivity of suspensions that contain solid particles have been conducted since

Maxwell's theoretical work was published more than 100 years ago (Maxwell, 1881)[1]. However, all of the studies on thermal conductivity of suspensions have been confined to those produced with millimeter or micrometer sized particles. Until now, researchers had no way to prevent solid particles from eventually settling out of suspension. The lack of stability of suspensions that involve coarse-grained particles is undoubtedly a primary reason why fluids with dispersed coarse grained particles have not been previously commercialized.

**Table-1.1:** Thermal Conductivities of Various Solids and Liquids

Material	Form	Thermal conductivity(W/Mk)
Carbon	Nanotube Carbon	1800-6600
	Diamond	2300
	Graphite	110-190
	Fullerene film	0.4
Metallic solids	Silver	420
	Copper	401
	Nickel	237
Non-metallic solids	Aluminous	40
	Sodium at 644k	72.3
Others	Water others	0.613
	Ethylene Glycol	0.253
	Engine oil	0.145

We are on the verge of a new scientific and technological era, the standard of which is the nanometer (billionths of a meter). Initially sustained by progress in miniaturization, this new development has helped form a highly interdisciplinary science and engineering community. Nanotechnology is expected to

have applications in a number of areas, including biotechnology, nano electronic devices, scientific instruments, and transportation. Modern nanotechnology provides great opportunities to process and produce materials with average crystallite sizes below 50 nm. Recognizing an opportunity to apply this emerging nanotechnology to established thermal energy engineering. Argonne has developed the concept of a new class of heat transfer fluids called "Nano fluids," which transfer heat more efficiently than conventional fluids (Choi, 1995)[2]. Nano fluids are engineered by suspending ultrafine metallic or nonmetallic particles of nanometer dimensions in traditional heat transfer fluids such as water, engine oil, and ethylene glycol. Thermal conductivities of various solids and liquids are given in table 1.

## 2. Methodology

Nano fluids are a new class of fluids engineered by dispersing nanometre-sized materials (Nano-particle, Nano-fibres, Nano-tubes, Nano-wires, Nano rods, Nano sheet, or droplets) in base fluids. In other words, Nano fluids are Nano scale colloidal suspensions containing condensed nanomaterial. They are two-phase systems with one phase (solid phase) in another (liquid phase). Nano fluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields.

Adding small particles into a fluid in cooling and heating processes is one of the methods to increase the rate of heat transfer by convection between the fluid and the surface. In the past decade, a new class of fluids called Nano fluids, in which particles of size 1–100 nm with high thermal conductivity are suspended in a conventional heat transfer base fluid, have been developed. It has been shown that Nano fluids containing a small amount of metallic or non-metallic particles, such as Al<sub>2</sub>O<sub>3</sub>, CuO, Cu, SiO<sub>2</sub>, TiO<sub>2</sub>, have increased thermal conductivity compared with the thermal conductivity of the base fluid. In this work, effective thermal conductivity models of Nano fluids are reviewed and comparisons between experimental findings and theoretical predictions are made. The results show that there exist significant discrepancies among the experimental data available and between the experimental findings and the theoretical model predictions [1].

In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to diameter. Coarse particles cover a range between 2,500 and 10,000 nanometres. Fine particles are sized between 100 and 2,500 nanometres. Ultrafine particles, or nanoparticles, are between 1 and 100 nanometres in size. The reason for

this double name of the same object is that, during the 1970-80s, when the first thorough fundamental studies with "nanoparticles" were underway in the USA (by Granqvist and Buhrmann) and Japan, (within an ERATO Project) they were called "ultrafine particles" (UFP). Nanoparticles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials. Although the size of most molecules would fit into the above outline, individual molecules are usually not referred to as nanoparticles.

### 2.1 About Nano fluids

- Nano fluid- solid liquid mixture in which metallic or non-metallic nanoparticles are suspended. The suspended ultrafine particles change transport properties & heat transfer performance.
- Nano fluids are different than conventional solid liquid mixtures which are used for heat transfer mechanisms as they settle rapidly, erode pipelines and cause severe pressure drop.
- Various Nano particles- Al<sub>2</sub>O<sub>3</sub>, CuO, TiO<sub>2</sub>, silica, CNT.

### 2.2 Features of Nano fluids

- Particle Volume Fraction.
- Particle Material- Al<sub>2</sub>O<sub>3</sub> as a nanoparticle shows better enhancement than TiO<sub>2</sub>.
- Particle size- 5 to 100 nm
- Particle shape- cylindrical and spherical.
- Particle material and Base Fluids- water, ethylene glycol, ammonia and engine oil.

### 2.3 Properties of Nanoparticles

Nanoparticles are of great scientific interest as they are, in effect, a bridge between bulk materials and atomic or molecular structures. Thus, the properties of materials change as their size approaches the Nano scale and as the percentage of atoms at the surface of a material becomes significant. For bulk materials larger than one micrometre (or micron), the percentage of atoms at the surface is insignificant in relation to the number of atoms in the bulk of the material. The interesting and sometimes unexpected properties of nanoparticles are therefore largely due to the large surface area of the material, which dominates the contributions made by the small bulk of the material. Nanoparticles often possess unexpected optical properties as they are small enough to confine their electrons and produce quantum effects. For example gold nanoparticles appear deep-red to black in solution. Nanoparticles of yellow gold and grey silicon are red in colour. Gold nanoparticles melt at much lower temperatures (~300 °C for 2.5 nm sizes) than the gold slabs (1064 °C). Absorption of solar radiation is much higher in materials composed of nanoparticles than it is in thin films of continuous sheets of material. In both solar PV and solar thermal applications, controlling the size, shape, and material of the particles, it is possible to control solar absorption. Suspensions of nanoparticles are possible

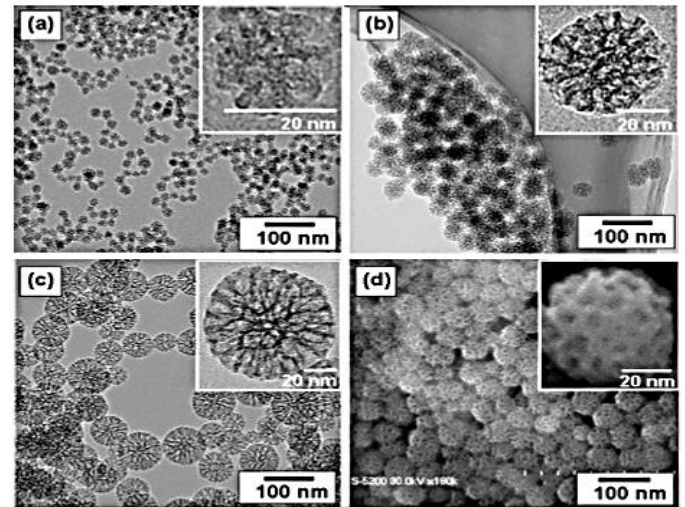
since the interaction of the particle surface with the solvent is strong enough to overcome density differences, which otherwise usually result in a material either sinking or floating in a liquid. The high surface area to volume ratio of nanoparticles provides a tremendous driving force for diffusion, especially at elevated temperatures. In theory, this does not affect the density of the final product, though flow difficulties and the tendency of nanoparticles to agglomerate complicates matters. The presence of titanium dioxide nanoparticles imparts what we call the self-cleaning effect, and, these being Nano-range, the particles cannot be observed. Zinc oxide particles have been found to have superior UV blocking properties compared to its bulk substitute. This is one of the reasons why it is often used in the preparation of sunscreen lotions, and is completely photo stable.

Nanoparticles with one half hydrophilic and the other half hydrophobic are termed Janus particles and are particularly effective for stabilizing emulsions. They can self-assemble at water/oil interfaces and act as solid surfactants. Uncontrolled agglomeration of powders due to attractive van der Waals forces can also give rise to in micro structural inhomogeneities. Differential stresses that develop as a result of non-uniform drying shrinkage are directly related to the rate at which the solvent can be removed, and thus highly dependent upon the distribution of porosity. Such stresses have been associated with a plastic-to-brittle transition in consolidated bodies, and can yield to crack propagation in the unfired body if not relieved. It would, therefore, appear desirable to process a material in such a way that it is physically uniform with regard to the distribution of components and porosity, rather than using particle size distributions that will maximize the green density.

## 2.4 Synthesis of Nanoparticles

There are several methods for creating nanoparticles. In attrition, macro- or micro-scale particles are ground in a ball mill, a planetary ball mill, or other size-reducing mechanism. The resulting particles are air classified to recover nanoparticles. In pyrolysis, a vaporous precursor (liquid or gas) is forced through an orifice at high pressure and burned [4]. The resulting solid (a version of soot) is air classified to recover oxide particles from by-product gases. Traditional pyrolysis often results in aggregates and agglomerates rather than single primary particles. Ultrasonic nozzle spray pyrolysis (USP) on the other hand aids in preventing agglomerates from forming [5].

Inert-gas condensation is frequently used to make nano particles from metals with low melting points. The metal is vaporized in a vacuum chamber and then super cooled with an inert gas stream. The super cooled metal vapour condenses into nanometre-size particles, which can be entrained in the inert gas stream and deposited on a substrate or studied in situ.



**Fig-2.1.** Microscopic Structure of Nanoparticles of Different Sizes

### a) Sol Gel Method

The sol-gel process is a wet-chemical technique (also known as chemical solution deposition) widely used recently in the fields of materials science. Such methods are used primarily for the fabrication of materials (typically a metal oxide) starting from a chemical solution (sol, short for solution), which acts as the precursor for an integrated network (or gel) of either discrete particles or network polymers.

In the case of the colloid, the volume fraction of particles (or particle density) may be so low that a significant amount of fluid may need to be removed initially for the gel like properties to be recognized. This can be accomplished in a number of ways. The simplest method is to allow time for sedimentation to occur, and then pour off the remaining liquid. Centrifugation can also be used to accelerate the process of phase separation. Removal of the remaining liquid (solvent) phase requires a drying process, which is typically accompanied by a significant amount of shrinkage and densification. The rate at which the solvent can be removed is ultimately determined by the distribution of porosity in the gel.

The ultimate microstructure of the final component will clearly be strongly influenced by changes implemented during this phase of processing. Afterward, a thermal treatment, or firing process, is often necessary in order to favour further polycondensation and enhance mechanical properties and structural stability via final sintering, densification, and grain growth. One of the distinct advantages of using this methodology as opposed to the more traditional processing techniques is that densification is often achieved at a much lower temperature.



### b) Polymer Mediated Growth Method

With the advent of nanotechnology, many methods of synthesis of nanoparticles have come into practice and the 'polymer mediated growth' technique is among them. In this route, ions of one of the reactants are allowed to diffuse from an external solution into a polymer matrix where the other reactant is complexes and bound. The exact role of ionic diffusion in the formation of nanoparticles was investigated in the current study by studying the patterns of kinetics of nanoparticle formation using UV via spectroscopy. Through this knowledge we optimized these parameters to obtain particles as small as 20 nm and confirmed that this technique can be used to control the size of nanoparticles. Different fillers have been prepared by PMG technique which essentially consists of forming the complex of reactants used for synthesis of Nanofillers with different polymers such As polyethylene Glycol, polyvinyl Acetate, polyvinyl Alcohol by Dissolving the Two components in desired proportions in appropriate solvents. The two will then be placed in contact in single container so that diffusion controlled reaction takes place and precipitate with controlled particle size is obtained.

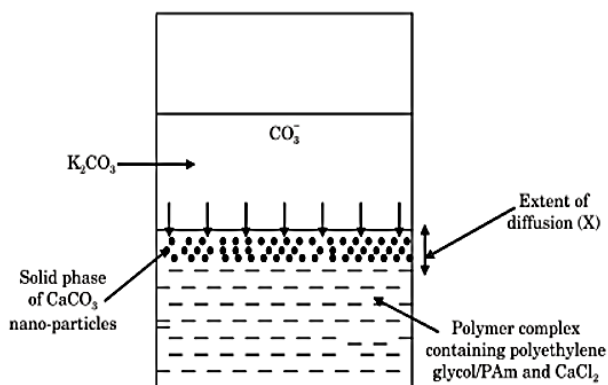


Fig-2.2. Schematic Representation of Polymer Mediated Growth Technique

### c) One Step Synthesis

The one-step process consists of simultaneously making and dispersing the particles in the fluids. In this method, the processes of drying, storage, transportation of Nanoparticles are avoided, so the agglomeration of Nanoparticles is minimized, and the stability of fluids is increased. The vacuum-SANSS (submerged arc Nanoparticle synthesis system) is another efficient method to prepare Nano-fluids using different dielectric liquids. One-step physical method cannot synthesize Nanofluids in large scale, and the cost is also high, so the one-step chemical method is developing rapidly.

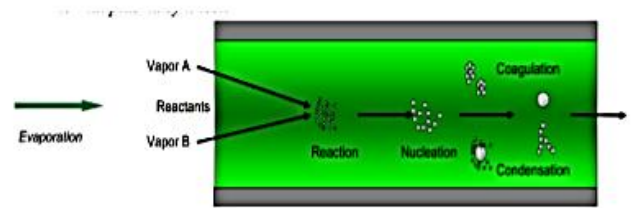


Fig-2.3. Vapour Phase Chemical Preparation

### d) Ultra sonication

Sonication is the act of applying sound energy to agitate particles in as ample, for various purposes. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultra-sonication or ultra-sonication. In the laboratory, it is usually applied using an ultrasonic bath or an ultrasonic probe, colloquially known as a sonication. In a paper machine, an ultrasonic foil can distribute cellulose fibres more uniformly and strengthen the paper.

Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves on chemical systems, called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Studies have shown that direct coupling of the acoustic field with chemical species on a molecular level can account for sono chemistry or sonolumine sciences. Instead, sono chemistry arises from acoustic cavitation: the formation, growth, and implosive collapse of bubbles in a liquid.

### 2.5 Base Fluid

Conventional fluids, such as water, engine oil, and ethylene glycol are normally used as heat transfer fluids. Although various techniques are applied to enhance the heat transfer, the low heat transfer performance of these conventional fluids obstructs the performance enhancement and the compactness of heat exchangers. The use of solid particles as an additive suspended into the base fluid is technique for the heat transfer enhancement. Improving the thermal conductivity is the key idea to improve the heat transfer characteristics of conventional fluids. Since a solid metal has a larger thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity of that fluid. However, they have not been of interest for practical applications due to problems such as sedimentation leading to increased pressure drop in the flow channel.

The recent advance in material technology has made it possible to produce innovative heat transfer fluids by suspending nanometre-sized particles in base fluids which can change the transport and thermal properties of the base fluid.

**a) Properties of Base Fluid**

Physical properties of base fluids and Nano fluids are illustrated in Table 2.1. Thermal conductivities of the base fluids are 0.6 for distilled water and 0.3 for ethylene glycol based coolant found in literature.

**Table No.2.1**

Fluid	Density (kg/m <sup>3</sup> )	Molar mass (g/mol)	Viscosity (Pa s)	Specific heat (J/kg K)	Conductivity k (W/m K)
Ethylene Glycol	1056	62.07	0.0161	2,470	0.258
Distilled water	999.9720	18.01528 (33)	0.001	4,190	0.58

**3. Thermal Conductivity Measurement Techniques for Nano fluids**

The thermal conductivity of Nano fluids is an important transport property in practical heat transfer applications. Generally, there are two types of methods for measuring the thermal conductivity of any liquids: the steady state method and the transient method. In the present study, the transient hot wire method is used for measuring the thermal conductivity of silver/water Nano fluids. This method was first introduced by Nagaska and Nagashima(1981). This method is preferred because of its accuracy, speed and ability to minimize the effects due to natural convection. This method, however, is normally restricted to electrically non-conducting fluids such as noble gases and organic liquids. Nano fluids are electrically conducting fluids. Thus, the Nagaska and Nagashima technique is modified, in which a platinum wire is coated with a thin electrical insulation layer, instead of a bare wire to measure the thermal conductivity of Nano fluids. Hence, in the present study, the transient hot-wire (Teflon coated platinum wire) technique is used for measuring the thermal conductivity of silver/water Nano fluids.

**A. Transient Hot Wire Techniques**

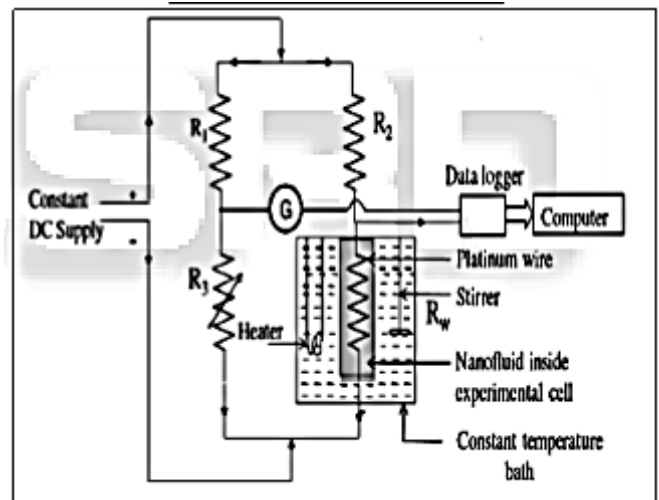
The transient hot wire method is the most appropriate and widely used method to measure the thermal conductivity of liquids. In this method, a thin platinum wire is used both as a line heat source and as a temperature sensor. The wire is surrounded by the liquid (Nano fluid) whose thermal conductivity is to be measured. The wire is then heated by sending electrical current through it. Now, the higher the thermal conductivity of the surrounding liquid, the lower will be the temperature rise of the wire. This principle is used to measure the thermal conductivity. This experiment lasts for a maximum of up to 4 seconds and eliminates the effects of natural convection; hence, it is very fast and accurate. This method is called transient because heat is supplied suddenly, and the readings are taken before reaching steady state when natural convection currents get set. The working equation is based on a specific solution of Fourier's law for radial (one dimensional) transient heat conduction with a line heat source at the axis of the cylindrical domain. From the solution presented by Carslaw and Jaeger (1967), the temperature distribution equation for

a line heat source is obtained by integrating it over the radial (r) direction from hot-wire radius (assumed zero) using r-zero and r-infinity boundary conditions and is given in equation .The infinite-series solution is then approximated with the first term only since the higher order terms virtually vanish after short initial transiency period.

$$T = \frac{q}{4\pi k} \ln \frac{4kt}{r^2 \rho c p} - \frac{r q}{4\pi k} \tag{i}$$

Where, J is the Euler's constant, q = the heat liberated per unit time per unit length of the line source in W/m and kf = the conductivity of the liquid in Wm-1K-1. If temperatures of the heat source at time t1 and t2 are T1 and T2 respectively, then putting these conditions in equation gives the conductivity of the liquid (Nano fluid) as:

$$K = \frac{q}{4\pi(T_2 - T_1)} \ln \frac{t_2}{t_1} \tag{ii}$$



**Fig-3.1:** Schematic diagram of the transient hot-wire apparatus

**3.1 Thermal Constants Analyser Techniques**

The thermal constants analyser utilizes the transient plane source (TPS) theory to calculate the thermal conductivity of nanofluid. In this method, the TPS element behaves both as the temperature sensor and the heat source. The TPS method uses the Fourier law of heat conduction as its fundamental principle for measuring the thermal conductivity, just like the THW method. Advantages of using this method are (a) the measurements are fast, (b) samples having wide range of thermal conductivities (from 0.02 to 200 W/m K) can be measured, (c) no sample preparation is required, and (d) sample size can be flexible. The experimental setup comprises of thermal constants analyser, a vessel, a constant temperature bath, and a thermometer. The probe of the thermal constants analyser is immersed vertically in the vessel containing the Nano fluid. The vessel is placed in the constant temperature bath and the thermometer is immersed in the vessel to measure the temperature of the Nano fluid. The thermal conductivity of the Nano fluid is determined by measuring the resistance of

the probe. The probe consists of an electrically conducting thin foil of a typical pattern which is sandwiched inside an insulating layer. In the vessel to measure the temperature of the Nano fluid. The thermal conductivity of the Nano fluid is determined by measuring the resistance of the probe. The probe consists of an electrically conducting thin foil of a typical pattern which is sandwiched inside an insulating layer.

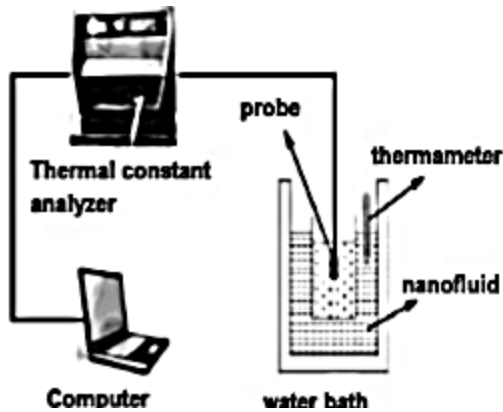


Fig-3.2: Schematic diagram of the experimental setup for transient plate source method

### 3.2 Steady State Parallel Plate Method

Based on steady-state heat conduction various design of test cells can be constructed for the measurement of thermal conductivity of liquids. To facilitate the heat transfer predominantly in one direction either parallel-plate type or concentric cylindrical cell type test facilities are preferred. The apparatus for the steady-state parallel-plate method can be constructed on the basis of the design by Challoner and Powell. A schematic diagram of the experimental set up is shown in Figure, where a small volume of the fluid sample is placed between two parallel round pure copper plates. A detailed description of the setup has been given by Wang et al. They have used this method for measuring the thermal conductivity of alumina and copper oxide based Nano fluids. In this method, two important parameters are to be carefully controlled. One needs to accurately measure the temperature increase in each thermocouple. The difference in temperature readings need to be minimized when the thermocouples are at the same temperature. As the total heat supplied by the main heater flows through the liquid between the upper and lower copper plates, the overall thermal conductivity across the two copper plates, including the effect of the glass spacers, can be calculated from the one-dimensional heat conduction equation relating the power  $q'$  of the main heater, the temperature difference  $\Delta T$  between the two copper plates, and the geometry of the liquid cell as

$$K = \frac{q' L_g}{S \Delta T} \quad (iii)$$

Where,  $L_g$  is the thickness of the glass spacer between the two copper plates and  $S$  is the cross sectional area of the top copper plate. The thermal conductivity of the liquid can be calculated as

$$K_e = \frac{K_s - K_g S_g}{S - S_g} \quad (iv)$$

Where,  $k_g$ ,  $S$ , and  $S_g$  are the thermal conductivity, cross-sectional area of the top copper plate, and the total cross-sectional area of the glass spacers, respectively. In this method, it has to be ensured that there is no heat loss from the fluid to the surrounding. To take care of this, guard heaters are used to maintain a constant temperature of the fluid. The guard heaters are heated to a temperature same as that of the fluid. If the fluid and the guard heater temperature are equal, then there will be no heat radiated to the surroundings from the fluid.

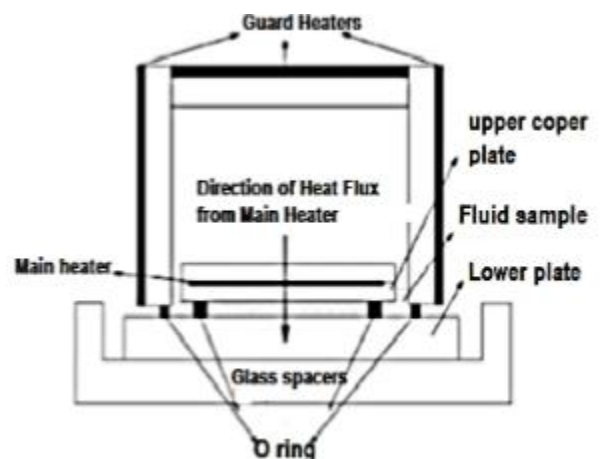


Fig-3.3: Experimental set up for steady state parallel plate method

### 3.3 Cylindrical Cell Method

Cylindrical cell method is one of the most common steady state methods used for the measurement of thermal conductivity of fluids. In this method the Nano fluid whose thermal conductivity is to be measured fills the annular space between two concentric cylinders. Kurt and Kayfeci have given a detailed description of the equipment. A brief description is as follows. The equipment (shown in Fig.1.7) consists of a coaxial inner cylinder (made of copper) and outer cylinder (made of galvanize). An electrical heater is placed inside the inner cylinder and the front and back sides of the equipment are insulated to nullify the heat loss during the measurement. During the experiment, heat flows in the radial direction outwards through the test liquid, filled in the annular gap, to the cooling water. Two calibrated Fe-Constantan thermocouples are used to measure the outer surface temperature of the glass tube ( $T_i$ ) and the inner cylinder ( $T_o$ ). The required measurements for the calculation of the thermal conductivity are the  $T_i$  and  $T_o$  temperatures, adjusted voltage and current of the heater.



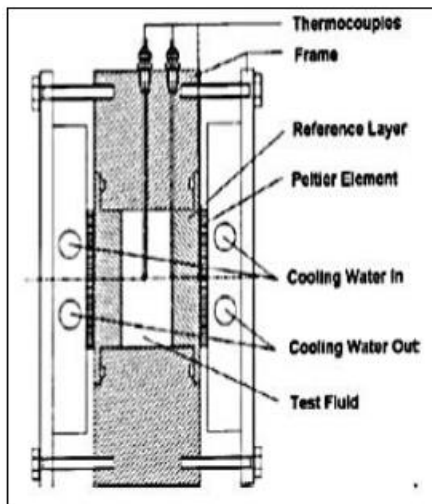


Fig-3.4: Cross-section of the cylindrical cell equipment

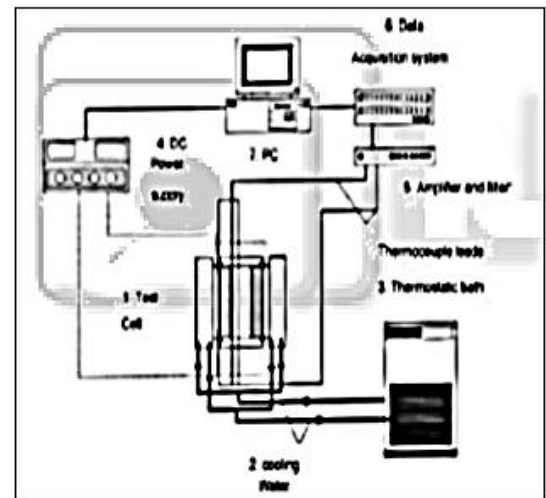


Fig-3.5: Schematic of experimental set up for temperature oscillation technique

#### 4.4 Temperature Oscillation Technique

This method measures the temperature response of the Nano fluid when a temperature oscillation or heat flux is imposed. The measured temperature response of the Nano fluid is the result of averaged or localized thermal conductivity in the direction of Nano fluid chamber height. The experimental method used here is based on the oscillation method proposed by Roetzel et al. And further developed by Czarnetski and Roetzel. The principle of thermal conductivity measurement has been described. Who have used this technique to measure the thermal conductivity of Nano fluids comprising of Al<sub>2</sub>O<sub>3</sub> and CuO nano particles dispersed in water. The experimental setup (shown in Fig.1.8) requires specially fabricated test cell (1) which is cooled by cooling water (2) on both the ends, coming from a thermostatic bath (3). Electrical connection provides power to the Peltier element (4). The temperatures are measured in the test section through a number of thermocouples and these responses are amplified with amplifier (5) followed by a filter which is finally fed to the data acquisition system (6) comprising of a card for logging the measured data. The data logger is in turn connected to a computer with proper software (7) for online display which is required to assess the steady oscillation and for recording data.

#### 3.5 30mega Method (3 $\omega$ method)

Similar to hot-wire technique, the 3 $\omega$  method uses a radial flow of heat from a single element which acts both as the heater and the thermometer. The use of the temperature oscillation instead of the time dependent response is the major difference. A sinusoidal current at frequency  $\omega$  passes through the metal wire and generates a heat wave at frequency  $2\omega$ , which is deduced by the voltage component at frequency  $3\omega$ . According to Cahill, the exact solution at a distance  $r = (x^2 + y^2)^{1/2}$  from an infinitely narrow line source of heat on the surface of an infinite half-volume.

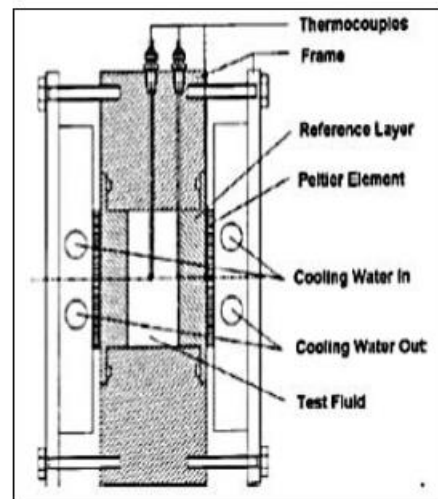


Fig-3.6: Test cell construction for 3 $\omega$  method

## 4. EXPERIMENTATION

### 4.1 Set up Description

#### 4.1.1 Chiller:

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This liquid can then be circulated through a heat exchanger to cool equipment, or another process stream (such as air or process water). As a necessary by product, refrigeration creates waste heat that must be exhausted to ambient or, for greater efficiency, recovered for heating purposes. Chilled water is used to cool and dehumidify air in mid- to large-size commercial, industrial, and institutional facilities. Water chillers can be water-cooled, air-cooled, or evaporative cooled. Water-cooled systems can provide efficiency and environmental impact advantages over air-cooled systems.

There are four basic types of compressors used in vapor compression

chillers: Reciprocating compression, scroll compression, screw-driven compression, and centrifugal compression are all mechanical machines that can be powered by electric motors, steam, or gas turbines. They produce their cooling effect via the "reverse-Rankine" cycle, also known as 'vapor-compression'. With evaporative cooling heat rejection, their coefficients-of-performance (COPs) are very high; typically 4.0 or more.

$$COP = \frac{\text{Cooling power}}{\text{Input power}}$$

Chiller Refrigeration system actual and block diagram as shown in fig below.

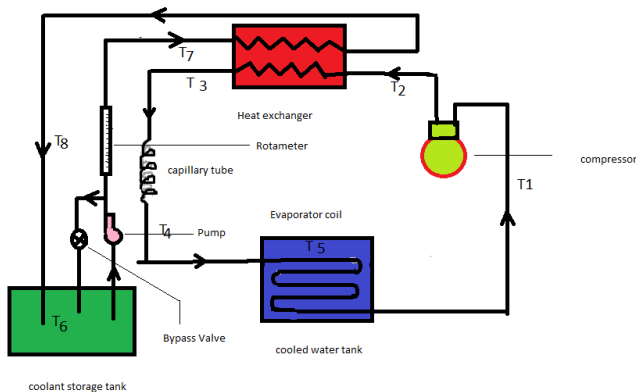


Fig-4.1 Flow Diagram of Chiller Plant System

#### 4.1.2 Compressor:

##### PARTS OF A HERMETIC REFRIGERATION COMPRESSOR

1. Housing with connectors and base plates
2. Top Cover
3. Block with stator bracket
4. Stator (with screws)
5. Rotor
6. Valve unit (screws, cylinder cover, gaskets, valve plate)
7. Crankshaft with grommet
8. Connecting rod with piston
9. Oil pick-up tube
10. Springs with suspensions
11. Internal discharge tube (screw, washer, gasket)
12. Start equipment (PTC device, cover, cord relief)



Fig-4.2 Parts of a Hermetic Refrigeration Compressor

In hermetic compressors, the motor and the compressor are enclosed in the same housing to prevent refrigerant leakage. The housing has welded connections for refrigerant inlet and outlet and for power input socket. As a result of this, there is virtually no possibility of refrigerant leakage from the compressor. All motors reject a part of the power supplied to it due to eddy currents and friction, that is, inefficiencies. Similarly the compressor also gets heated-up due to friction and also due to temperature rise of the vapour during compression. In Open type, both the compressor and the motor normally reject heat to the surrounding air for efficient operation. In hermetic compressors heat cannot be rejected to the surrounding air since both are enclosed in a shell. Hence, the cold suction gas is made to flow over the motor and the compressor before entering the compressor. This keeps the motor cool. The motor winding is in direct contact with the refrigerant hence only those refrigerants, which have high dielectric strength, can be used in hermetic compressors. The cooling rate depends upon the flow rate of the refrigerant, its temperature and the thermal properties of the refrigerant. If flow rate is not sufficient and/or if the temperature is not low enough the insulation on the winding of the motor can burn out and short-circuiting may occur. Hence, hermetically sealed compressors give satisfactory and safe performance over a very narrow range of design temperature and should not be used for off-design conditions. The COP of the hermetic compressor based systems is lower than that of the open compressor based systems since a part of the refrigeration effect is lost in cooling the motor and the compressor. However, hermetic compressors are almost universally used in small systems such as domestic refrigerators, water coolers, air conditioners etc, where efficiency is not as important as customer convenience (due to absence of continuous maintenance). In addition to this, the use of hermetic compressors is ideal in systems, which use capillary tubes as expansion devices and are critically charged systems. Hermetic compressors are normally not serviceable. They are not very flexible as it is difficult to vary their speed to control the cooling capacity.

#### 4.1.3 Magnetic Pump

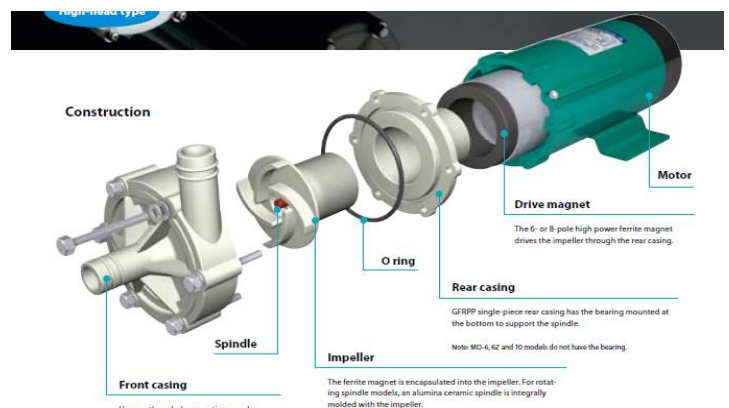


Fig-4.3 Parts of Magnetic Pump



**Working:**

A magnetic drive pump uses a balanced magnetic field to create the rotation of the fluid impeller. Unlike a traditional centrifugal pump which has a direct drive connection between impeller and motor, a mag-drive pump eliminates the direct drive mechanism and replaces it with a magnetic field. Outer magnetic bell housing is mounted on the end of the pump shaft. This outer bell is aligned on the outside of the rear casing. The pump impeller is connected to a smaller magnet assembly and rides on an internal shaft and bushing assembly. (The liquid end parts are all isolated within the fluid head of the pump without the need for a mechanical seal.) The smaller magnet assembly is mounted within the centre of the magnetic field of the outer bell housing. Although these two magnet assemblies are separated by a fluid barrier, the magnetic fields are aligned. When the pump motor is started the outer bell housing begins to rotate. As the outer bell rotates, the rotating magnetic field affects the inner impeller magnet. As the two magnets begin to turn together, the impeller begins turning and displacing fluid. Now you know how it works.

**Features:**

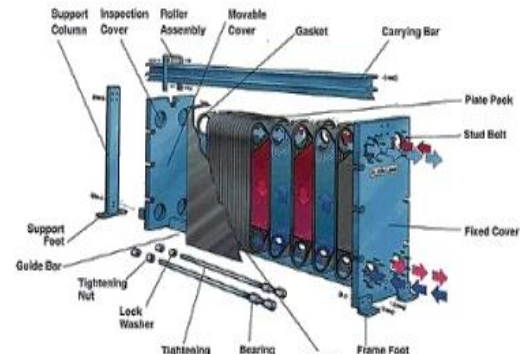
- Corrosion resistant
- Limited dry run capability
- Hydraulically efficient
- Quiet operation
- No shaft seals
- Flexible mounting and body discharge positions
- Low current draw and heat rise
- NSF certified models available

**4.1.4 Plate Type Heat Exchanger:**

The plate heat exchanger consists of a frame, which consists of a head, follower, column, carrying bar, guiding bar, and a number of clamping bolts. In between head and follower a varying number of pressed plates are clamped together. Each plate is supplied with a gasket, so that the plates form a closed system of parallel flow channels, through which the Media flow alternatively at every second interval.

All plate heat exchangers look similar on the outside. The difference lies on the inside, in the details of the plate design and the sealing technologies used. Hence, when evaluating a plate heat exchanger, it is very important not only to explore the details of the product being supplied, but also to analyze the level of research and development carried out by the manufacturer and the post-commissioning service and spare parts availability.

A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This has a major advantage over a conventional heat exchanger in that the fluids are exposed to a much larger surface area because the fluids spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change. Plate heat exchangers are now common and very small brazed versions are used in the hot-water sections of millions of combination boilers.



**Fig-4.4** Parts of Plate Type Heat Exchanger

The high heat transfer efficiency for such a small physical size has increased the domestic hot water (DHW) flowrate of combination boilers. The small plate heat exchanger has made a great impact in domestic heating and hot-water. Larger commercial versions use gaskets between the plates, whereas smaller versions tend to be brazed.

The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. In most cases, the exchanger consists of a coiled pipe containing one fluid that passes through a chamber containing another fluid. The walls of the pipe are usually made of metal, or another substance with a high thermal conductivity, to facilitate the interchange, whereas the outer casing of the larger chamber is made of a plastic or coated with thermal insulation, to discourage heat from escaping from the exchanger.

The plate heat exchanger (PHE) was invented by Dr Richard Seligman in 1923 and revolutionized methods of indirect heating and cooling of fluids.<sup>[1]</sup> Dr Richard Seligman founded APV in 1910 as the Aluminum Plant & Vessel Company Limited, a specialist fabricating firm supplying welded vessels to the brewery and vegetable oil trades.

**1) 4.1.5 Capillary Tube:**

Capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners.



**Fig-4.5** Capillary Tube

**Working:**

When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to very small diameter of the capillary. In capillary the fall in pressure of the refrigerant takes place not due to the orifice but due to the small opening of the capillary.

The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary. Smaller is the diameter and more is the length of the capillary more is the drop in pressure of the refrigerant as it passes through it.

In the normal working conditions of the refrigeration plant there is drop in pressure of the refrigerant across the capillary but when the plant stops the refrigerant pressure across the two sides of the capillary equalize. Due to this reason when the compressor restarts there won't be much load on it. Also, due to this reason one cannot over-charge the refrigeration system with the refrigerant and no receiver is used.

**4.1.6 Rota meter:**

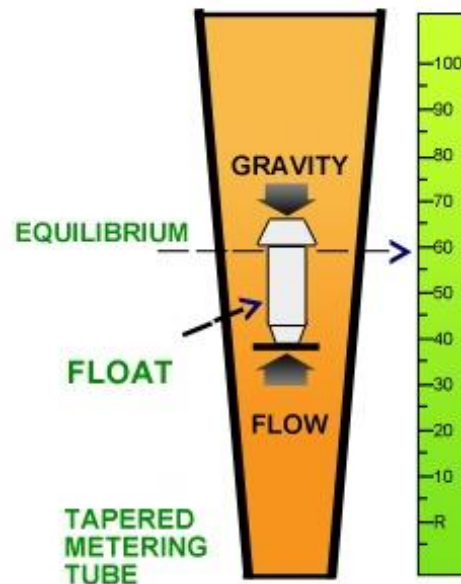
A Rota meter consists of a tapered tube, typically made of glass with a 'float', made either of anodized aluminum or a ceramic, actually a shaped weight, inside that is pushed up by the drag force of the flow and pulled down by gravity. The drag force for a given fluid and float cross section is a function of flow speed squared only, see drag equation.

A higher volumetric flow rate through a given area increases flow speed and drag force, so the float will be pushed upwards. However, as the inside of the Rota meter is cone shaped (widens), the area around the float through which the medium flows increases, the flow speed and drag force decrease until there is mechanical equilibrium with the float's weight.

Floats are made in many different shapes, with spheres and ellipsoids being the most common. The float may be diagonally grooved and partially colored so that it rotates axially as the fluid passes. This shows if the float is stuck since it will only rotate if it is free. Readings are usually taken at the top of the widest part of the float; the center for an ellipsoid, or the top for a cylinder. Some manufacturers use a different standard.

The "float" must not float in the fluid: it has to have a higher density than the fluid, otherwise it will float to the top even if there is no flow.

The mechanical nature of the measuring principle provides a flow measurement device that does not require any electrical power. If the tube is made of metal, the float position is transferred to an external indicator via a magnetic coupling. This capability has considerably expanded the range of applications for the variable area flow meter, since the measurement can be observed remotely from the process or used for automatic control.[8]



**Fig-4.6** Theoretical Diagram of Rota meter

**Working Principle:**

Rota meters are a particular kind of flow meter, based on the variable area principle. They provide a simple, precise and economical means of indicating flow rates in fluid systems. This variable area principle consists of three basic elements: A uniformly tapered flow tube, a float, and a measurement scale.

**4.1.7 Coil Type Evaporator:**

The evaporator is a heat transfer system, and is that part of a refrigeration cycle in which liquid refrigerant is evaporated for the purpose of removing heat from the refrigerated space or product.

The solution containing the desired product is fed into the evaporator and passes across a heat source. The applied heat converts the water in the solution into vapour. The vapour is removed from the rest of the solution and is condensed while the now-concentrated solution is either fed into a second evaporator or is removed. The evaporator, as a machine, generally consists of four sections. The heating section contains the heating medium, which can vary. Steam is fed into this section. The most common medium consists of parallel tubes but others have plates or coils typically made from copper or aluminium. The concentrating and separating section removes the vapour being produced from the solution. The condenser condenses the separated vapour, then the vacuum or pump provides pressure to increase circulation. [9]

Copper has approximately twice the conductivity of heat transfer of aluminium and therefore is more efficient at transferring heat. An air conditioner or heat pump works on the principle of refrigeration. The classic definition of refrigeration is moving heat from one place where it is not wanted to another place where it doesn't matter. That means it is important to use materials that efficiently move or

transfer heat. Another pro for copper is the ease of repairing the copper coils in the field if they become damaged. Aluminium coils, if damaged, are very difficult to repair and often times need to be replaced.



Fig-4.7 Coil Type Evaporator

**4.1.8 R134a Refrigerant:**

R134a is also known as Tetrafluoroethane (CF<sub>3</sub>CH<sub>2</sub>F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement.

It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.

Currently it is also being widely used in the air conditioning system in newer automotive vehicles. The manufacturing industry uses it in plastic foam blowing. Pharmaceuticals industry uses it as a propellant.

It exists in gas form when expose to the environment as the boiling temperature is -14.9°F or -26.1°C. This refrigerant is not 100% compatible with the lubricants and mineral-based refrigerant currently used in R-12. Design changes to the condenser and evaporator need to be done to use this refrigerant. The use of smaller hoses and 30% increase in control pressure regulations also have to be done to the system.

Table- 4.1- R134a Refrigerant

No	Properties	R-134a
1	Boiling Point	-14.9°F or -26.1°C
2	Auto-I gnition Temperature	1418°F or 770°C
3	Ozone Depletion Level	0
4	Solubility In Water	0.11% by weight at 77°F or 25°C
5	Critical Temperature	252°F or 122°C
6	Cylinder Colour Code	Light Blue
7	Global Warming Potential (GWP)	1200

**Detection of Leakage:**

When you suspect a leak of R-134a in your air conditioning system, detection can be done by using one of the following 5 methods. The simplest method and cost effective is by the use of soap solution. Workshops may use more sophisticated equipment's to do this.

- Fluorescent Dyes
- Soap Solution
- Electronic Leak Detectors
- Halogen selective detectors
- Ultrasonic leak detectors

**4.2 Experimental Procedure:**

- The process flow diagram is shown in figure. This system consists of a plate type heat exchanger, rota meter, magnetic pump, cooling water tank, water storage tank, and vapour compression system.
  - The rota meter is provided to measure the flow of fluid.
  - The volume flow rate of the fluid can be varied with changing the position of bypass valve.
  - The fluid then enters into the heat exchanger first, which has two inlets and two outlets.
  - One inlet for coolant and one for hot refrigerants.
  - One outlet for passing hot coolant and one for cooled refrigerant.
  - The temperature sensor T1- fitted at the compressor inlet.
  - T2- fitted at outlet of compressor.
  - T3- fitted before capillary tube.
  - T4-fitted after capillary tube.
  - T5 - fitted at the cooling water tank.
  - T6- fitted where coolant will pass through heat exchanger.
  - T7- fitted at inlet of heat exchanger at coolant side.
  - T8- fitted at the outlet of heat exchanger.
- The effective thermal conductivity is calculated by taking the difference in temperatures. Sensors are connected to the digital temperature indicator. The procedure is as follows:
- The set-up is first dry run to ensure complete removal of air/water bubbles in the heat exchanger tubes as well as in the pump.
  - The fluid to be tested is filled in the storage tank up to a certain required level.
  - The fluid (normal water) to be cooled is filled in another storage tank.
  - Then start the chiller.
  - Adjust the flow of coolant into the heat exchanger for different flow rate like 1.4, 2, 3 lpm.
  - Then took each reading for 10 minutes of interval.
  - Each measurement is repeated at least once.

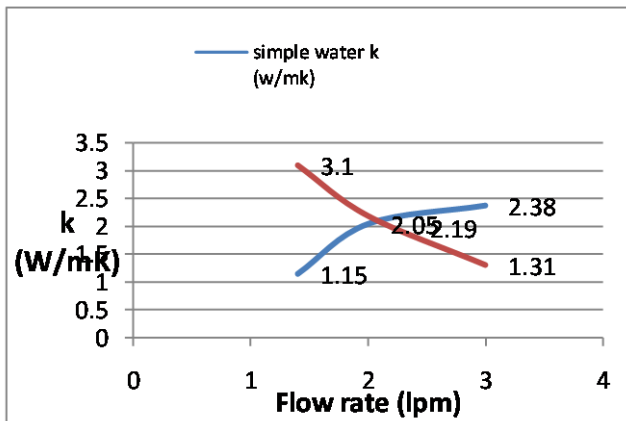


### 5. Observations

#### Graphs from observations

**Table No.5.1-** Coolant (0.25 gm/ltr Al2O3 mixed with Distilled water)

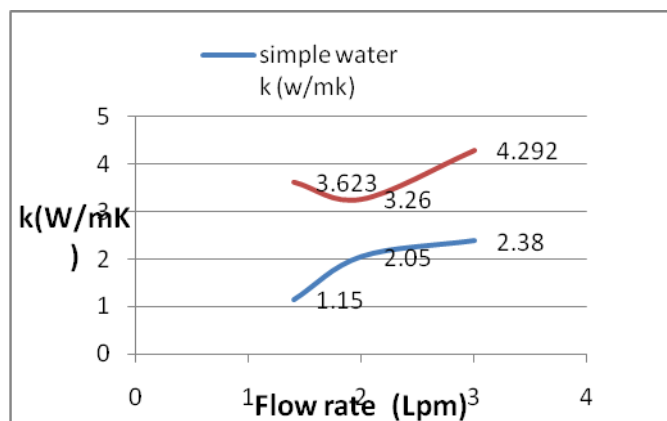
coolant	Lpm	1.4	2	3
simple water	k (W/mK)	1.15	2.05	2.38
0.25 gm/ltr Al2O3	k (W/mK)	3.1	2.19	1.31



**Chart-5.1** Thermal conductivity k v/s Flow rate in lpm

**Table No.5.2-** Coolant (0.5 gm/ltr Al2O3 mixed with Distilled water)

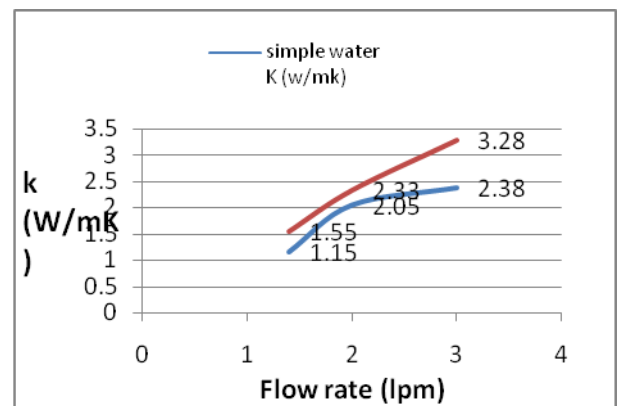
coolant	Lpm	1.4	2	3
simple water	k (W/mK)	1.15	2.05	2.38
0.5 gm/ltr Al2O3	k (W/mK)	3.623	3.26	4.292



**Chart- 5.2** Thermal conductivity k v/s Flow rate in lpm

**Table No.5.3-** Coolant (0.75 gm/ltr Al2O3 mixed with Distilled water)

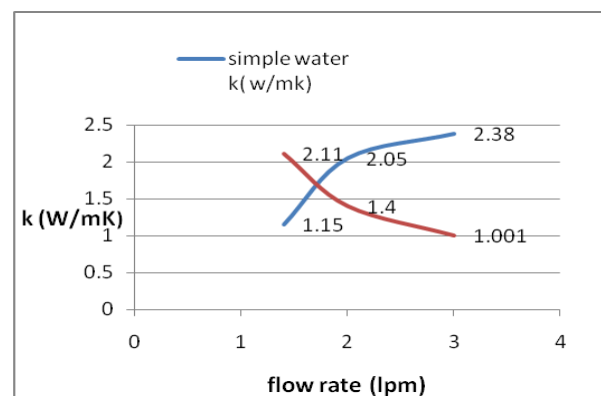
coolant used	Lpm	1.4	2	3
simple water	k (W/mK)	1.15	2.05	2.38
0.75 gm/ltr Al2O3	k (W/mK)	1.55	2.33	3.28



**Chart- 5.3** Thermal conductivity k v/s Flow rate in lpm

**Table No.5.4-** Coolant (1gm/ltr Al2O3 mixed with Distilled water)

Coolant	Lpm	1.4	2	3
Simple water	k (W/mK)	1.15	2.05	2.38
1 gm/ltr Alumina	k (W/mK)	2.11	1.4	1.001

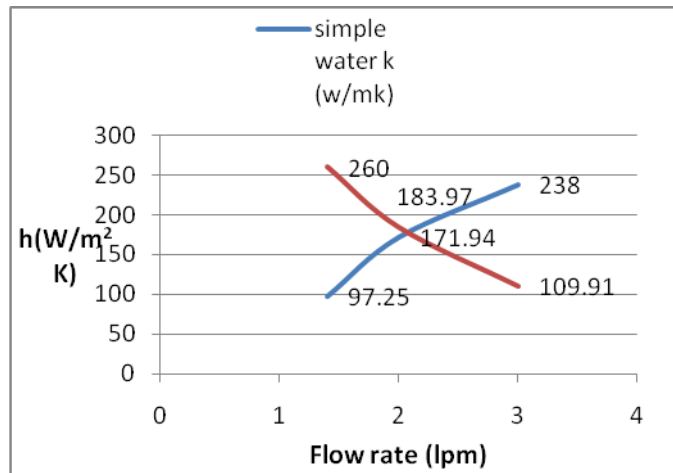


**Chart- 5.4** Thermal conductivity k v/s Flow rate in lpm

**Graphs for h:**

**Table No.5.5-** Coolant (0.25 gm/ltr Al2O3 mixed with Distilled water)

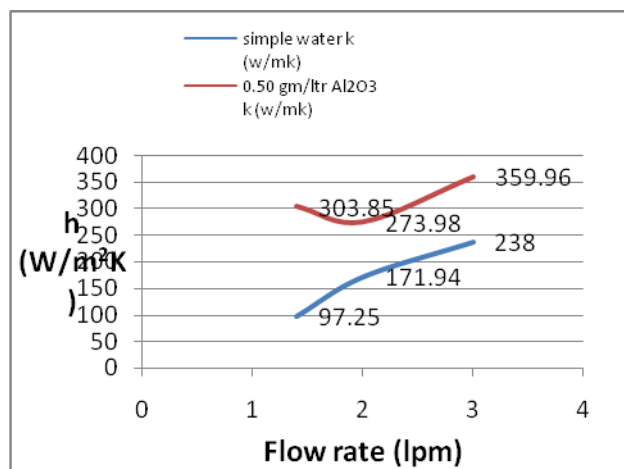
Coolant	lpm	1.4	2	3
simple water	h(W/m <sup>2</sup> K)	97.25	171.94	238
0.25 gm/ltr Al2O3	h(W/m <sup>2</sup> K)	260	183.97	109.91



**Chart-5.5** Heat transfer coefficient hVs flow rate (lpm)

**Table No.5.6-** Coolant (0.50 gm/ltr Al2O3 mixed with Distilled water)

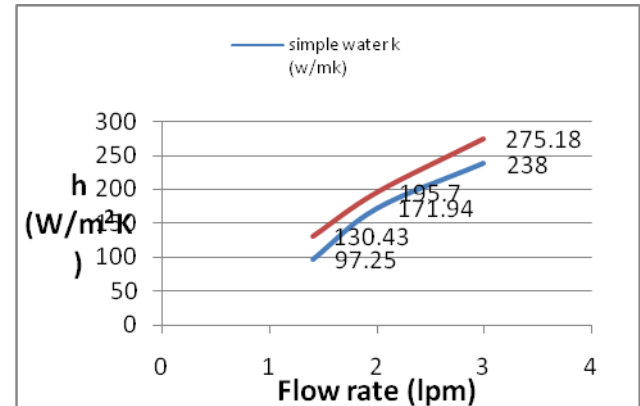
Coolant	Lpm	1.4	2	3
simple water	h(W/m <sup>2</sup> K)	97.25	171.94	238
0.50 gm/ltr Al2O3	h(W/m <sup>2</sup> K)	303.85	273.98	359.96



**Chart-5.6** Heat transfer coefficient hVs flow rate (lpm)

**Table No.5.7-** Coolant (0.75 gm/ltr Al2O3 mixed with Distilled water)

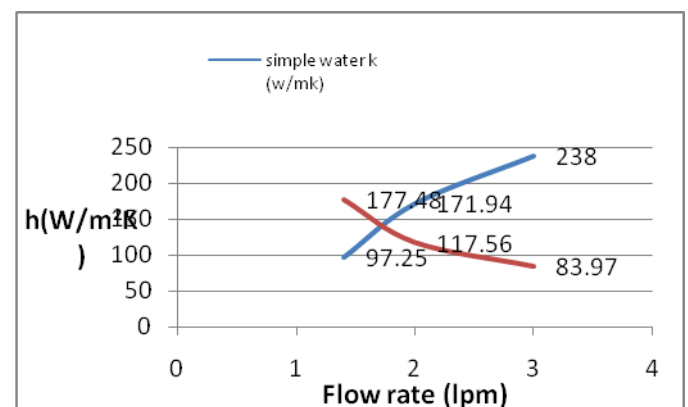
Coolant	Lpm	1.4	2	3
simple water	h(w/m <sup>2</sup> k)	97.25	171.94	238
0.75 gm/ltr Al2O3	h(w/m <sup>2</sup> k)	130.43	195.7	275.18



**Chart-5.7** Heat transfer coefficient Vsflowrate (lpm)

**Table No.5.8-** Coolant (1gm/ltr Al2O3 mixed with Distilled water)

Coolant	Lpm	1.4	2	3
simple water	h(W/m <sup>2</sup> K)	97.25	171.94	238
1 gm/ltr Al2O3	h(W/m <sup>2</sup> K)	177.48	117.56	83.97

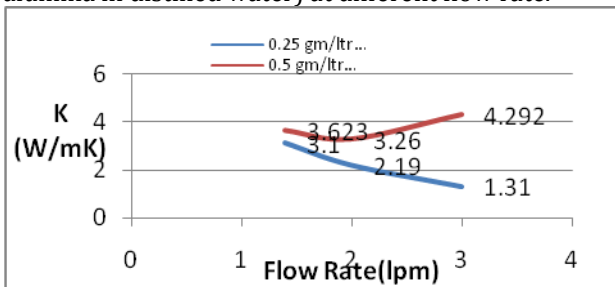


**Chart-5.8** Heat transfer coefficient h v/s Flow rate in lpm

## 6. RESULT ANALYSIS

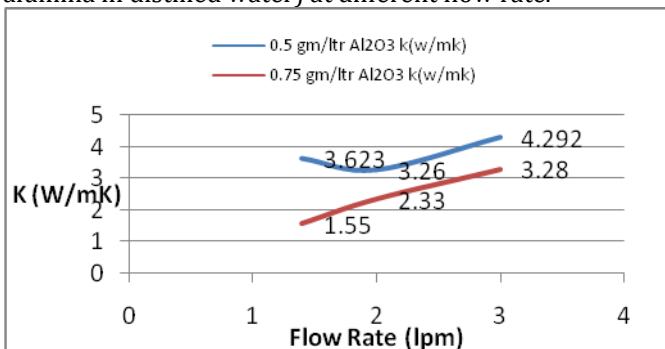
The results of this experimental study can be studied from the following graphs.

1. The following graph shows the relation between thermal conductivity of Nano fluid (0.25 gm/ltr alumina in distilled water) and thermal conductivity of Nano fluid (0.5 gm/ltr alumina in distilled water) at different flow rate.



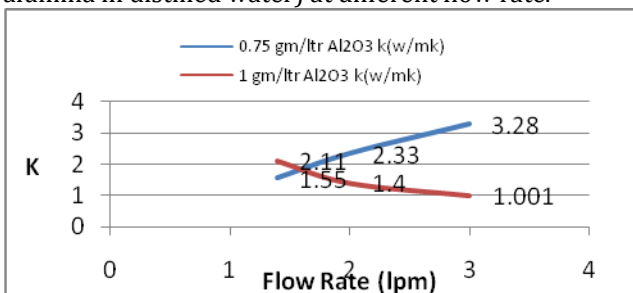
**Chart - 6.1** Thermal conductivity k Vs flow rate (lpm)  
The percentage increase in thermal conductivity is 38.45 %.

2. The following graph shows the relation between thermal conductivity of Nano fluid (0.50 gm/ltr alumina in distilled water) and thermal conductivity of Nano fluid (0.75 gm/ltr alumina in distilled water) at different flow rate.



**Chart - 6.1** Thermal conductivity k Vs flow rate in lpm  
The percentage increase in thermal conductivity is 30.85 %.

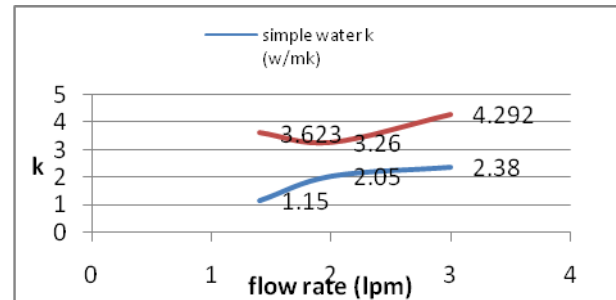
3. The following graph shows the relation between thermal conductivity of Nano fluid (0.75 gm/ltr alumina in distilled water) and thermal conductivity of Nano fluid (1 gm/ltr alumina in distilled water) at different flow rate.



**Chart - 6.3** Thermal conductivity k Vs flow rate in lpm  
The percentage increase in thermal conductivity is 55.45 %.

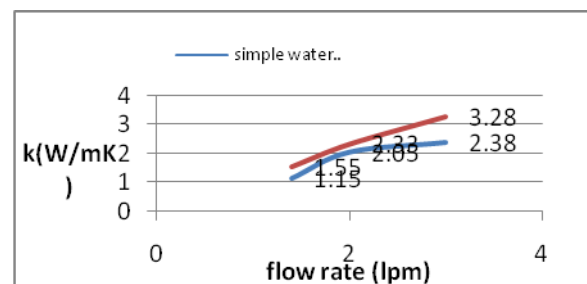
4. The following graph shows the relation between thermal conductivity of Nano fluid (0.50 gm/ltr alumina in distilled

water) and thermal conductivity of simple water at different flow rate.



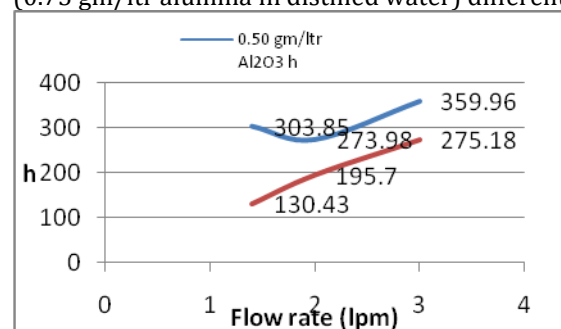
**Chart - 6.4** Thermal conductivity k Vs flow rate in lpm  
The percentage increase in thermal conductivity is 18.45 %.

5. The following graph shows the relation between thermal conductivity of Nano fluid (0.75 gm/ltr alumina in distilled water) and thermal conductivity of simple water at different flow rate.



**Chart - 6.5** Thermal conductivity k Vs flow rate in lpm  
The percentage increase in thermal conductivity is 37.81 %.

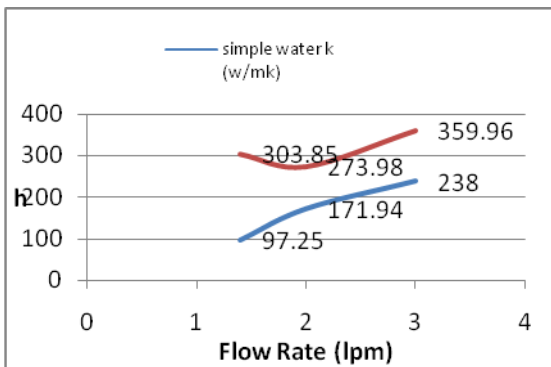
6. The following graph shows the relation between heat transfer coefficient of Nano fluid (0.50 gm/ltr alumina in distilled water) and heat transfer coefficient of Nano fluid (0.75 gm/ltr alumina in distilled water) different flow rate.



**Chart - 6.6** Heat transfer coefficient h v/s Flow rate in lpm  
The percentage increase in heat transfer coefficient is 30.80 %.

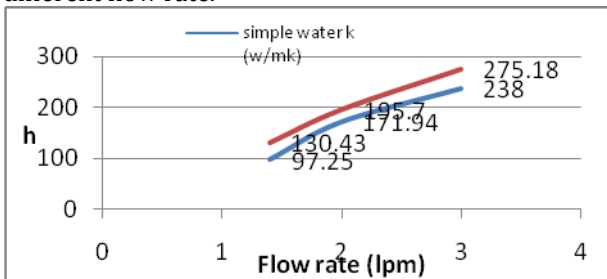
7. The following graph shows the relation between heat transfer coefficient of Nano fluid (0.50 gm/ltr alumina in distilled water) and heat transfer coefficient of simple water different flow rate.





**Chart – 6.7** Heat transfer coefficient h v/s flow rate in lpm  
The percentage increase in heat transfer coefficient is 51.24 %.

8.The following graph shows the relation between heat transfer coefficient of Nano fluid (0.75gm/ltr alumina in distilled water) and heat transfer coefficient of simple water different flow rate.



**Chart – 6.8** Heat transfer coefficient h v/s flow rate in lpm  
The percentage increase in heat transfer coefficient is 15.24 %.

### 7. Theoretical Thermal Conductivity

To compute the effective thermal conductivity of solid particle suspensions, several models were developed since the treatise by Maxwell (1891). These models were based on different aspects such as the solid particle, volume fraction and thermal conductivity. Some classical and recently developed models which are cited in this study are elaborated here. Various models for thermal conductivity of Nano fluid have been proposed. However, none of these models could successfully account for the observed enhancement of thermal conductivity Nano fluids. Following are some of the expressions of the conventional model of effective thermal conductivity of solid-liquid suspension.

#### Models used to predict the Effective Thermal Conductivity of CNT Nano fluid

- Maxwell [12]
- $$\frac{k_{eff}}{k_m} = \frac{3(\alpha-1)v}{(\alpha+2) - (\alpha-1)v} \quad (v)$$
- Hamilton and Crosser [12]
- $$\frac{k_{eff}}{k_m} = \frac{\alpha+(n-1)-(n-1)(1-\alpha)v}{\alpha+(n-1)+(1-\alpha)v} \quad (vi)$$
- Jeffery [12]
- $$\frac{k_{eff}}{k_m} = \frac{\alpha+(n-1)-(n-1)(1-\alpha)v}{\alpha+(n-1)+(1-\alpha)v} \quad (vii)$$

- Davis [12]
- $$\frac{k_{eff}}{k_m} = \frac{3(\alpha-1)}{(\alpha+2) - (\alpha-1)v} [v + f(\alpha)v^2 + D(v^3)] \quad (viii)$$
- Yu and Choi [2]
- $$K_{eff} = K_f \left[ \frac{K_p + (n-1)K_f - \phi_{eff}(n-1)(K_f - K_p)}{K_p + (n-1)K_f + \phi_{eff}(K_f - K_p)} \right] \quad (ix)$$
- Where,
- $\alpha = K_2/K_m, \beta = (\alpha-1)/(\alpha+2),$
- $K_{eff} = \frac{4}{3} \pi (r + h) = \phi (1 + \beta)^3$

$k_p$  and  $k_2$  - are the thermal conductivity of the particle.  
 $K_m$  and  $k_f$  - are the thermal conductivity of the base fluid.  
 $v$  - is the particle volume fraction.

$n$  - The particle shape factor.

$K_{eff}$ - is the effective thermal conductivity of solid/liquid suspensions.

$T$ - Nanolayer thickness.

$d_p$ - the particle diameter.

$\Phi_{eff}$ - Effective volume fraction.

### 8. FUTURE SCOPE - LATEST DEVELOPMENT

The recent discovery that R-134a contributes to global warming has caused the European Union to ban its use on new cars starting from year 2011. Other countries are expected to follow suit.

#### Nano fluid:

Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory (Maxwell, 1873) for effective properties of mixtures. Fine tuning of the dimensions of these solid suspensions to millimeter and micrometer ranges for getting better heat transfer performance have failed because of the drawbacks such as still low thermal conductivity, particle sedimentation, corrosion of components of machines, particle clogging, excessive pressure drop etc. Downscaling of particle sizes continued in the search for new types of fluid suspensions having enhanced thermal properties as well as heat transfer performance. These nanoparticle-fluid suspensions are termed nanofluids, obtained by dispersing nanometer sized particles in a conventional base fluid like water, oil, ethylene glycol etc. Nanoparticles of materials such as metallic oxides (Al<sub>2</sub>O<sub>3</sub>, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO<sub>2</sub>, SiC), single, double or multi walled carbon nanotubes (SWCNT, DWCNT, MWCNT), alloyed nanoparticles (Al<sub>70</sub>Cu<sub>30</sub>) etc. have been used for the preparation of Nano fluids.

- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wet ability, by varying particle concentrations to suit different applications.

## 9. REFERANCES

- [1] Sezer O` zerinc, SadıkKakac, AlmılaGu`venc, Yazıcıođlu., Enhanced thermal Conductivity of nanofluids: a state-of-the-art review, \_ Springer-Verlag 2009, pp.1-26.
- [2] Goharshadi\* E.K. Ahmadzadeh, Samiee.S and Hadadian.M, Nanofluids for Heat Transfer Enhancement-A Review, Department of Chemistry, Ferdowsi University of Mashhad, Mashhad 91779, Iran (Received 12 December 2012, Accepted 28 March 2013), PP.1-33
- [3] HamedMosavian, M. T. And S. ZeinaliHeris, S And Etemad ,GH and. Nasr Esfahany, Heat Transfer Enhancement By Application Of Nano-Powder, J Nanopart Res (2010) 12:2611–2619, pp.1-9.
- [4] Das. K, Sarita, and Choi, S and Pradeep, T, Nanofluid Science and Technology Book, Indian Institute of Technology Madras, Chennai, India,pp.1-407
- [5] Kostic.M and Kalyan C. Simham, Computerized, Transient Hot-Wire Thermal Conductivity (Hwtc) ApparatusforNanofluids. Department Of Mechanical Engineering Northern Illinois University Dekalb, Il 60115.Pp.1-7.
- [6] Chopkar.MandSudarshan.S and Das. P.K and Manna.I, Effect Of Particle Size On Thermal Conductivity Of Nanofluid ,Doi: 10.1007/S11661-007-9444-7\_ Minerals, Metals &Materials Society andAsm International 2008, Pp.1-8
- [7] Tian1,F And Sun1. , L, And Venart1, 2, Prasad1, R.Cand S. Mojumdar1, 3\*C development Of A Thermal Conductivity Cell With Nanolayer coating For Thermal Conductivity Measurement Of Fluids department Of Engineering, University Of New Brunswick, Saint John, Nb, E2l 4l5, Canada2department Of Mechanical Engineering, University Of New Brunswick, Fredericton, Nb, E3b 5a3, Canada3 Department Of Chemical Engineering And Applied Chemistry, University Of Toronto, 200 College St., Toronto, On, M5s 3e5, Canada, pp.1-7.
- [8] A Textbook of Heat transfer, by J.P.Holman.
- [9] Assael, M.Jl. Metaxa, N, Kakosimos.K And Constantinou D Thermal Conductivity Of Nanofluids – Experimental And Theoretical1International Journal Of Thermo physics, Vol. 27, No. 4, July 2006 (© 2006).pp1-19.
- [10] YunshengXu\*, Gunawidjaja Ray, Beckry Abdel-Magid, Thermal behavior of single Walled carbon nanotube polymer–matrix composites, Composite Materials Engineering Program, Winona State University, Winona, MN 55987, USA Received 25 May 2004; Revised 11 April 2005; accepted 11 April 2005, pp.1-8.
- [11] Xue, Q, Wen-Mei Xu, A model of thermal conductivity of nanofluids with interfacial Shells Department of Applied Physics, University of Petroleum, Dongying, Shandong 257062, PR China Received 24 February 2004; received in revised form 28 April 2004; Accepted 22 May 2004
- [12] Kumlutas, D.; Tavman, I.H. A numerical and experimental study on thermal conductivity of particle filled polymer composites. J. Thermoplastic. Compos. Mater. 2006, 19, pp- 441
- [13] Cheng, S.C.; Vachon, R.I. The prediction of the thermal conductivity of two and three Phase solid heterogeneous mixtures. Int. J. Heat Mass Transfer 1969, 12, pp- 249.
- [14] Agari, Y.; Uno, T. Estimation on thermal conductivities of filled polymers. J. Polym. Sci. 1986, 32, pp- 570.
- [15] Shahil KMF, Balandin AA; Graphene based Nano composites as highly efficient thermal Interface materials, 16 Nano letters, 2012, 12, pp- 861.
- [16] Nan Ce-Wen; Birringer R; Clarke Dr; Gleiter H; Effective thermal conductivity of Particulate composite with interfacial resistance, J.Appl.Phys, 1997, 81, pp- 66
- [17] S.Radhakrishnan, A.Khare, IndraneelZope, Electrical and Thermal conductivity of Graphite-CNT-Polymer Hybrid Composite, Proceedings IPST 2013, OS115, Indonesia October 2013 pp.89.