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# Concept of Nano Fluid in Heat Transfer Applications: A Review

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**Abstract -** *Heat transfer is an important field for the object of increasing the efficiency of thermal device. One of the way of increasing heat transfer rate by the use of Nano fluid. Nanoparticles result in the increase of thermal conductivity, heat capacity, viscosity, density of Nano fluid. The increase in these parameter of base fluid, increase the rate of heat transfer. This paper presents the increased efficiency, effectiveness in different device by the use of Nano fluid and presents many experimental results on different thermal device which had performed by a number of researchers. Thus availability of a thermal device can be increased and increased availability will help us reduction in carbon emission, pollution and entropy of this earth.*

***Key Words***: Nano fluid; Nanoparticles; Thermal conductivity; collectors; solar still; solar pond.

## 1. INTRODUCTION

In 21 centuries, energy has become back bone of a nation. The resources of energy are classified into two parts, Renewable energy and Non-renewable energy.

In whole world, most of the countries are dependent on the non-renewable energy. But the sources of non-renewable energy are limited. Thus it become necessary either shift on the renewable energy or effective utilization of non-renewable energy. Effective utilization of non-renewable energy includes increased efficiency of heat engine, effectiveness of heat exchanger etc. so that reduces the irreversibility. This can be done by using of Nano fluid. The use of Nano fluid improves the thermal conductivity, viscosity, density, specific heat etc. which improves the heat transfer rate. We use this increased heat transfer rate in many applications such as solar still, heat exchanger, solar collectors, solar pond, photovoltaic thermal system, vapour absorption refrigeration system, thermal energy storage etc. In this manner we can achieve the maximum utilization of energy in order to reduce the wastage of energy and cost of energy source.

## 2. NANO FLUID

Nano fluid is the name conceived by Choi and Eastman [1] in 1995 at the Argonne National Laboratory (ANL), USA, to Describe a fluid in which nanometer-sized particles are suspended. Nano fluids are a class of heat transfer fluids created by dispersing solid nanoparticles in traditional heat transfer fluids. Nano fluids are a new class of fluid introduce by modern nanotechnology engineered by mixing nanometre-sized materials (nanoparticles, Nano rods, Nano sheet, nanofibers and nanotubes) in base fluids. In other words, Nano fluids are nanoscale colloidal suspensions containing condensed nanomaterial. There is an existence of a double phase system, one is solid phase and other is liquid phase. Nano fluids possess enhanced thermos-physical properties such as, specific heat capacity, density, thermal diffusivity, viscosity, and convective heat transfer coefficients, thermal conductivity compared to those of base fluids like water, ethylene glycol and oil etc.

### 2.1 Types of Nano fluids

Nano fluids can be normally classified into two categories

- Metallic Nano fluids
- Non-metallic Nano fluids.

Metallic Nano fluids are those fluid in which containing metallic nanoparticles such as Cu, Al, Zn, Ni, Si, Fe, Ti, Au and Ag etc.

while non-metallic Nano fluids are those fluid in which containing non-metallic nanoparticles such as copper oxide (CuO), aluminum oxide ($Al_2O_3$), and silicon carbide (SiC, ZnO, TiO2) etc. and are also includes as non-metallic Nano fluids such as Carbon Nanotubes (Single Wall Carbon Nano Tube (SWCNT), Double Wall Carbon Nano Tube (DWCNT) and Multi Wall Carbon Nano Tube (MWCNT)), nanoparticles core polymer shell composites, semiconductors (TiO2) etc.

### 2.2 Properties of Nano fluids

1) **Thermal conductivity**: The thermal conductivity is one of the important parameters for heat transfer enhancement, some studies have been done on thermal conductivity of Nano fluids. All experimental results have indicated the enhancement of thermal conductivity by addition of nanoparticles. For example, Wang et al. [2], Lee et al. [3], and Das et al. [4] measured the thermal conductivity of Nano fluids containing Al2O3 and CuO nanoparticles and investigated the effect of the base fluid on the thermal conductivity of the Nano fluids. Xie et al. [5] examined the effect of base fluid on thermal conductivity of Al2O3 Nano fluid. Li et al. [6] investigated on the temperature dependency of thermal conductivity enhancement of Al2O3/water and CuO/water Nano fluids.

The thermal conductivity of water at 343K is 0.663 but when Al2O3 nanoparticle is mixed with water the thermal conductivity increased upto 0.744 and when Cu nanoparticle is mixed with water the thermal conductivity increased upto 0.749 and when Al nanoparticle is mixed with water the thermal conductivity increased upto 0.749 and when Ti2O nanoparticle is mixed with water the thermal conductivity increased upto 0.730 [7]. The unit of thermal conductivity is W/m.K.

**Table -1** Thermal conductivity of various Solids and Liquid [5]

| ***Material*** | ***Thermal conductivity(W/m.K)*** |
|---|---|
| Copper | 401 |
| Aluminum | 237 |
| Silver | 429 |
| Silicon | 148 |
| Graphite | 25-470 |
| Alumina | 40 |
| Carbon Nano Tube | 2000 |
| Water | 0.663 |
| Ethylene Glycol | 0.253 |

2) **Density:** The density of water at 343K is 977.5 but when Cu nanoparticle is mixed with water the density increased upto 1136.7 and when Al nanoparticle is mixed with water the density increased upto 1012.3 and when $Al_2O3$ nanoparticle is mixed with water the density increased upto 1037.4 and when $Ti_2O$ nanoparticle is mixed with water the density increased upto 1034.9 [7]. The unit of density is $kg/m^3$.

3) **Specific heat capacity:** The specific heat capacity of water at 343K is 4.190 but when Al nanoparticle is mixed with water The specific heat capacity increased upto 4.121 and when Cu nanoparticle is mixed with water The specific heat capacity increased upto 4.111 and when $Al_2O3$ nanoparticle is mixed with water The specific heat capacity increased upto 4.119 and when $Ti_2O$ nanoparticle is mixed with water The specific heat capacity increased upto 4.117 [7]. The unit of specific heat capacity is kJ/kg.K.

4) **Dynamic viscosity:** The dynamic viscosity is one of the important parameters, some studied have been done on the dynamic viscosity of Nano fluid. Zhao et al. [8] investigated by using $SiO_2$ Nano fluid and he observed that the dynamic viscosity of Nano fluid depends on volume fraction. M. Kole et al. [9] observed that the commercial engine coolant mixed with alumina nanoparticle. The unit of dynamic viscosity is kg/m.s

The dynamic viscosity of water at 343K is 4.040×10-4 but when $Ti_2O$ nanoparticle is mixed with water The dynamic viscosity increased upto 4.271×10-4 and when $Al_2O3$ nanoparticle is mixed with water The dynamic viscosity increased upto 4.271×10-4 and Al nanoparticle is mixed with water The dynamic viscosity increased upto 4.271×10-4 and Cu nanoparticle is mixed with water The dynamic viscosity increased upto 4.271×10-4 [7].

## 2.3 Properties of Nano fluids

### 1) Specific Heat of Nano fluids

$$C_{pnf} = \frac{[(1 - f_v)\, \rho_{bf}\, C_{bf} + f_v\, \rho_{np}\, c_{np}]}{\rho_{nf}}$$

Where $C_{pnf}$, $C_{bf}$, $C_{np}$ are the specific heats of Nano fluid in kJ/kg K, base fluids and nanoparticles, respectively [10].

### 2) Density of Nano fluids

$$\rho_{nf} = f_v\, \rho_{np} + (1 - f_v)\, \rho_{bf}$$

Where $f_v$ is the volume fraction of the nanoparticles, $\rho_{nf}$, $\rho_{np}$, $\rho_{bf}$ are the densities of the Nano fluid in kg/m3, nanoparticle and the base fluids respectively [11].

### 3) Dynamic Viscosity of Nano fluids

$$\mu_{nf} = \frac{1}{(1 - f_v)^{2.5}} \mu_{bf}$$

Where $\mu_{nf}$, $\mu_{bf}$ are the dynamic viscosities of Nano fluids and base fluids in $m^2/s$ & $f_v$ is the volume fraction of the nanoparticles respectively [12].

### 4) Thermal Conductivity of Nano fluids

$$k_{nf} = \left[\frac{k_{np} + 2k_{bf} + 2f_v\,(k_{np} - k_{bf})}{k_{np} + 2k_{bf} - f_v\,(k_{np} - k_{bf})}\right] k_{bf}$$

Where $k_{nf}$, $k_{bf}$, $k_{np}$, are the thermal conductivities of Nano fluid, base fluids and nanoparticles in W/m-K, respectively, & $f_v$ is the volume fraction of the nanoparticles [12].

## 3. APPLICATION OF NANO FLUID

### 3.1 Solar still

For the desalination and purification of water solar still are very useful. It contains a container which is used for collecting sea water/waste water. A glass cover use for trapping the heat is at top of a container. The temperature of water rises and evaporation starts as the trapping of solar energy takes place. Evaporated water vapour reaches the top and cools down to condense into water which is collected along the edges of glass cover [13-14]. However very slow at starting because of low temperature and low absorption rates, it is capable to produce around 25 litres of fresh water per day.

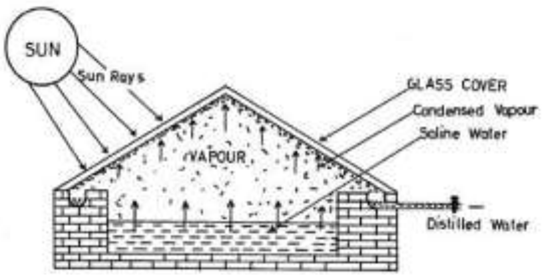


Fig 1. Nano fluid based Solar Still [15]

An instance research work is in progress for this technology solar stills and different methods are invented to improve their efficiency. In recent times, Gnanadason et al. [15] stated that solar stills efficiency can be increased by using Nano fluids. Their results showed that the efficiency is improved by 50% with addition of Nano fluids. The author is investigated that by using dyes in base fluid efficiency can be increased of solar still [16]. Their results shown that efficiency of solar still increased by 29% by using violet dyes in water, which is extraordinary.

Kabeel et al. [17] investigated that for the desalination of water of a small unit which is coupled with Nano fluid based Cu/water solar collector as a source of heat. The system involves a solar water heater (flat plate solar collector), a tank for mixing and a flashing chamber with a helical heat exchanger and condenser. Due to the evaporation of sea water with a very low pressure (vacuum) the desalination process takes place. For obtaining the fresh water condensation of evaporated water is being carried out. The report for the cost of water as design by the author shows that a decrease from 16.43 to 11.68 $/m3 at volume fraction of 5% and production also increases therefor nanoparticle concentration is important factor as can be seen by simulation result.

Kabeel et al. [18] used nanoparticle of $Al_2O3$ along with water in a single basin solar still. Use of Nano fluid improves a solar still water productivity by about 116% with the use of vacuum fan and 76% without the use of vacuum fan. An increase of rate of evaporation inside the still is the result of above increment. Rate of evaporation increases by utilizing Nano fluid in addition to this the evaporation rate increases further through the vacuum inside the still and productivity increases in comparison to the working of still at atmospheric condition.

## 3.2 Heat Exchanger

Heat exchanger is an adiabatic steady flow device in which two flowing fluid exchange or transfer heat between themselves due to temperature difference without losing or gaining any heat from the ambient.

The heat transfer in a heat exchanger involves convection on each side of fluid and conduction taking place through the wall which is separating the two fluids. In the analysis of heat, it is convenient to work with an overall heat transfer coefficient (U) that accounts for the contribution of all these effects on heat transfer. The rate of heat transfer between the two fluids at a location in a heat exchanger depends on the magnitude of temperature difference at that location, which varies along the heat exchanger. In a heat exchanger, the temperature of fluid keeps on changing as it passes through the tubes and also the temperature of the dividing wall located between the fluids varies along the length of heat exchanger. For example:

- Steam condenser
- Economizer
- air pre-heater
- Cooling tower
- Oil cooler of heat engine

1) CLASSIFICATION OF HEAT EXCHANGER

On the basis of nature of heat exchange process:
- Direct transfer type heat exchanger
- Direct contact type heat exchanger
- Regenerative type heat exchanger

On the basis of relative direction of fluid motion:
- Parallel flow
- Counter flow
- Cross flow

On the basis of design and constructional features:
- Concentric tubes
- Shell and tube
- Multiple shell and tube passes
- Compact heat exchanger

On the basis of physical state of fluids:
- Condensers
- Evaporators

2) EFFECTIVENESS OF HEAT EXCHANGER

Effectiveness of heat exchanger is defined as the ratio between actual heat transfer rate between hot and cold fluid in heat exchanger and the maximum possible heat transfer rate between hot and cold fluid in heat exchanger. Mathematically it is given by-

$$\epsilon = \frac{Q_{actual}}{Q_{maximum}}$$

Effectiveness of heat exchanger depends on specific heat capacity, convection of heat transfers co-efficient, between hot and cold fluid wall separating thermal conductivity, type of heat exchanger, etc.

When volume fraction of nanoparticle increases in Nano fluid so that convection heat transfer rate increases. Convection heat transfer rate increases, overall heat transfer rate of heat exchanger also increases. By dispersing nanoparticle in hot or cold fluid the heat transfer rate can be improved due to following way.

- The surface area, thermal conductivity and heat capacity of the fluid increased by using nanoparticle
- The interaction and collision among nanoparticles, fluid, flow passage surface, mixing fluctuation and turbulence of the fluid are intensified.
- The dispersion of nanoparticles flattens the transverse temperature gradient of the fluid

In the analysis, different mass flow rate flows in four different heat exchanger. Their results show that effectiveness of heat exchanger changing from 61% to 68% and also found the effectiveness of the heat transfer varied from 40% to 92%. It was also found that the major effect of inlet temperature and mass flow rate of hot and cold fluid on effectiveness of heat exchanger [19].

By using aluminum oxide ($Al_2O3$) as nanoparticle with base fluid DI water (Deionized Water). We analyze that effectiveness (by using Log Mean Temperature Deference (LMTD) method and Number of Transfer Units (NTU) method) of heat exchanger increases when using the Nano fluid as compare to DI water as a cooling fluid. The effectiveness of heat exchanger by using DI water as a hot fluid and DI water as a cold fluid the effectiveness of heat exchanger is 0.381. While after using the Nano fluid as a cooling fluid in place of DI water, and remaining value and conditions are same the value of effectiveness increases to 0.46. There is increment of about 8% in effectiveness of heat exchanger. As we see that the effectiveness of heat exchanger after using Nano fluid increases as compare to using DI water as a Nano fluid [20].

### 3.3 collector and solar water heater

The conventional direct absorption solar collector is a well-known technology, and it has been suggested for different type of applications. The efficiency of these collectors is restricted due to the absorption properties of the working fluid [21] such as water because it has poor specific heat capacity, thermal conductivity, dynamic viscosity, density.

Tyagi et al. [22] investigated by using Aluminium/water Nano fluid (0-20nm) and he observed that Efficiency remarkably increases for volume fraction less than 2% while efficiency remains nearly constant for volume fraction higher than 2% and Efficiency increases slightly using an increase in the size of Nanoparticles.

Otanicar et al. [23] investigated by using Graphite/water Nano fluid (30nm), silver/water Nano fluid (20 and 40nm), carbon nanotube/water Nano fluid (6-20nm diameter, 1000-5000nm length) and he observed that efficiency considerably increase upto 5% for volume fraction less than 0.5% while efficiency for volume fraction higher than 0.5% may even decrease and efficiency increase by 6% with decreasing the nanoparticle size in silver/water Nano fluid from 40nm to 20nm. Otanicar and golden et al. [24] investigated by using Graphite/water and propylene glycol Nano fluid and he observed that a Nano fluid based solar collector leads to scarcer CO2 emissions compared to the conventional solar collector. Faizal et.al (2013) [25] investigated by using MWCNT (multi wall carbon Nano tube) / Absorbing medium Nano fluid (0.2 wt. % and 0.4 wt. %) and used as surfactant and he observed that 37% size reduction is possible by employing MWCNT as working fluid. Yousefi et al. [26] investigated by using $Al_2O3$/water Nano fluid (15nm) with Triton X-100 is used as a surfactant and he observed that efficiency of solar collector with 0.2% weight fraction (wt.) Nano fluid is higher than that with water by 28.3% while efficiency increase by 15.63% using the surfactant. Yousefi et al. [27] investigated by using Multi wall carbon nanotubes (MWCNT)/water Nano fluid (10-30nm) with Triton X-100 is used as a surfactant and he observed that efficiency of the collector increase remarkably for 0.4 wt. % Nano fluid, whereas with 0.2 wt. % the efficiency reduced compared to water and for 0.2 wt. % Nano fluid, using surfactant increase the efficiency of the collector compared to the water.

Li et.al [28] investigated by using $Al_2O3$/water Nano fluids, ZnO/water Nano fluids & MgO/water Nano fluids on the tubular solar collectors and he observed that 95% of the incoming sunlight can be absorbed effectively while using the Nano fluid of volume fraction less than 10 ppm. Liu et al. [29] experimentally showed a better collecting performance of solar collector integrated with open thermosyphon in comparison to collector with concentric tube and efficiency can be increase by using a working fluid of CuO/water Nano fluid. These results shows that by using the Nano fluid in collector with open thermosyphon. The maximum and mean value of collecting efficiency is increased by 6.6% and 12.4% respectively.

### 3.4 concentrating collector

Parabolic solar collector of concentrating type based on a Nano fluid is very much synonymous to a parabolic trough collector of conventional design but the exception is only on account of linear receiver or heat collector element (HCE) part of the collector. according to constructional point of view the above two type of receiver have a difference in respect to the case of replacing the absorber tube by a glass tube containing the Nano fluid resulting in solar irradiance interacting with working fluid for Nano fluid based concentrating parabolic solar collector (NCPSC). There would have been paradigm shift for solar radiant energy capturing technique with the use of this novel type of Nano fluid based HCE [30]. Absorber tube firstly absorb the solar radiant energy in the HCE of conventional type and then through conduction and convection modes working fluids receives it i.e. there is not any kind of direct interaction between working fluid and incoming solar irradiance. But in NCPSC there is a direct interaction between working fluid and incoming solar irradiance due to which absorption and scattering mechanism results in a volumetric energy absorption. Moreover, the fractional volume of nanoparticle and its special distribution for the energy absorption at a desired level can be engineered.

For the parabolic concentrator the incoming solar irradiance perpendicularly incident on aperture area resulting in maximum concentration on the receiver as the solar irradiance reaches the HCE a fraction of it is absorbed and the glass envelope and glass tube reflex it and the remaining is able to reach the Nano fluid (depending on the transmissivity of the glass tube and glass envelope). An approximate estimate for combined conductive and radiative heat transfer is made for absorbing, emitting and scattering medium between the interaction of solar irradiance and Nano fluid. There is a scattering and absorption of solar irradiance by nanoparticle, however there is a negligible scattering for base fluid resulting in unaccounted for current model [30].

Taylor et.al [29] investigated by using graphite/ therminol VP-1 Nano fluids, aluminium/therminol VP-1 Nano fluids, silver/therminol VP-1 Nano fluids, copper/therminol VP-1 Nano fluid (10-100nm) and he observed that efficiency increase up to 10% by using a Nano fluid in the receiver section using graphite/therminol VP-1 Nano fluid with volume fraction less than 0.001% is beneficial for 10-100 MW power plants. Khullar et al. [30] investigated by using Aluminium/therminol VP-1 Nano fluids (5nm) and he observed that Thermal efficiency of Nano fluid concentrating parabolic collectors compared to a conventional parabolic solar collector is about 5-10% higher. Khullar and Tyagi et al. [32] investigated by using Aluminum/water Nano fluids and he observed that using this type of collector leads to fewer CO2 emission by 22.2 x 103 kg in 1 year.

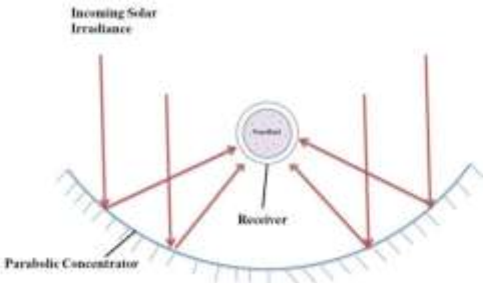


Fig 2. Nano fluid based concentrating collector [28]

### 3.5 Solar pond

The mass of shallow water which is 2-5m deep with a large collection area and acts as a storage of heat is called solar pond. In order to generate a stable density gradient, it contains dissolve salt. A portion of solar radiation incident on the surface of a pond is absorbed through of the depth and the other portion which is absorbed at the black bottom penetrates the pond. There would be temperature rise in the lower layer, expansion and rise on the surface when the pond is initially field by fresh water. Due to the relatively low conductivity, insulating action in the water takes place and bottom layer has a temperature over 90c. A thick durable plastic layer liner is laid in bottom of pond. Butyl rubber, black polyethylene and hypo a reinforce with are the material used for liner. Salt of magnesium chloride, sodium chloride or sodium nitrate are dissolve in water resulting in variation on concentration from 20 to 30% at the bottom to almost zero at the top [33].

The most commonly used of solar pond is called salinity gradient solar pond. Dissolve salt are used to create layers of water with different density resulting in more salt content, denser water thus according to salinity with depth there are three zones in salinity gradient solar pond.

- Surface zone (0.3-0.5m), with salinity<5% concentration
- Gradient zone (1-1.5m, salinity increase with Depth)
- Storage zone (1.5-2m, salt=20%)

The gradient zone is much thicker and conquers more than half the depth of the pond. Both the concentration and the temp increase with the depth in it. It mainly serves as insulating layer and reduces the heat transfer. Some part of this zone also acts as thermal storage. The lower zone is the storage zone. Both the concentration and temp are constant in this zone. It is the main thermal storage medium. The deeper the zone. The more is the heat stored. The storage zone traps heat energy for longer periods. The capacity to store heat for long periods is the topmost advantage of solar ponds. Even in the cloudy days and in the ice covered regions the energy can be stored, since the salt water near the bottom heats up and expands. However, it cannot rise to because it is denser than the less salty water above. Hence a salinity gradient solar pond is best utilized for storing the solar energy at a reasonable cost [33]. Through the bottom a thermal energy at 80-90c can be extracted which can be used in space heating, moisture removal from livestock and dairy heat requirements etc.

Heat extraction can be done with fresh water, but heat exchange rate is very less at low temperature ranging between 80-90c resulting in heat losses because of delay. Nano fluids with superior heat exchange rates are advantageous for this cause. At the bottom of solar pond, a heat exchanger is mounted through which a Nano fluid flows to absorb the heat. There is a possibility that at the bottom of solar pond rate of heat removal can be enhanced through the Nano fluids. For this Nano fluid transfer the energy from solar pond to the system through a close loop operation. Between the heat exchanger and Nano fluid tank the Nano fluid is a circulating modulator.

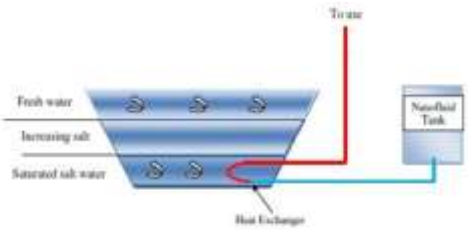


Fig 3. The Experiment set-up proposed for using Nano fluid in solar pond [32]

Al-Nimr et al. [34] presented the effects of using silver water Nano fluid through a mathematical model for the thermal performance of a shallow solar pond and found that a Nano fluid pond has energy about 216% more than that in brine pond. Mineral oil use to make upper layer of pond and silver based Nano fluids forms the lower layer. A depth of less than 25 cm in order to absorb the light in Nano fluid pond results in a solar radiation of 1000W/$m^2$, however brine pond needs a depth of more than 25m for same amount of light. The increment in thermal conductivity of base fluid due to nanoparticle addition that leads to distribution of temperature with in the layer to be uniform along with reduction in heat losses could be a result of increment in store energy.

### 3.6 Photovoltaic/thermal system

A photovoltaic/thermal (PV/T) system is a crossbreed structure that converts part of the solar radiation to electricity and part to thermal energy [35]. We can have observed the effect of Nano fluid on photovoltaic/thermal system in the form of increased efficiency which is due to the enhancement in the heat exchange rate. The effects of different volume fractions, nanoparticle size on the efficiency of the system can be studied. Many researches has shown that the cooling rate can be increased by use of Nano fluid on many thermal systems such as Electronic device [34-36], automobile radiator [39], micro channel heat sink [38] etc.

thus the use of Nano fluid will increase the cooling rate of photovoltaic/thermal system certainly.

Sardarabadi et al. [41] performed an experiment for observing the increased efficiency of photovoltaic/thermal system by using Nano fluid (SiO2/water). He attached a flat plate solar collector with photovoltaic panel. He set the tilt angle at 32. He observes increased exergy by using three cases

- Pure Water – It increases by 19.36%
- 1% Silica/water Nano fluid – It increases by 22.61%
- 3% Silica/water Nano fluid – It increases by 24.31%

He observes thermal efficiency of photovoltaic/thermal system increased by using two cases

- 1% Silica/water – It increases 7.6%
- 3% Silica/water – It increases 12.8%

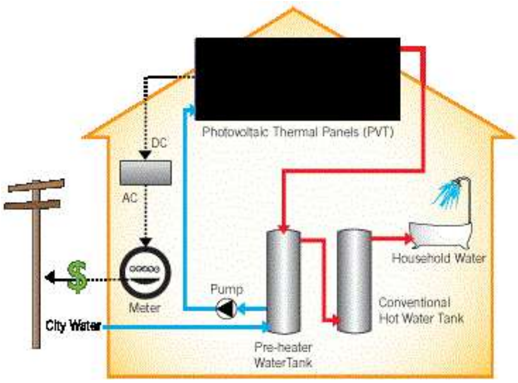


Fig 4. Schematic daigram of Photovoltaic/Theraml system [41]

### 3.7 Thermal energy storage

For the purpose of thermal energy storage, we require a material which has high thermal conductivity and heat capacity so that it can absorb heat very quickly and can store for large time period. But in practical life, we have such few materials which contains these properties but they work at high temperature. Due to these reason, we had limited scope in this field. But in recent time, Shin and Banerjee [42] stated that mixing of nanoparticle in base fluid known as Nano fluid give us the desired property. He observed that, increased by 14.5% the specific heat capacity of Nano fluid. Thus now we become able to store thermal energy.

Gumus et al. [43] has performed an experiment with Nano fluid ($Na_2SO4.10H_2O$) which is a phase change material. He stored thermal energy for per-heating of internal combustion engine. He observed that, after absorbing the heat, engine temperature was increased to 17.4°C in 500second and recorded the maximum thermal efficiency 57.5% and 2277kJ of heat absorbed during charging. This pre-heating results in reduced emission of carbon mono oxide (CO) and hydro carbon (HC) by about 64% and 15% respectively.

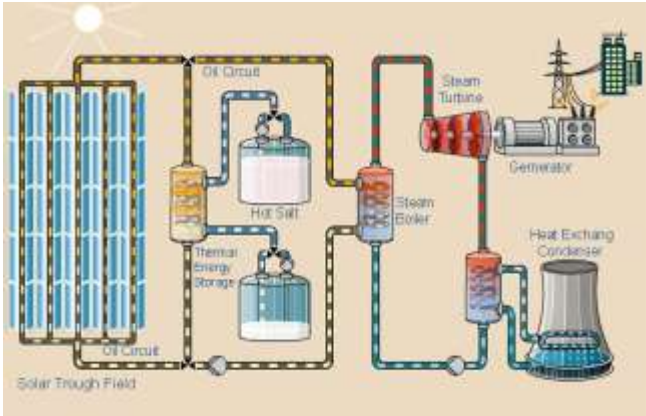


Fig 5. Schematic daigram of Thermal Energy Storage [40]

### 3.7 Vapour absorption refrigeration system

A simple vapour absorption system is same as vapour compression system except compressor, compressor is replaced by an absorber, a pump, a generator and a pressure reducing valve. The vapour absorption system operates on low grade energy (heat) and used where the large waste heat is available. Most popular vapour absorption system are ammonia-water ($NH_3.H_2O$) system in which ammonia is the refrigerant and water is the absorbent. The schematic diagram of the vapour absorption (ammonia water) system is shown in figure.

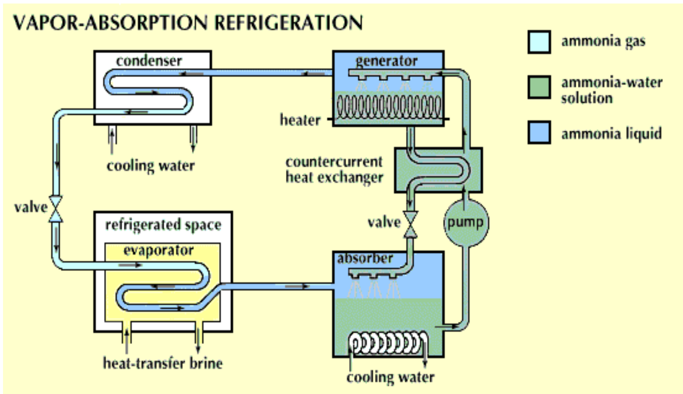


Fig 6. Schamatic daigram of Vapour-Absoption Refrigeration system

#### *Working of Ammonia water system*

Ammonia vapour leaves the evaporator and enter the absorber where it dissolves and react with water to form liquid $NH_3.H_2O$. This is an exothermic reaction and the amount of $NH_3$ that can be dissolve in $H_2O$ is inversely proportional to temperature. The liquid $NH_3.H_2O$ solution is then pumped to generator where heat is supplied from external source such as steam, electricity, gas flame etc. In generator as the temperature is high the ammonia separates from the water those creating high pressure vapour reach in NH3 passes through rectifier where traces of water are removed and sent back to generator. High pressure $NH_3$ from generator enter into condenser where ammonia vapour condenses and ammonia vapour is throttled by the expansion valve. Then ammonia vapour enter in the evaporator where evaporates and continued its journey.

Nanoparticle can be mix with $H_2O$ in ammonia-water vapour absorption refrigeration system. This Nano fluid help us to increase the heat absorption from ammonia vapour in absorber. Thus condensation rate of ammonia vapour increases, it comes in liquid state and mixes with Nano fluid. Now Nano fluid with ammonia pumped to generator. In generator, Nano fluid start absorption of thermal energy very quickly which increases the vaporization rate of ammonia. In this manner, coefficient of performance of vapour absorption refrigeration system can be enhanced.

## 4. CONCLUSIONS

Enhance rate of heat transfer is observed in the solar still, heat exchanger, collector and solar water heater, solar pond, photovoltaic/thermal system, thermal energy storage etc. which increasing the effectiveness and efficiency. Thus increased heat transfer results in increased availability and increased availability saves our energy resources and money. Which also saves our environment from pollution and produces a concept of sustainable development with a combination of Nano fluid and solar device.

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