FINAL ISPG Report

on

ATMOSPHERIC WATER HARVESTING

ISHRAE Jadavpur University Students' Chapter

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Abstract

Water Scarcity is one of the burning issues of today's world. Though water covers more than two-third (about 70%) of the Earth's surface but still fresh water which is used for drinking and other household chores remains scarce (about 2.5%). The acute problem of water shortage, is mainly faced by the countries with long coastlines and the island nations, which do not have adequate fresh water sources like rivers and ponds. As a result, most of these countries meet their water demands by desalination of sea water which is a very costly affair. Also, it may so happen that these desalination plants may fail which will cause acute water shortage. That is what just recently happened in Maldives. So, there is an urgent need for countries like Maldives and others, who depend solely on desalination plants to meet their water requirements, to find alternative methods to generate water in order to meet their water security needs. India also needs to work forward in this direction in order to address this issue. Even though it has a very large coastline but still people face water scarcity. Till now India has not devised any method by which water from sea can be used to provide drinking water to the people. This project aims to solve this problem. In the coastal areas the relative humidity is quite high (about 70-80%). So, the air in coastal areas can be used to meet the water needs of people by using a dehumidifier unit. Further the solar insolation in these areas is quite high round the year. This can be used to provide necessary power to the dehumidifier unit. Thus, drinking water can be obtained from the atmosphere by harnessing solar energy. Such a device is called Atmospheric Water Generator.

➢ Introduction

The aim of the project is to create a portable device that can be used to meet the water requirements of a regular household. The device will first condense water present in the atmosphere and then purify it so that it can be used for drinking.

➢ Objectives:

- To eliminate the emission of CFC (Chlorofluorocarbon) from water dispensers, this could ultimately reduce global warming and also reduce power consumption.
- GENERATING water from atmosphere using Peltier technology which is energy efficient and portable.
- Potability of Water - Water produced by the design must conform to the World Health Organization (WHO) drinking water quality standards.
- Simplicity of Use - Design must be operable by persons of limited technical experience.
- Safety - Design must not pose a hazard to users at any point during its normal operation.
- Flexibility in Power Source - The design should be able to utilize a variety of power sources, including (but not limited to) solar, wind, and the traditional power grid.
- Maximize Efficiency - The design should maximize the water produced per unit energy.
- Minimize Cost - The design should minimize the cost per unit water production for both capital cost and production cost.

1. Dehumidification techniques

When approaching the problem of atmospheric water generation, the first step is to analyze different methods of dehumidification. In this application we seek to harness this water from the atmosphere and utilize it for drinking. Three common psychometric methods of dehumidification stood out during preliminary research; a temperature drop below the dew point (refrigeration condensing), pressure condensing, or a combination of the two. Along with this wet desiccation technique can also be used for the above purpose. Each of these techniques are discussed below:

1.1 Dehumidification by refrigeration

Traditional refrigeration cycle dehumidification remains the most prevalent method for generating water from atmospheric humidity. This method circulates air over cooling coils connected in refrigeration cycle to bring the water in the air below its dew point. The dew point of the water is dependent on the vapour pressure and humidity and tends to be a relatively low temperature compared to the ambient conditions. To reach the dew point the air running through the unit will have to be cooled a considerable amount. This approach is expressed in Figure 1 below:

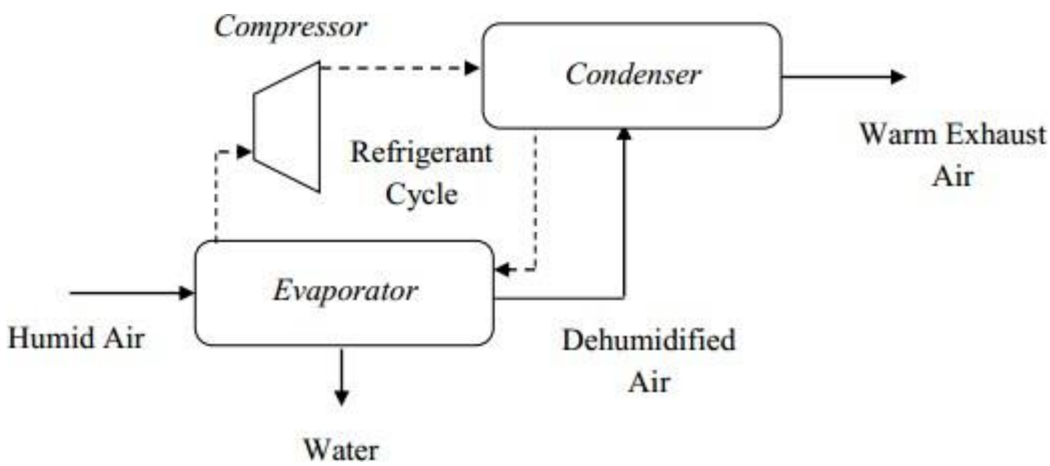


Fig – 1: Dehumidification by Refrigeration cycle

Refrigeration can be achieved by many methods. Some of these are discussed below:

A. Vapour Compression Method

Vapour-compression refrigeration is the most widely used method for air-conditioning in today's world. The vapour-compression consists of a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat to the atmosphere. Figure 2 depicts a single-stage vapour-compression system. Basically, the system has four components: a compressor, a condenser, a thermal expansion valve and an evaporator. Circulating refrigerant enters the compressor as saturated vapour and is compressed [1]. This results in high pressure which in turn is responsible for higher temperature. The compressed vapour then comes out as superheated vapour and attains a temperature and pressure at which condensation can take place with the help of cooling water or cooling air. That hot vapour is passed through a condenser where it is cooled and condensed. This is where the circulating refrigerant rejects heat from the system.

The condensed liquid refrigerant known as saturated liquid is next passed through an expansion valve where there is a sudden drop in pressure. This results in the adiabatic flash evaporation of the liquid refrigerant. The Joule-Thomson effect [2] as it is called lowers the temperature of the liquid and vapour refrigerant mixture which makes it colder than the temperature to be achieved (temperature of the enclosed space).

The cold mixture is passed through the coils in the evaporator. A fan circulates the warm air in the enclosed space across the coils carrying the cold refrigerant liquid and vapour mixture. That warm air evaporates the liquid part of the cold refrigerant and at the same time, the circulating air is cooled and as a result it lowers the temperature of the enclosed space to the temperature to be achieved. The circulating refrigerant absorbs and removes heat from the evaporator which is then rejected in the condenser and transferred by the water or air used in the condenser.

For the completion of the refrigeration cycle, the refrigerant vapour coming out of the evaporator which is again a saturated vapour is returned back into the compressor.

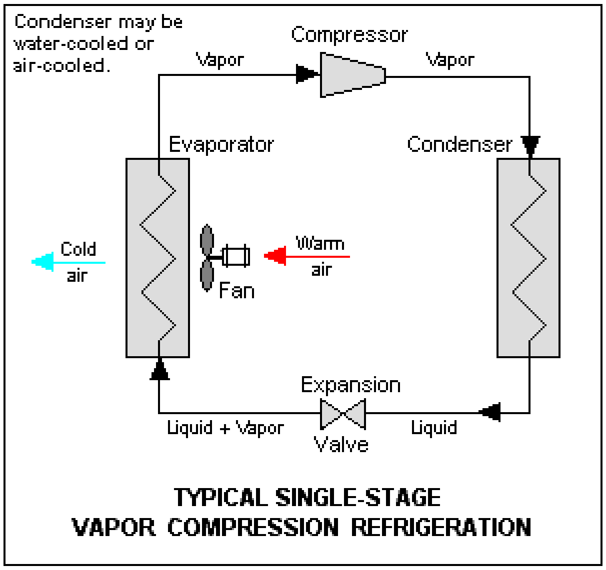


Fig – 2: Vapour Compression Refrigeration cycle

B. <u>Peltier cooling</u>

This method is exactly same as that of Vapour Compression Refrigeration method but here we use a Peltier device to achieve the required dew point temperature. Peltier device is compact, has less number of moving parts, is energy efficient and has a very long life span which requires very less maintenance.

➢ **<u>Principle of Peltier Device</u>**

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC) [5].

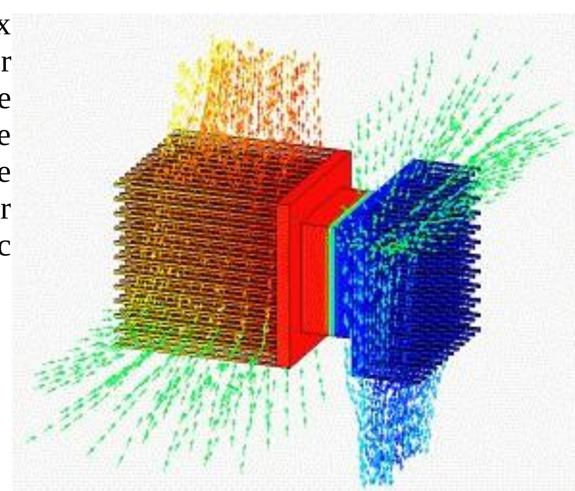


Fig – 3: Peltier device

1.2 Dehumidification by compressing atmospheric air so as to increase its dew point temperature

It is possible to compress humid air so much that it will condense at the ambient temperature. As pressure increases the dew point rises; thus, enough compression will force the dew point above the ambient temperature resulting in spontaneous condensation; heat will transfer from the pressurized humid air to the ambient air. Compressing air to extract water could potentially require pressures up to five times the ambient pressure. This will require a very sturdy tank that can handle high amounts of stress in its walls. This method has great potential for low energy demands, especially if one was able to recapture some of the energy in the compressed air using a turbine or

piston. The energy efficiency of this design option has great promise but it is heavily dependent on compressor and decompressor efficiency and humidity. Figure 5 below is a representation of this approach. The primary advantage of pressure dehumidification is the low energy requirement; the only unavoidable loss is the pressure applied to the water vapour. However, any inefficiency in the compression/decompression cycle is amplified by the large volume of air processed per unit water produced. Additionally, the rate of production when driven by natural convection cooling to the atmosphere is too slow for significant production; some mechanism to speed up this heat transfer needs to be implemented, increasing the energy cost. No existing atmospheric water generators utilize this approach.

1.3 Dehumidification by liquid desiccant method

A desiccant is a hygroscopic substance that induces or sustains a state of dryness (desiccation) in its vicinity. Commonly encountered pre-packaged desiccants are solids that absorb water.

Wet desiccation is a process where a brine solution is exposed to humid air in order to absorb water vapour from that air. The solution is then sent into a regenerator where the water vapour is extracted from the solution 2. This method has grown in popularity because of its efficiency and the ease with which it can be adapted to renewable energy, particularly solar.

A primary advantage to this approach is that the desiccant accomplishes the most difficult part of dehumidification, extracting the water from the air, without a direct expenditure of energy. The problem is thus recast into terms of regenerating the desiccant and capturing the resultant water. The main disadvantage of wet desiccation is the complexity that is introduced, both in terms of system and materials.

2. Filtration unit

The water obtained from the device after condensation is not fit for drinking. It contains a lot of germs and harmful bacteria which may cause diseases. Also, it contains suspended particles which needs to be filtered out.

This can be achieved by first passing the condensed water through activated carbon filter. Then it is subjected to UV light so as to kill the harmful microbes.

➢ <u>Literature Review:</u>

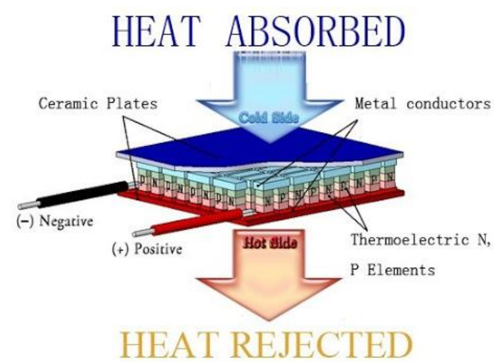
There are several studies in the literature focusing on atmospheric water harvesting using chillers and dehumidification by Vapour Compression Refrigeration Cycles, however there were some focusing on AWH using Peltier Modules. One of the works published in 2017 presented an insight on the experimental results of such model. The experimental investigation of a portable thermoelectric fresh water generator is presented. The mass flow rate of moist air, humidity and electric current, supplied to the Peltier modules are directly proportional to the amount of water generated. It is found that the placement of internal heat sink on the cold side of the Peltier modules in the cooling channel increases the water generated by the system by 81%. The maximum water generated is found to be **240ml for 10 hours** running of the system.

Another paper highlighted the application of atmospheric water generator in regions where there is water scarcity. Contingent upon the moistness and temperature of the air, the limit of water vapour noticeable all around will change. At the point when this kind of get together is kept under testing, the main considerations to be seen are the temperature. Thus, this paper conclude that an Atmospheric water generator is the one which is intended to meet the circumstances where the water turns into the emergency. This can be executed to confront the catastrophic events like surge, tidal wave, betrayed regions, and furthermore in country territories. As it uses air which is inexhaustible, there is an incredible breadth for this strategy in water requesting zones. Despite the fact that numerous organizations had effectively executed this thought for household erasure and the relative dampness. A shut circle or association is required to quantify these parameters proficiently and adequately. Through the estimation and perception, it is estimated that this framework is fit for delivering 2-5ml of water in three hours amid daytime at the required working condition.

In a different paper published in 2014 highlighted the use of Solar Power cells in the generator. Applying this system in a highly humid region almost 1 Litre of condensed water can be produced per hour during the day light, this is a promising result; then a more enhanced system can be designed that encounters higher power solar cells and also has the adroitness to store the excess energy during the day light that is to be used at night; indeed, the economic advantage of this kind of system is a bit obscure due to the relatively high installation cost. This idea can be extended further in future – 1) For large scale implementation, RO and UV water filter can be used for producing such water that meets the standard of WHO and BIS easily. 2) Peltier device has many types of models which are much efficient than TEC1. Those can be used. 3) As the project aims at producing water from atmosphere and keeping these device handy, large sized scrubbers are not used for better air filtration. Scrubbers can remove all the oxides from the air. For large implementation it can be handled. 4) The concept of this project can also be used as a better alternative in refrigeration science against conventional systems. It can also be observed in this way i.e., the usage of such low power semiconductor devices is indicating towards more prominent evolution of cooling engineering that is going to alter the whole scenario and myths about the power consumption of refrigeration science. Thus, in near future, such devices that are now limited within the project works can be used extensively.

The most recent work was done in April, 2020, highlighting some of the limitations of such device. The device made is tested and it was found that the water output from the device was at least **5ml/hour**. After diligent study and research, it was found that the following reasons may be responsible for the low water output of the device. 1. As such the cold surface area of the Peltier device is very less **(4cm*4cm)**. So, we propose to use a copper plate in contact with the cooling surface of the Peltier device because of its high conductivity expecting that the cold surface area will increase thereby increasing the condensation area. But finally, in the prototype when copper plates were used, proper thermal contact between the cold Peltier surface and the copper plate could not be achieved. This maybe the possible reason for low efficiency. 2. One of the most important limitations is the Peltier device itself. The Peltier we have found in market is not that much effective in producing water. While experimenting with the local available Peltier device it has been observed that these devices lose their ability frequently and doesn't work perfectly.

- **TEC Calculations:** The TEC using Peltier modules as a heat pump is fed directly by 12V DC power supply. The TEC modules will be extracting heat from the air flowing along the cold side channel and rejecting heat from the hot side channel of the module.
  Heat rejected around (Q_h) requires electric power (P_{el}) can be formulated one
  $Q_h = P_{el} + Q_c$



Q_c = Cooling Capacity given by

$$Q_c = (KT_C) - (0.5 \times I^2R) - (C \times (T_h - T_c))$$

Fig – 4: TEC Working Principle

I= Current T_c= Cold Side temperature T_h= Hot side Temperature = Thermal conduction K = Seebeck Coefficient

Condensation Ratio (CR), which means water produced per hour compared to that of ideal water vapour, that the incoming airflow can hold per hour (W_h) by the system.

$$W_h = 60 \times Q_{freq} \times \chi$$

Fig – 5: Peltier Device

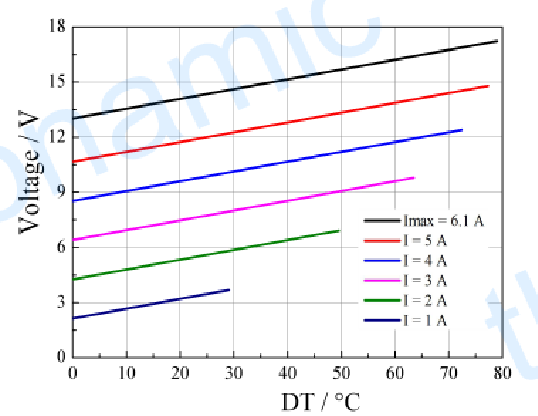
Calculations:

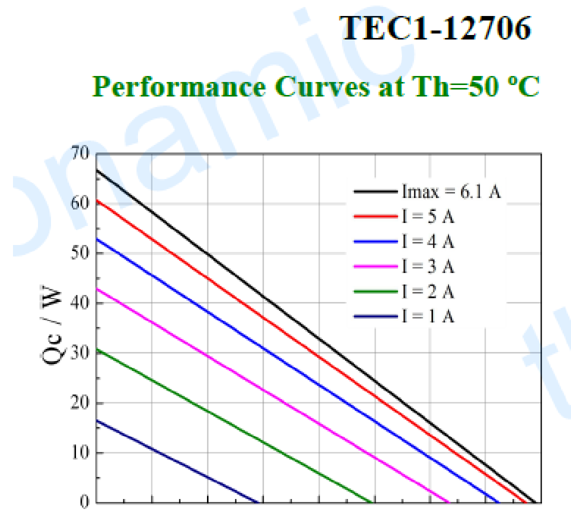
- TEC Charts
- Psychrometric Calculations
- Condensation Heat Transfer

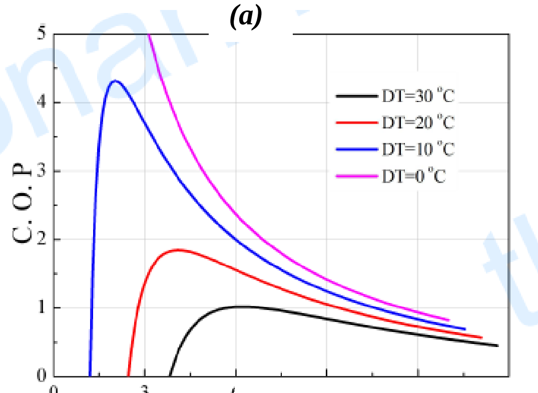
TEC Charts:

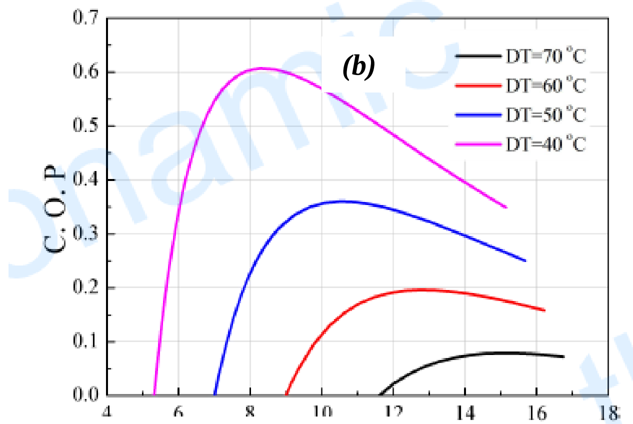
T_h = 50ºC: Hot side temperature at environment: dry air, N_2
DT_{max} = 79ºC: Temperature Difference between cold and hot side of the module when cooling capacity is zero at cold side
U_{max} = 17.2V: Voltage applied to the module at DT_{max}
I_{max} = 6.1 amps: DC current through the modules at DT_{max}
QC_{max} = 66.7W: Cooling capacity at cold side of the module under DT=0 ºC
AC resistance = 2.2 ohm: The module resistance is tested under AC
Tolerance (%) = ± 10 For thermal and electricity parameters

*Fig – 6: Performance Curves of TEC1-12706**









V (c) *erformance curves are taken from www.thermonamic.com* (d) V

- ## **Psychrometric Calculations:**
  - ### **Terms:**
    - **Ambient Conditions:**
      - Ambient Temperature = T_∞
      - Relative Humidity = **φ**
    - **Volume Flow Rate of Fan: Q**
    - **Specific Volume at T_∞ and φ: *v***
    - **Air Density: $\rho_a = 1/v$**
    - **Mass Flow Rate of Air: $m_a = \rho_a Q$**
    - **Hot Side Temperature: Th**
    - **Cold Side Temperature: Tc**
    - **Temperature Difference: DT**
    - **Current Passed through TEC: i**
    - **Corresponding Cooling Effect: Qc**
    - **Change in Enthalpy: Δh**

$$\Delta h = \frac{Qc}{ma}$$

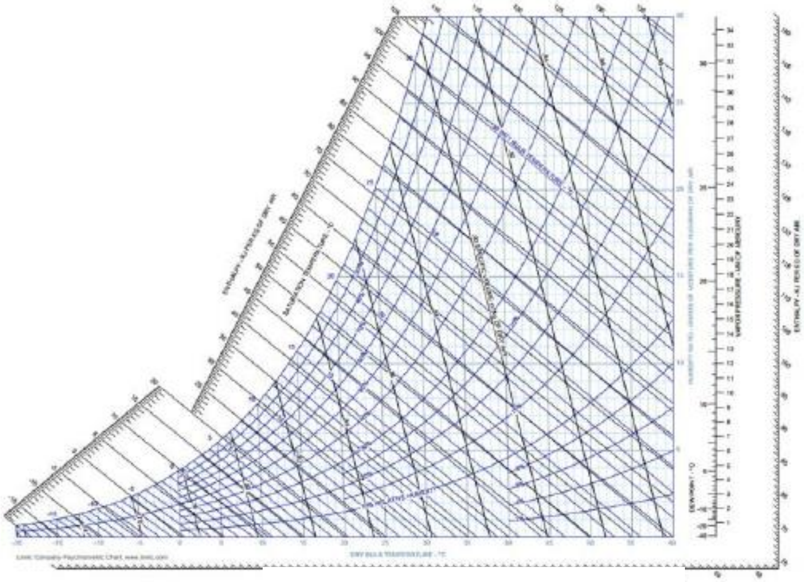


Fig – 7: Psychrometric Chart

  - ### **Assumptions:**
    - Steady State
    - Fins have Uniform Temperature (Base Temp = Fin Tip Temp)
    - No Radiation Heat Loss
    - Lumped Model
    - Film Condensation (Instead of Dropwise)

Dew-point Temperature (DPT)- It is the temp at which humidity of air starts condensing at the same rate at which it is evaporating at a given constant barometric pressure.

Dry-Bulb Temperature (DBT)- It is the temperature of air measured by a thermometer freely exposed to air, but shielded from radiation and moisture.

- DBT = T_∞

Relative Humidity (RH)-It is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at the same temperature.

  - ### **Formulation:**
    - At a particular ambient condition (T_∞ and φ), specific volume is *v*, thus density is $\rho_a = 1/v$.

      Volume Flow Rate of Fan is Q; therefore, Mass Flow Rate of Air is $m_a = \rho_a Q$.

      Starting Considerations: Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C

      Corresponding Cooling Effect of TEC = Qc; Change in Specific Enthalpy, $\Delta h = Qc/m_a$
    - On the Psychrometric Chart, for a particular ambient temperature, T_∞ (on the DBT axis) and Relative Humidity, φ (on the φ axis) a point is marked on the intersection of constant DBT and φ curves. Let this point be 'A'. The corresponding specific enthalpy, h is also marked (on the h axis). Let this point be 'C'. Specific Enthalpy is decreased by $\Delta h = Qc/m_a$ and marked on the h axis. This new point is 'D'.
    - Tc is marked on the DBT axis. Constant DBT line is drawn upto the Saturation curve (φ = 1). Let this point be point 'B' and it is joined with A. Constant h line is drawn from point D and it intersects the line AB. Let this point be 'E'.
    - From A, a horizontal constant absolute humidity (w) line is drawn meeting the w axis. From E, another constant w line is drawn. $\Delta w = w_a - w_e$
    - Mass of Water Condensed per unit second: **m_{cond}**, $mcond = \Delta w \times ma$
      Therefore, in 1hr, total mass of water condensed,

$\underline{m_{cond} = \Delta w \times m_a \times 3600}$ (gm/hr)

Fig – 8: Plot on Psychrometric Chart.

$\underline{T_\infty = 30\ ^\circ C}$

$\underline{\varphi = 50\ \%}$

$\underline{Q = 150 m^3/hr}$

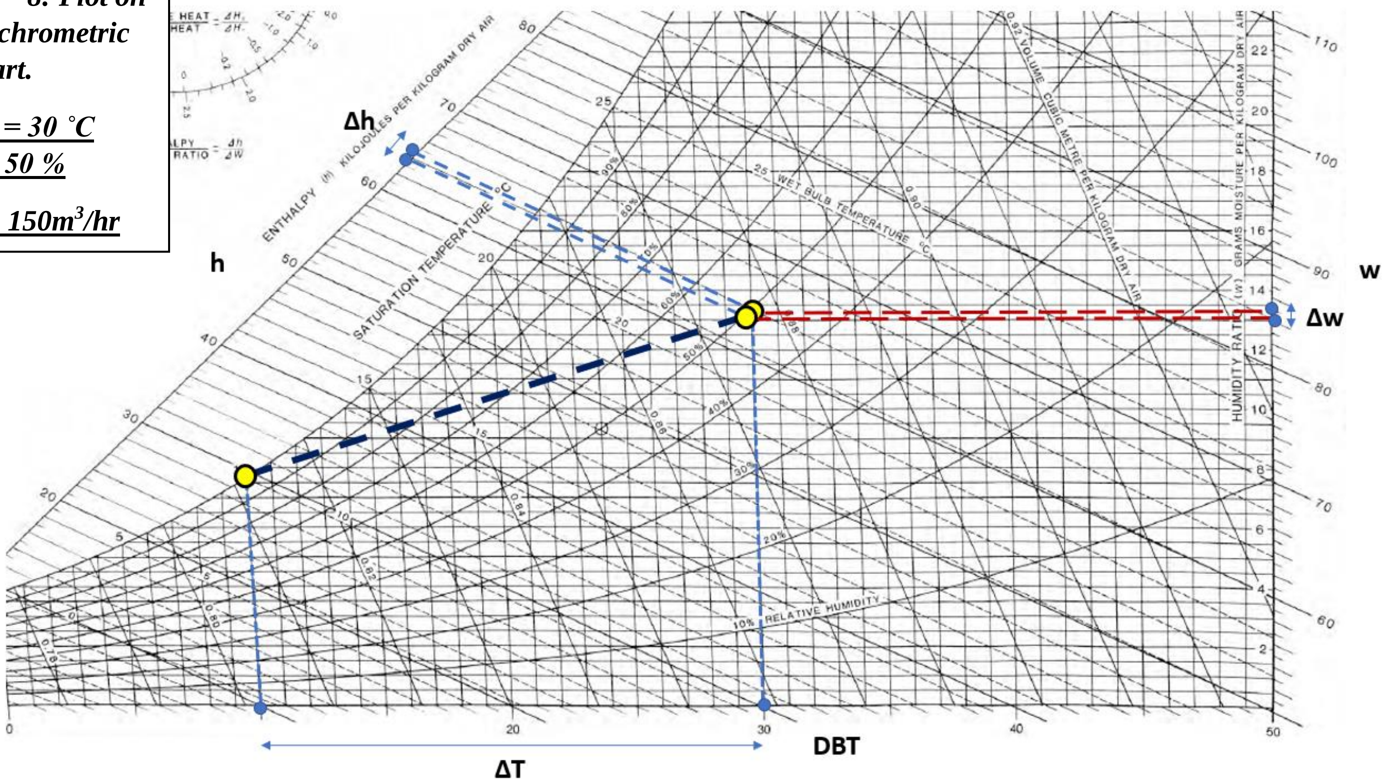
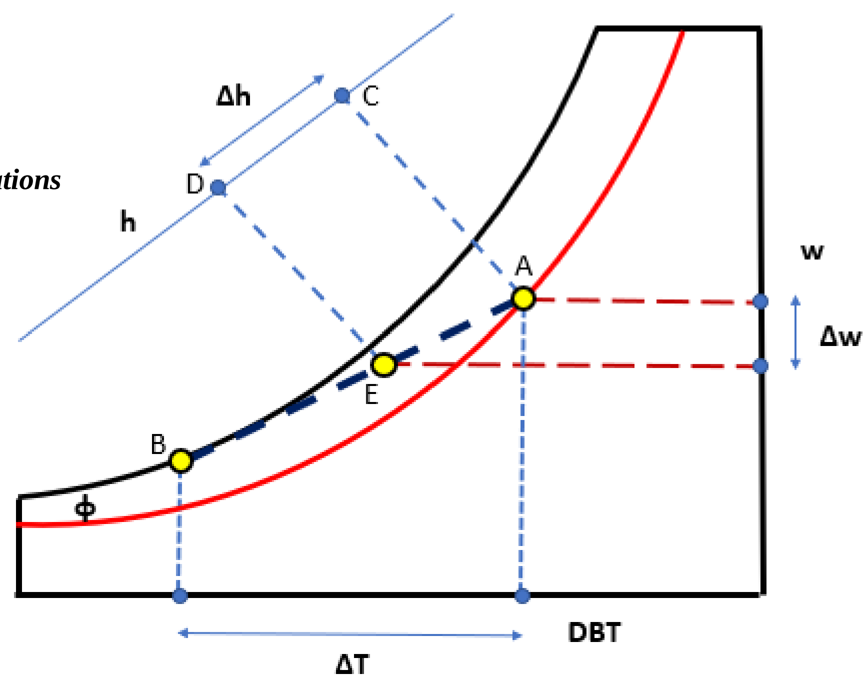


Fig – 9: Schematic of Psychrometric Calculations



- **Ambient Conditions:** $\underline{T_\infty = 25 – 35\ ^\circ C}$ and $\underline{\varphi = 50 – 80\ \%}$
- **Fan:** Q = 150m^3/hr = 0.04167 m^3/s
- **$\underline{T_\infty = 25\ ^\circ C}$**
  - **<u>Case – 1</u>:** **$\underline{\varphi = 50\%}$**; v = 0.8575 m3/kg; $\rho_a = 1/v$ = 1.166 kg/m3; $m_a = \rho_a Q$ = 0.04858 kg/s. Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.

Corresponding Cooling Effect of TEC = Qc = 30W.
Change in Specific Enthalpy, Δh = Qc/m_a = (30 W/s)/ (0.04858 kg/s) = 0.6175 kJ/kg.
In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 26.23 gm**

- **<u>Case – 2</u>: <u>φ = 60%</u>;** *v* = 0.8615 m3/kg; ρ_a = 1/*v* = 1.16 kg/m3; m_a = ρ_a Q = 0.04837 kg/s.
  Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.
  Corresponding Cooling Effect of TEC = Qc = 30W.
  Change in Specific Enthalpy, Δh = Qc/m_a = 0.6203 kJ/kg.
  In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 43.53 gm**

- **<u>Case – 3</u>: <u>φ = 70%</u>;** *v* = 0.863 m3/kg; ρ_a = 1/*v* = 1.158 kg/m3; m_a = ρ_a Q = 0.04828 kg/s.
  Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.
  Corresponding Cooling Effect of TEC = Qc = 30W.
  Change in Specific Enthalpy, Δh = Qc/m_a = 0.6213 kJ/kg.
  In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 69.53 gm**

  Similarly, for **<u>φ = 80%</u>;** m_a = 0.04812 kg/s; Δh = 0.623 kJ/kg; $\boldsymbol{mcond}$ **= 138. 58 gm/hr.**

- **<u>T_∞ = 30 ˚C</u>**
  - **<u>Case – 1</u>: <u>φ = 50%</u>;** *v* = 0.877 m3/kg; m_a = 0.0475 kg/s.
    Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.
    Corresponding Cooling Effect of TEC = Qc = 30W.
    Change in Specific Enthalpy, Δh = Qc/m_a = 0.632 kJ/kg.
    In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 68.4 gm**

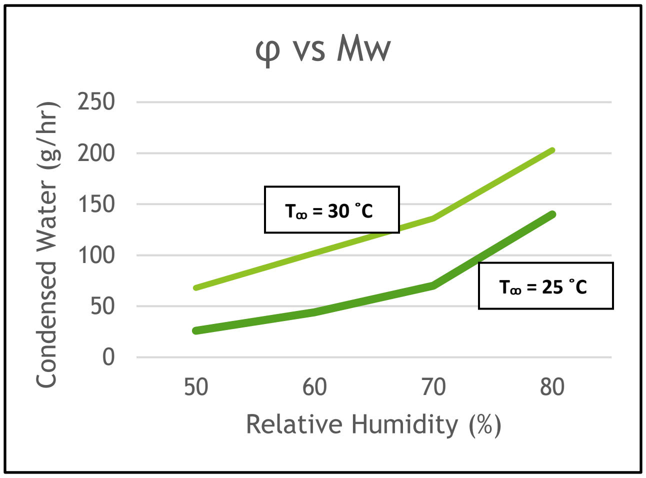
  - **<u>Case – 2</u>: <u>φ = 60%</u>;** *v* = 0.881 m3/kg; m_a = 0.0473 kg/s.
    Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.
    Corresponding Cooling Effect of TEC = Qc = 30W.
    Change in Specific Enthalpy, Δh = Qc/m_a = 0.635 kJ/kg.
    In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 102.168 gm**

  - **<u>Case – 3</u>: <u>φ = 70%</u>;** *v* = 0.885 m3/kg; m_a = 0.0471 kg/s.
    Th = 50˚C (fixed), i = 5amp (fixed), DT = 40˚C (fixed). Therefore, Tc = 10˚C.
    Corresponding Cooling Effect of TEC = Qc = 30W.
    Change in Specific Enthalpy, Δh = Qc/m_a = 0.637 kJ/kg.
    In 1hr, $\boldsymbol{mcond = \Delta w \times ma \times 3600}$ **= 135.648 gm**

    Similarly, for **<u>φ = 80%</u>;** m_a = 0.0469 kg/s; Δh = 0.639 kJ/kg; $\boldsymbol{mcond}$ **= 202.6 gm/hr.**

    In tabular form

T_∞ (˚C)	φ (%)	m_w (g/hr)
25	50	26
	60	44
	70	70
	80	140



T∞ (˚C)	φ (%)	mw (g/hr)
30	50	68
	60	102
	70	136
	80	203

Fig – 10: m_{cond} vs φ curves

The above analysis is on the maximum amount of condensate formation that can take place on the fins and not the actual amount of condensate that can be collected.

- **NOTE:** Δh increases => mcond increases.

  $(T_\infty - T_c)$ increases => mcond increases.

  But, Δh increases => $(T_\infty - T_c)$ decreases.

- **Condensation Heat Transfer:**
  The total heat transfer to the surface may be obtained by the following formula of Newton's law of cooling:

  $$q = h_L A\,(T_{sat} - T_s)$$

  The total condensation rate may then be determined from the relation:

  $$m = \frac{q}{hfg'} = \frac{h_L A\,(Tsat - Ts)}{hfg'}$$

  Where $h_{fg'}$ = Modified Latent Heat of Condensation
  h_L = Average Convective Heat Transfer Coefficient.
  A = Heat Transfer Area = Area of Fins
  T_{sat} = Saturation Temperature for Condensation
  T_s = Surface Temperature of the Fins = Assumed to be the Temperature of the Cold Side of Peltier.

  - $$h_L = 0.943\left[\frac{g\rho_l(\rho_l - \rho_v)k_l^3\,hfg'}{\mu_l(Tsat - Ts)L}\right]^{1/4}$$ where k_l = Thermal conductivity of liquid.
    ρ_l = Density of Water; ρ_v = Vapour Density; μ_l = Coefficient of viscosity of liquid.

  - $h_{fg'} = h_{fg}\,(1+ 0.68\,Ja)$ where hfg = Latent Heat of Condensation; Ja = Jakob Number.

  - Assumptions:
    - Film Condensation instead of Dropwise condensation.
      Film Condensation has less Heat transfer coefficient compared to Dropwise Condensation.
    - Ts = Tc = Uniform throughout the Fins. Base Temp of Vertical Fins = Tip Temp of the Fins.
    - Flow is assumed to be Laminar. Condensate Flow is constant.
    - Negligible concentration of non-condensable gases.

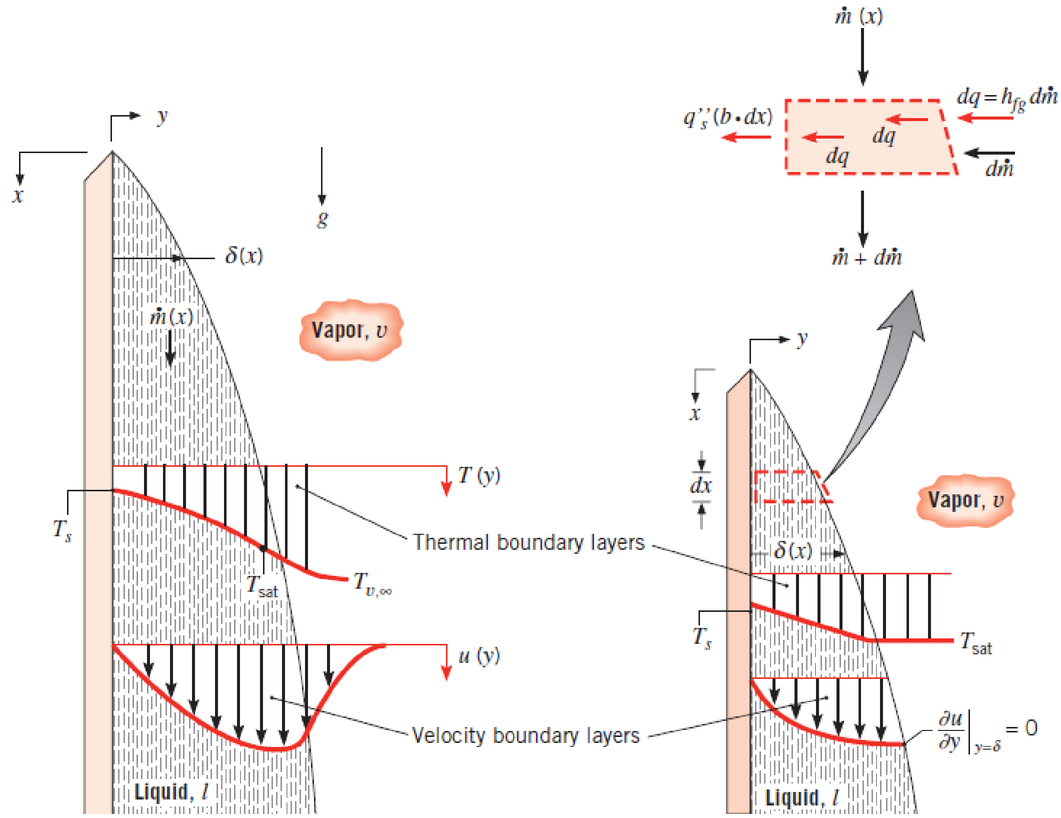


Fig – 11: Film Condensation in Vertical Plate

- **<u>Conclusion:</u>**
  - From the above calculations, it can be concluded that theoretically it is possible for Atmospheric Temp at 25˚C, Relative humidity of 50%, maximum 25ml of water can be condensed on the surface of the fins by 4 Peltier Units, when Lumped Analysis is done. However, practically because of various constraints like Non-uniform temperature of the fins, formation of Condensate Film on the Heat Transfer Surface, dropwise condensation, turbulence in air flow, significantly less amount of the condensate is collected at the bottom. It is inferred from different journals that maximum amount of water collected per hour is from **<u>5ml – 10ml</u>** by using 4 Peltier Units (TEC1 – 12706).
  - As humidity increases, amount of condensate collected increases. As atmospheric temperature increases, amount of condensate collected increases. For T_∞ = 30˚C - 35˚C and relative humidity of φ = 70% - 80%, the amount of water collected becomes substantially higher (around 25ml).
  - After Practical experiments under different operating conditions - T_∞, φ, CFM of Fan, the results should be evaluated and tallied with the theoretical values.

- <u>**Schematic of the Working Model:**</u>

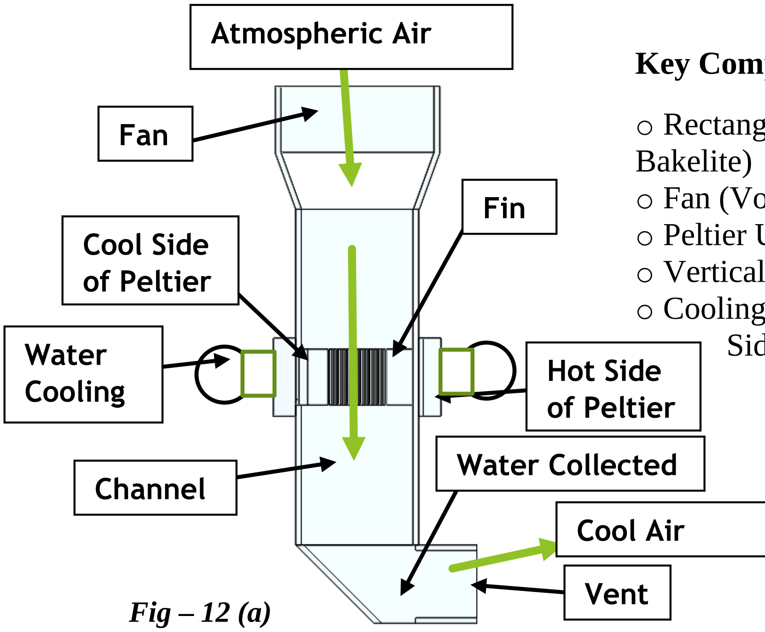


Fig – 12 (a)

Key Components:

○ Rectangular Channel (Cross Section: 100 x 100 mm^2; Bakelite)
○ Fan (Volume Flow Rate = 150 m^3/hr)
○ Peltier Unit (4 x TEC1- 12706) – 40 x 40 mm^2 Plates.
○ Vertical Fins, Mesh
○ Cooling Unit (Liquid Cooling using Pump - To Cool the Hot Side of the Peltier Unit)

Fig – 12: Schematic Diagram of Experimental Setup

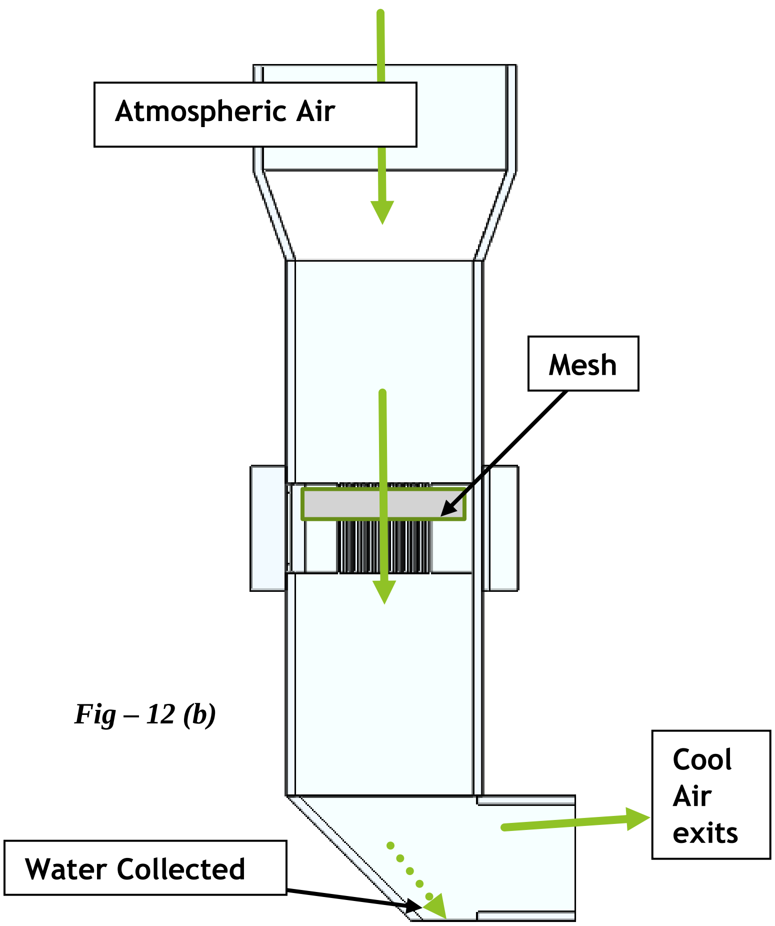


Fig – 12 (b)

<u>Experimental Set Up</u>:

The Setup was modified constantly during evaluation, taking effectiveness, availability of materials and economic considerations into account. The final model is as –

- It is a straight Rectangular Channel, made up of Bakelite. Top of this channel lies the Exhaust Fan to Blow Air into the Channel, the Volume Flow Rate of the Fan can be manually controlled. Air passes through the channel.
- 4 Peltier Units surround the Periphery of the Channel at the Mid location of the Channel. Each Peltier Unit is located at each wall. The Cold Side is inside the Channel while the Hot Side is outside the Channel.
- Series of Aluminium Vertical Fins emerge from the Cold Side of the Peltier. As the Air flows through these fins, condensation takes place and water droplets are formed on the Fin Surface.
- As the Air reaches the bottom, It passes through the vent while the condensate is collected at the bottom.

- One of the most important aspect of this model is to maintain the temperature difference across the Cold and Hot side of the Peltier Model. The Hot side is supposed to be maintained at 50˚C, for which a particular cooling arrangement is required. It can be either Water cooled or Air Cooled. To minimise Power Requirement for Fan and to increase the Rate of cooling by high value of Convective Heat

Transfer Coefficient, Water cooling arrangement is preferred. Pump is used to pump in Cool water while pump out the hot water.

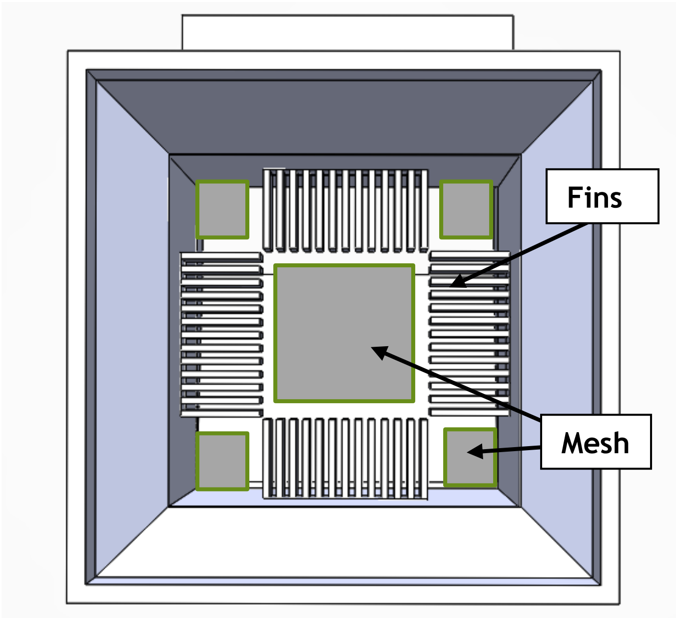


Fig – 13 (a)

- To increase the effectiveness of the Condensation, it is required to forcibly allow the Incoming air to pass through the space between the fins only. For this case, we cover the remaining portion of the cross section by mesh. Water condensation takes place at the Mesh as well and forms a layer of resistance through which air cannot pass. Thus, air is forced to pass through the remaining space left.

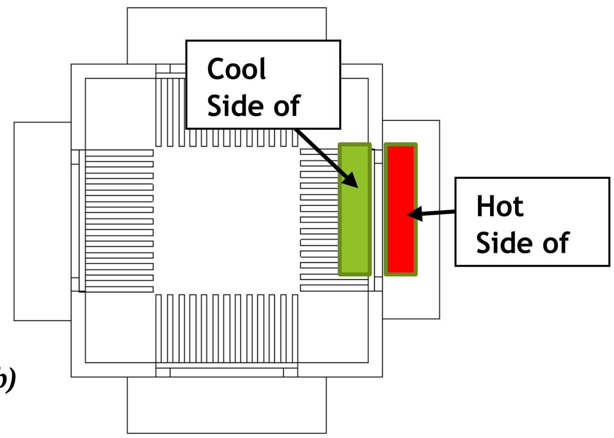


Fig – 13 (b)

Fig – 13: Top View of the 3D Model of the Setup

- **<u>3D Model of Setup:</u> (Channel excluding the Hot Side of the Peltier Module)**

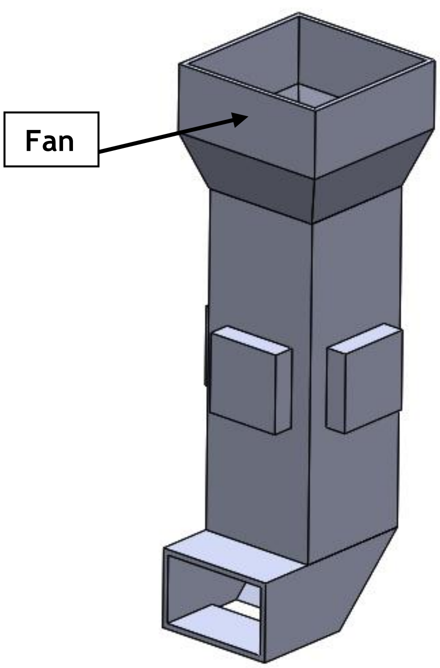


Fig – 14 (a): Dimetric View

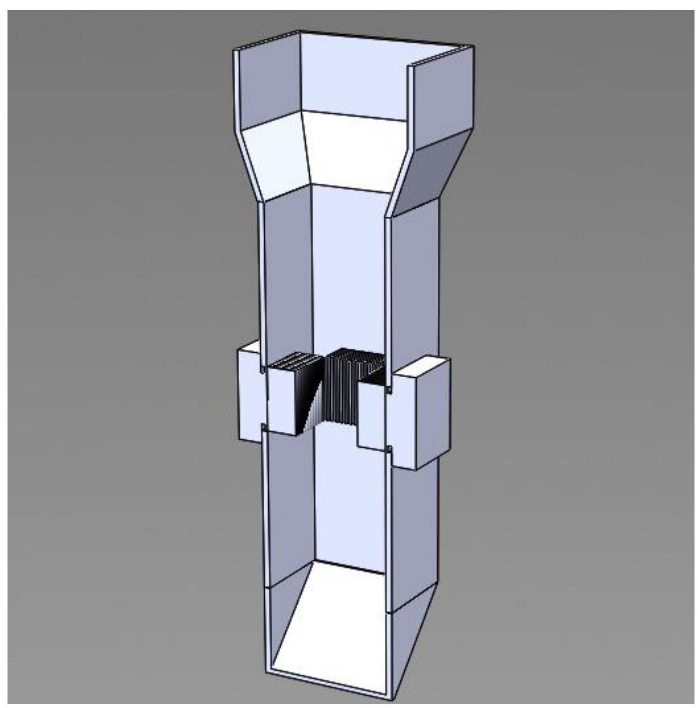
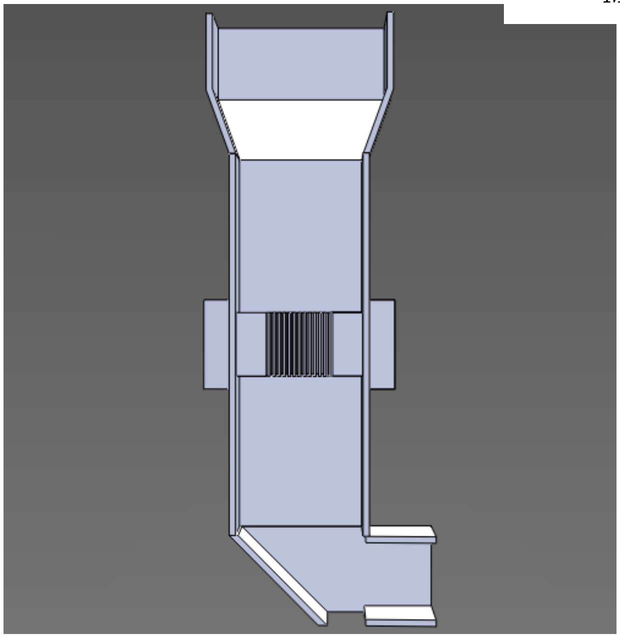


Fig – 14 (b): Cross Section View

Fig – 14: Top View of the 3D Model of the Setup



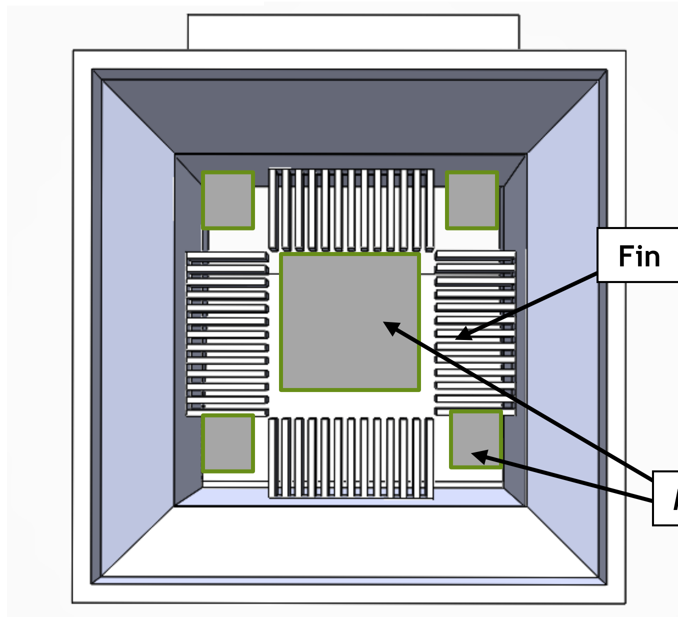
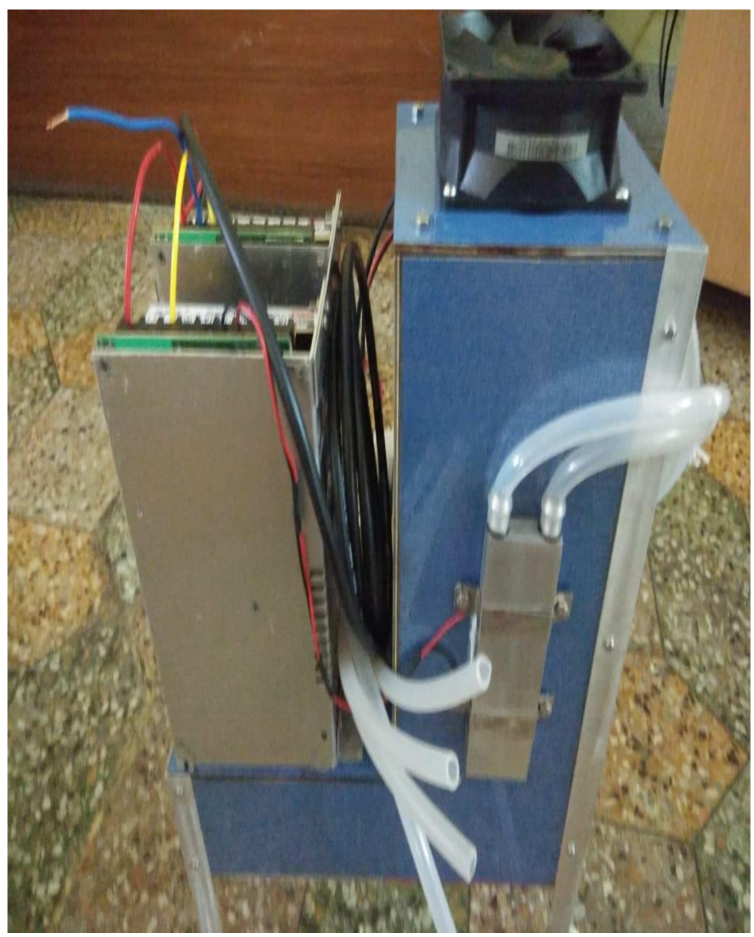


Fig – 14 (c): Side View

Fig – 14(d): Top View

EXPERIMENTAL SETUP




64MP AI QUAD CAMERA

EXPERIMENTAL PROCEDURE

Case 1: BY USING AIR-COOLED SYSTEM

- The setup is switched ON and we use only the AIR-COOLED SYSTEM.
- We firstly measured the humidity of the room before experiment. Using hygrometer.
- The voltage and current are measured across each device using voltmeter and ammeter respectively.
- As soon as power is provided the suction pump drives the air from inlet towards outlet.
- We experience sudden drop of temperature of the heat sink Due to use of TEC-12706 Thermocouple.
- After 5 minutes, we observed due formation in the heat sink.
- After allowing the system to be in steady state, water collection is taken place in the collection chamber.
- Then a TDS equipment is used to verify if the water is safe for drinking.
- But after some time, we encountered an issue of temperature rising in the heat exchanger
- The above process is repeated 5 times for different power supply and different humidity environment, each run is carried out at an interval of 2 hour.

Case 2: BY USING LIQUID-COOLED SYSTEM

- The setup is switched ON and we use only the LIQUID-COOLED SYSTEM.
- We firstly measured the humidity of the room before experiment. Using hygrometer.
- The voltage and current are measured across each device using voltmeter and ammeter respectively.
- As soon as power is provided the suction pump drives the air from inlet towards outlet.
- We experience sudden drop of temperature of the heat sink Due to use of TEC-12706 Thermocouple.
- After 2.46 minutes, we observed due formation in the heat sink.
- After allowing the system to be in steady state, water collection is taken place in the collection chamber.
- Then a TDS equipment is used to verify if the water is safe for drinking.
- But after some time, we encountered THE same issue of temperature rising in the heat exchanger but this time the efficiency was good to maintain high efficiency the LIQUID/COOLANT for the cooling purpose used uses heat exchangers. (case-3)
- The above process is repeated 5 times for different power supply and different humidity environment, each run is carried out at an interval of 2 hour.

Case 3: BY USING HYBRID-COOLED SYSTEM (LIQUID+AIR COOLED)

- The setup is switched ON and we use BOTH COOLING SYSTEM INCORPORATED.
- We firstly measured the humidity of the room before experiment. Using hygrometer.
- The voltage and current are measured across each device using voltmeter and ammeter respectively.
- As soon as power is provided the suction pump drives the air from inlet towards outlet.
- We experience sudden drop of temperature of the heat sink Due to use of TEC-12706 Thermocouple.
- After 1.54 minutes, we observed due formation in the heat sink.
- After allowing the system to be in steady state, water collection is taken place in the collection chamber.
- Then a TDS equipment is used to verify if the water is safe for drinking.
- AS BOTH HEAT EXCHANGERS are used the efficiency is increased and the problem we encountered initially was resolved upto some extent but also our power input has also increased
- The above process is repeated 5 times for different power supply and different humidity environment, each run is carried out at an interval of 2 hour.

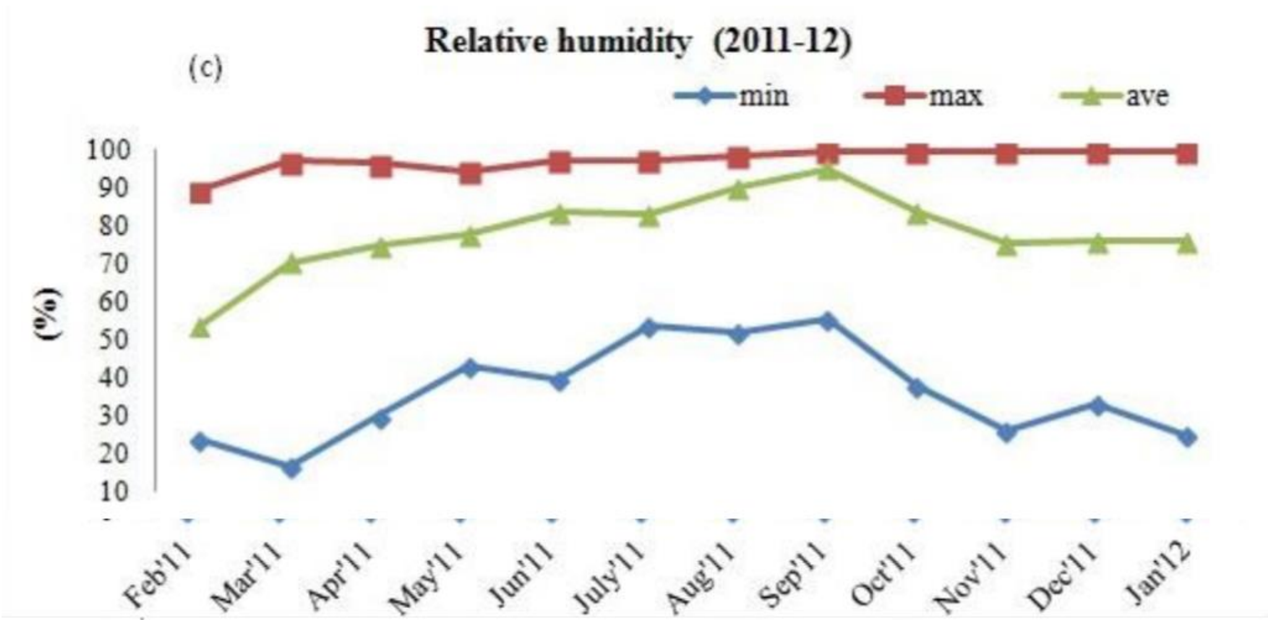
➢ Conclusion:

After carrying out various calculations the results obtained are tallied and analyzed. Earlier we had calculated the dew point temperatures required for different atmospheric conditions.

From all the above inferences we can finally conclude that if ambient temperature is 35^0C or higher and if relative humidity is greater than 50% then the device will function well and it will start condensing water. Thus, in order to find if the device will work in the coastal areas of India

- Meteorological data are collected from internet for major coastal cities of India and the data are presented below:

Sundarbans



PURI

Monthly Averaged Relative Humidity (%)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000	49.68	68.94	60.61	77.98	78.51	84.37	82.50	81.86	81.07	74.19	54.16	43.30	69.72
2001	51.05	63.10	77.95	75.83	83.77	82.68	84.44	84.83	83.07	82.07	73.22	50.51	74.42
2002	66.46	61.62	71.27	80.11	81.51	85.15	81.70	82.57	82.60	77.50	62.43	50.69	73.69
2003	56.90	78.35	73.71	80.10	83.21	85.38	86.83	86.10	84.06	85.04	63.00	58.15	76.71
2004	61.36	56.73	65.13	84.47	79.58	80.45	83.62	78.44	83.90	77.71	51.21	53.88	71.41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Mumbai

Monthly Averaged Relative Humidity (%)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000	57.28	59.72	67.23	77.99	76.51	80.69	81.00	80.83	78.30	75.89	56.42	56.83	70.76
2001	61.43	69.19	72.98	70.09	79.36	80.28	80.25	80.77	79.74	70.97	53.86	56.72	71.32
2002	54.21	67.96	69.83	73.79	79.82	79.88	79.31	78.76	75.44	71.31	59.96	60.77	70.93
2003	66.20	75.84	70.40	77.51	76.43	81.42	81.20	81.53	80.16	72.65	62.38	59.32	73.72
2004	57.51	69.49	69.34	74.63	73.64	77.55	78.99	80.08	76.80	64.89	61.01	53.10	69.72
2005	53.33	64.33	76.40	68.14	72.67	76.64	80.63	79.71	79.16	71.04	57.18	50.60	69.18
2000 - 2005	58.33	67.76	71.03	73.69	76.41	79.41	80.23	80.28	78.27	71.12	58.47	56.22	70.93
Min Dif	-5.00	-8.04	-3.80	-5.56	-3.73	-2.77	-1.24	-1.52	-2.83	-6.24	-4.61	-5.63	-4.25
Max Dif	7.87	8.09	5.37	4.30	3.42	2.01	0.97	1.25	1.89	4.77	3.91	4.55	4.03

Kanyakumari

Monthly Averaged Relative Humidity (%)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2000	68.28	70.48	70.50	82.31	81.94	80.39	77.51	81.37	82.59	81.41	72.06	65.04	76.15
2001	67.37	72.49	73.22	85.64	83.84	80.90	82.74	81.69	77.48	84.32	80.15	73.93	78.67
2002	67.81	66.84	70.21	85.57	83.87	81.42	80.60	83.03	75.42	83.33	84.33	72.90	77.99
2003	65.08	73.20	74.17	84.11	83.42	83.64	82.80	82.41	81.99	81.68	80.93	70.04	78.62
2004	67.02	61.50	70.24	84.56	80.26	79.96	81.26	77.64	80.71	83.53	79.24	68.18	76.20
2005	68.77	64.88	75.28	82.49	82.32	80.06	82.45	71.65	78.89	81.08	81.79	78.31	77.40
2000 - 2005	67.39	68.23	72.27	84.11	82.61	81.06	81.23	79.63	79.51	82.56	79.75	71.40	77.48
Min Dif	-2.31	-6.73	-2.06	-1.80	-2.35	-1.10	-3.72	-7.98	-4.09	-1.48	-7.69	-6.36	-3.97
Max Dif	1.39	4.96	3.01	1.52	1.26	2.58	1.57	3.39	3.08	1.76	4.58	6.91	3.00

From the above meteorological data, it is clear that the relative humidity of coastal cities in India remains above 50% throughout the year. Hence the developed device will work round the year without any problems.

➢ References:

- Experimental investigations on a portable fresh water generator using a thermoelectric cooler V. P. Joshi, V. S. Joshi, H. A. Kothari, M. D. Mahajan, M. B. Chaudhari, K. D. Sant Vishwakarma Institute of Technology, Bibwewadi, Pune-411037, India
- FUNDAMENTALS OF HEAT & MASS TRANSFER – Frank P. Incropera and David P. Dewitt
- AUTOMATED ATMOSPHERIC WATER GENERATOR C. S. Abirami1, A. Anitha2, V. Kishore Kumar3 1,2,3Department of Electronics Communication and Engineering, IFET College of Engineering, Villupuram, India
- A Project on Atmospheric Water Generator with the Concept of Peltier Effect Aditya Nandy1, Sharmi Saha2, Souradeep Ganguly3, Sharmistha Chattopadhyay4
- PORTABLE ATMOSPHERIC WATER GENERATOR Sajil V.P1, Ameer E.A2, Anfal P3 Aswin Vas C4, Binshad Ibnu Masood5, Faris Ahamad6, Vivek V.N7 1Lecturer, Department of Mechanical Engineering, Orphanage Polytechnic College, Edavanna, Kerala, India. 2,3,4,5,6,7Diploma students, Department of Mechanical Engineering, Orphanage Polytechnic College, Edavanna, Kerala, India.

Fund Summary

Sl No.	Description	Amount (in Rs)
1.	Total Grant Sanctioned	48268/-
2.	Total amount spent (as of 30/06/21): Bill(1+2+3+4)	47419/-
4.	Amount received from ISHRAE (as of 30/06/21)	24134/-
5.	**Amount Requested :**	**23285/-**

Concepts International

Engineering , Scientific Instrument & Equipment Division
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Department of Mechanical Engineering
Jadavpur Univewrsity , Kolkata - 700032

GST registration No.: 19AGSPG0364K3ZY

BANK DETAIL

Bank : State Bank of India
Branch : Jadavpur University
Account No. : 11079700635
IFS Code : SBIN0000093

COMPOSITION SCHEME UNDER GST

SL .	Description	Quantity	Unit Price	Amount
1	Heavy Angle Structure with Epoxy Paint	1 No.	5600.00	5600.00
2	Thicked Insulated Board , 1552 Sq. Inch.	1552 sq. in	2.10	3259.20
3	Pt 100 Sensor with 2 mtr. Teflon Wire	1 No.	780.00	780.00
			Total	9639.20
			Rounded Off	-0.20
			Grand Total	9639.00

Rupees Nine Thousand Six Hundred Thirty Nine Only

Invoice No. CI / 01 / 2021 - 22 **Date** 07.04.2021
Challan No. 1 **Date** 07.04.2021
Order No. **Date**

Organization / Costomar GST registration **19AAAJJ0500E1ZU**

For Conceps International

Autorised signatory

Concepts International

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BANK DETAIL

Bank : State Bank of India
Branch : Jadavpur University
Account No. : 11079700635
IFS Code : SBIN0000093

COMPOSITION SCHEME UNDER GST

SL.	Description	Quantity	Unit Price	Amount
1	Insulated Board Structure for Fog Harvester	1 No.	6860.00	6860.00
2	Aluminum Water Cooling Block , Size : 150 X 40 X 12 mm	2 Nos.	880.00	1760.00

Total	8620.00
Rounded Off	0.00
Grand Total	8620.00

Rupees Eight Thousand Six Hundred Twenty Only

Invoice No. **CI / 04 / 2021 - 22** **Date** 09.04.2021
Challan No. 4 **Date** 09.04.2021
Order No. **Date**

Organization / Costomar GST registration **19AAAJJ0500E1ZU**

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Engineering , Scientific Instrument & Equipment Division
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Jadavpur Univewrsity , Kolkata - 700032

GST registration No.: 19AGSPG0364K3ZY

BANK DETAIL

Bank : State Bank of India
Branch : Jadavpur University
Account No. : 11079700635
IFS Code : SBIN0000093

COMPOSITION SCHEME UNDER GST

SL .	Description	Quantity	Unit Price	Amount
1	Diaphragm pump with bypass line arrangement	1 No.	4800.00	4800.00
2	Silicone tube , ID : 5.6 mm & OD : 9.5 mm	10 Mtr.	385.00	3850.00
3	3 core cable with 15 amps top (3 mtr. long)	1 No.	540.00	540.00

Total	9190.00
Rounded Off	0.00
Grand Total	9190.00

Rupees Nine Thousand One Hundred Ninety Only

Invoice No. CI / 05 / 2021 - 22 **Date** 12.04.2021
Challan No. 5 **Date** 12.04.2021
Order No. **Date**

Organization / Costomar GST registration **19AAAJJ0500E1ZU**

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Jadavpur University
Kolkata - 700032

GST registration No.: 19AANFC6835C1ZB

BANK DETAIL

Bank : State Bank of India
Branch : Jadavpur University
Account No. : 11079700635
IFS Code : SBIN0000093

COMPOSITION SCHEME UNDER GST

SL.	Description	Quantity	Unit Price	Amount
1	Atmospheric Fog Harvester :-			
	* Heavy duty fan with fins, Size : 100 X 100 mm Made of engineering plastic & cast aluminum	2 Nos.	2950.00	5900.00
	* Power Ful Semiconductor Refrigeration Chip Capacity : 12 V / 15 Amp. Make : Ecluma	2 Nos.	2270.00	4540.00
	* Heavy Duty Circulator, Size : 90 X 90 mm Make :	2 No.	1360.00	2720.00
	* 12 Volt, 20 Amp. SMPS Power Supply Make : ARTIS	3 Nos.	2270.00	6810.00

Total	19970.00
Rounded Off	0.00
Grand Total	19970.00

Rupees Nineteen Thousand Nine Hundred Seventy Only

Invoice No. CI / 22 / 2020 - 21 **Date** 15.02.2021
Challan No. 22 **Date** 15.02.2021
Order No. **Date**

Organization / Costomar GST registration **19AAAJJ0500E1ZU**

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