STUDY ON ENHANCING THE EFFICIENCY OF ZERO LIQUID SYSTEM IN TANNERY SECTOR

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LIST OF SYMBOLS AND ABBREVIATIONS

Y_1' - Humidity at of Air at Inlet

Y_2' - Humidity at of Air at Outlet

$m_{\text{dry air}}$ - Mass of Dry Air

Y_{as}' - Saturation Humidity

K_y - Mass transfer Co-Efficient of Air-Water System

Z - Height of the Atomizer to be placed

RPM - Revolutions per minute

m - Metre

DBT - Dry Bulb Temperature

WBT - Wet Bulb Temperature

1. INTRODUCTION

India has emerged as a major tanning centre of the world. The main centres of tanning in India Kanpur, Unnao, Jalandhar in the north and Kolkata in the east; and Chennai, Ranipet, Ambur, Vaniyambadi, and Dindigul in the south. Being a water intensive process, tanning generates considerable volume of waste water. On the average, about 28-30 cubic meter per hour of waste water is generated while processing one ton of raw material. In the process of leather making, a number of chemicals are used in the tanning and post tanning processes. It has been observed that the amount of chemicals absorbed by the leather is not more than 20%, the rest 80% being washed away with the process water. The effluent of tanneries, thus, carries a huge volume of a cocktail of chemicals. Besides, the solid waste generated while processing hides and skins works out to about 65% of the weight of the raw material. This includes hair, flesh, trimmings of raw, semi processed or finished leather, shavings and leather dust, besides the sludge generated by waste water treatment plants. The waste generated by tanning process thus poses a major challenge of treatment and management. This study deals about wastewater management. In India all the tanneries are bound to have/achieve Zero Liquid Discharge with the twin objectives of recovery of process water and prevention of contamination. This calls for employment of RO/mechanical evaporation systems/Multi effect Evaporator system. In terms of capital investment, it works out to more than Rs. 1.5 lakhs additional investment per cubic meter of waste water treated. With regard to O&M cost, it is about Rs.120 per cubic meter, about 4 times the operational cost of conventional treatment systems. About 65% of the cost of operation of a ZLD system is accounted for energy and fuel.

The major issues are: Very highly energy intensive 20-40 kWh/m3 as against 2-4 kWh/m3 for desalination, Corrosion and scaling of the evaporators resulting reduced life and efficiency and also frequent interruptions and downtime affect processing capacity.

The main aim of the work is to increase the efficiency of the existing evaporator used for concentrating the tannery effluent. The evaporator works on the principle of using ambient air instead of hot air for the process of evaporation. The average inlet and outlet concentration for the existing setup were 40483 mg/l to 43306 mg/l with mass of dry air as 38570 kg/h and the maximum water losses for 1000 LPH was 38.57 kg/h. In the existing unit, atomizer is placed at a height of 1.8 meter from the bottom, height calculations are performed for appropriate placement of atomizer with the humidity values.

At first modification, hot steam introduced along with ambient air and a partition was included to direct the air flow towards the atomizer for higher residence time and contact area. Maximum water loss for 1000LPH (Standard Feed Flow Rate) was 32.758 kg/h and average concentration changed from 37940mg/l to 40128.667 mg/l with mass of dry air 26857.33 kg/h due to air flow restrictions.

Another modification was suggested to increase the capacity of forced air draft fan to provide high pressure air flow rate and the average inlet and outlet concentration for this setup were 41392mg/l to 53960mg/l with mass of dry air 43060 kg/hr. Maximum water loss for 1000 LPH (Standard Feed Flow Rate) was 81.12kg/h

The study presents variation in concentrations and humidity and their relative effect on specific design considerations and process flow parameters.

2. Ambient Air Evaporator

The basic idea of an ambient air evaporator is to increase the TDS concentration by mechanical fracturing of RO reject. The effluent, i.e., reject from RO plant is collected in a sump and it is pumped to atomizer operating at very high speed of about 11000 rpm. The effluent is fractured mechanically into a very fine mist, reportedly of size 4 to 5 micron in a chamber. Ambient Air is provided by bottom placed forced air draft fans. The evaporation is primarily based on ambient air temperature and humidity. The moist air is sent outside from the top of the chamber after mist elimination. The concentrated effluent falls at the bottom and is recirculated until it reaches desirable TDS concentration. The TDS increases further by solar pond evaporation and spray drying which reduces the area required for the same. The evaporator is able to evaporate about 15,000 liters per day from the initial reject volume of 20,000 liters. The TDS is increased from about 60,000 to 175,000mg/l. The operating cost is Rs.0.27/L, i.e., Rs.270/m^3 of effluent, without use of diesel. If the diesel burners are operated the diesel consumption is about 34 liters per hour and cost is about Rs.20,000 per day.

Fig: 1.1 Evaporator setup

1.2 MAIN FEATURES

Capacity : 20 m^3/day

Material of construction : SS 304 for the towers, SS316L for the high speed motor and PP for mist separator.

Installed power : 15 HP (11 kW) in each tower

Installed in 2 towers, each tower has inlet flow rate 500 l\h –

1000l\h Speed of the fan to fracture the effluent: 11,000 rpm.

Average evaporation achieved so far is 75%, i.e., 15,000 liters in two towers per day out of inlet of 20,000 liters.

Increase in relative humidity of fresh air inside the tower: 20% (April / May)

Air flow rate: 18000 CFM in each tower.

Cost of the system: Rs.55 lakhs.

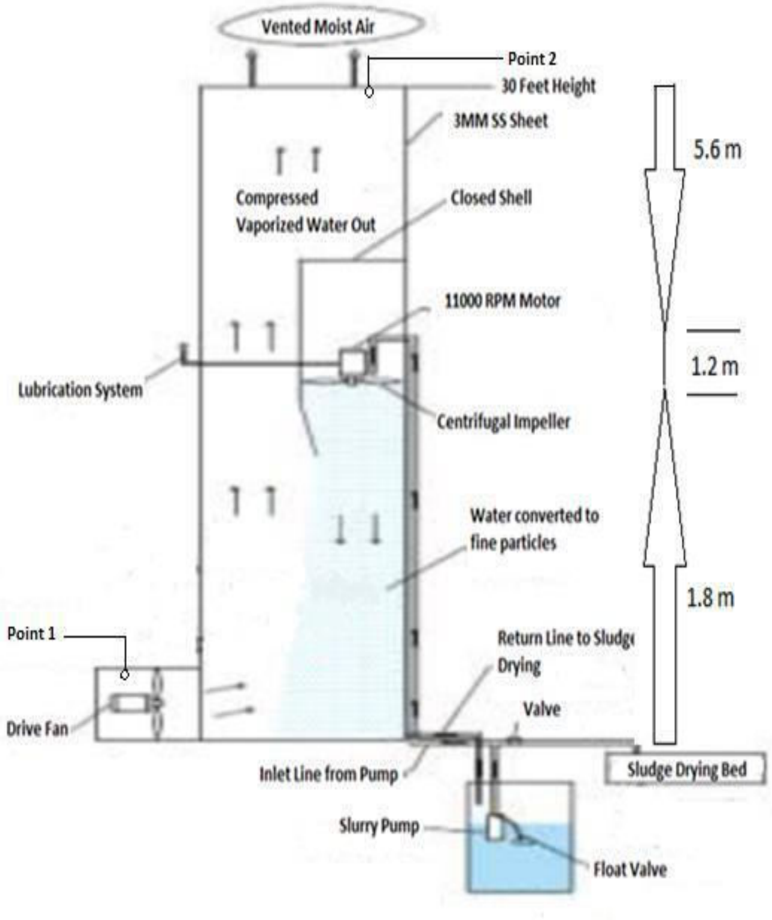

Fig: 1.2 Schematic representation of Evaporator

TABLE: 1.1 Existing Specification of the Evaporator

Parameters	Values
Duct Area	2.7 x 1.8 m^2
Height of Tower	8.6 m
Height between the bottom of Atomizer and Forced Draft Fan	1.8 m
Height between Top of tower to top of Atomizer	5.1 m
Atomizer Speed	11000 RPM

TABLE: 1.2 Temperature measured outside the column at sheet metal cover

Height(m)	Temperature(^{o} C)
1.5	26
3.0	26
4.5	26
6.0	26
7.5	27
8.6	27

TABLE: 1.3 Comparisons of Evaporators

Ambient Air Evaporator	Multiple Effect Evaporator
Heat energy from ambient source.	Requires huge energy from steam/boiler.
Lesser Area required for plant setup.	Requires large area.
Very low running cost i.e. 20 paisa per liter.	High on running costs.
Lower on capital cost.	Requires huge investment.
Simple operation does not require skilled manpower.	Requires trained man power.
Can handle very high TDS content in excess of 3,50,000 ppm.	Cannot handle high TDS in excess of 80,000 ppm.
No clogging.	Frequent clogging.
No additional reagents/chemicals required.	Anti - clogging salts added.
Very minimal maintenance.	Very high on maintenance.
Liquid is indirectly heated by air.	Liquid in direct contact with hot SS pipes thereby scaling
Zero liquid discharge done with only this equipment. No additional crystallizer required.	Crystallizer required to achieve Zero liquid discharge.
Seasonal Changes have considerable effects on the setup.	No effect of season variations.
Solar Ponds are also required for concentration of the outlet.	No need of solar ponds.

2. AIM AND SCOPE

The main aim is to increase the outlet concentration leaving the evaporator by employing various techniques in order to achieve Zero Liquid Discharge (ZLD). Normal evaporator uses large amount of energy in the form of heat in order to acquire the desired TDS at the outlet. So the process of evaporation using ambient air flow is employed.

The project was undertaken to understand the process flow and design of the setup, study the humidity influence on the evaporation process and increase the evaporation rate thus increasing the water loss by the setup. The outlet concentration needed is around 1 lakh ppm for discharge. . Initially the mist eliminator was not provided and the salts carried over were deposited around the evaporator. The mist eliminator was provided and this needed more pressure for ambient air fans. Hence these fans have been redesigned and new fans were provided. The salts present in the mist eliminator have to be cleaned by spraying clean water on top of it. This requires about 60 Liters/day of freshwater which adds to the effluent to be evaporated. Studies on the evaporation rate for various flow rates, design considerations and changes brought forth like passing a preheated feed that can ease the evaporation rate and partitioning to increase the contact area and time of fractured effluents and dry air. Studies on the backpressure can be done so as to reduce load on the air motor. Formulation of the process for evaporation calculations with higher air inflow rate via higher capacity air drafters. Finally try to get a concentration that can be easily vaporized by solar evaporation and spray drying without need of large areas or alternate effluent treatment process.

The main idea is to be techno-economical in our approach for industrial as well as environmental benefits.

3. MATERIALS AND METHODS

3.1 MEASUREMENT AND CALCULATION

DBT and WBT (with cotton wick) is calculated at Point 1(between fan and inner evaporator walls) and Point 2 (at the top of evaporator) using thermometer.

Density is calculated by measuring weight of sample (gm/100ml) for inlet and outlet.

Concentration are measured using conductometer with suitable conversion factor.

Water loss is calculated using density and concentration data and humidity is measured using psychrometric charts.

Mass of dry air is calculated using water loss and humidity difference that gives the height of the atomizer at different flow rates and design consderations.

Comparisons of the outlet concentrations and design considerations were done.

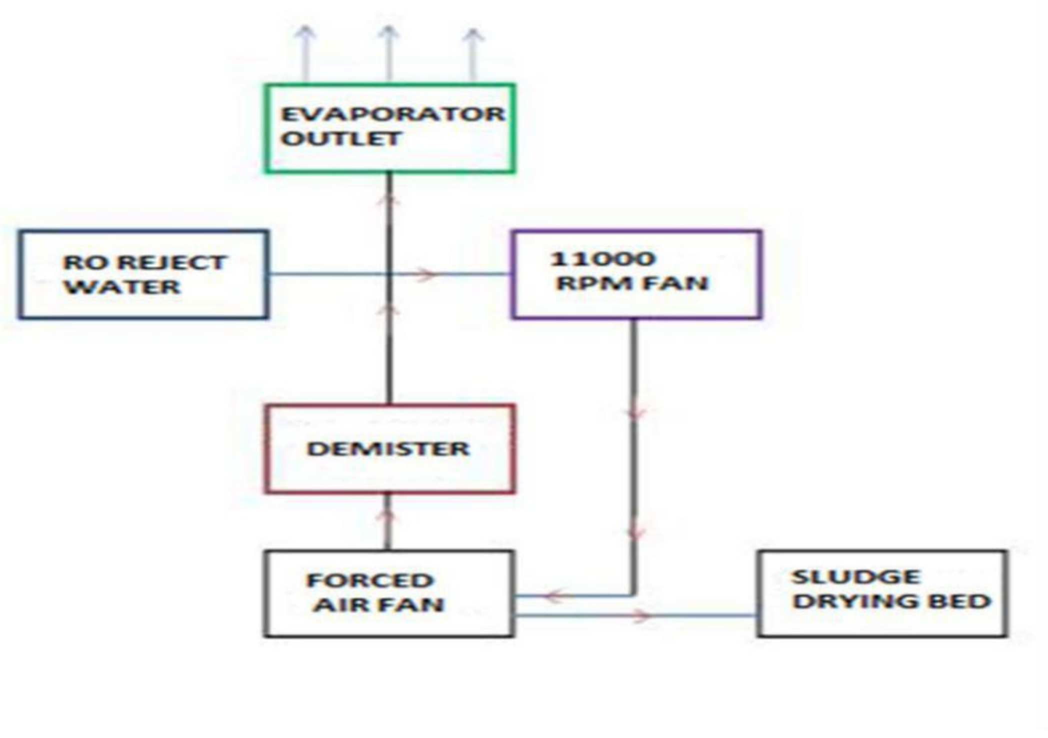

Fig: 3.1 Flow Chart

3.2 PROCESS OF EVAPORATION

A large volume of ambient air is passed through a stainless steel tower in which the saline effluent is dispersed to a fine mist. The air and mist are mixed within the chamber and the effluent gets evaporated. Sufficient space and time are provided for the mist to get evaporated. The evaporation is primarily based on ambient air temperature and humidity. The moist air is sent outside from the top of the chamber after mist eliminator. The concentrated saline effluent falls at the bottom and it is recirculated until it reaches desirable concentration. The effluent, i.e., reject from RO plant is collected in a sump and it is pumped from the sump to atomizer operating at very high speed of about 11000 rpm. The effluent is fractured mechanically into a very fine mist, reportedly of size 4 to 5 micron in a chamber. Very high volume of ambient air is injected into the chamber from the bottom. The ambient air mixed with the effluent is pushed to the top and this travel to the top of the tower helps complete the evaporation. A mist separator, made of polypropylene baffles, traps the salt carried by the air and only the moist air is sent outside the tower. The temperature inside the chamber becomes less than ambient temperature because of evaporation. The slightly higher temperature of the ambient air aids the evaporation. The liquid falling down is sent to a conical bottom settling tank. The cycle is repeated until the salt concentration reaches about 150,000 to 200,000 mg/l. Then the effluent drawn from the bottom of the conical bottom settling tank is sent to solar tunnel driers for solidification. The supplier claimed that they could increase the concentration to 350,000 mg/l, but the percentage of evaporation becomes less, i.e., about 20% as the concentration increased.

3.3 PRE HEATER

In order to raise the temperature of the incoming air, a pre heater is used. Tubular preheaters consist of straight tube bundles which pass through the outlet ducting of the boiler and open at each end outside of the ducting. Inside the ducting, the hot furnace gases pass around the preheater tubes, transferring heat from the exhaust gas to the air inside the preheater. Ambient air is forced by a fan through ducting, with one end collecting air for the preheater and at other end gives the heated air by passing through the preheater tubes towards the atomizer. An extension is made to the air inlet which consists of the preheater.

Fig: 3.2 Preheater

3.4 PARTITIONING

Steam from the tannery boiler unit is passed to the evaporation unit with the use of pipeline. The ambient air acquires heat after passing through the pre heater and this hot air comes into contact with atomizer. A partition is placed inside the evaporation unit. This increases the directional flow of the incoming air towards the atomizer. Since the air coming in will be directed towards the atomizer, it will provide more residence time and higher contact area, thus providing a good chance of increase in outlet concentrations.

Fig: 3.3 Partition

3.5 INCREASED AIR CAPACITY

Fans and blowers provide air for ventilation and industrial process requirements. Fans generate a pressure to move air (or gases) against a resistance caused by ducts, dampers, or other components in a fan system. The fan rotor receives energy from a rotating shaft and transmits it to the air. The operation of the fan is to suck in the ambient air present outside and provide it to the evaporator for evaporation. Since considerable change cannot be obtained through the normal setup and through alternative setup, fans are replaced in order to achieve the required efficiency. These fans are connected to a source of maximum horse power of 10 HP. The fan is designed in such a way that the rear end is partially enclosed in order to provide a higher velocity of air to the evaporation unit. This also reduces the time of contact of air towards the atomizer. This fan is fitted to the evaporation unit covering the entire bottom portion.

Fig: 3.4 Fan with Changed design-Front View

3.6 OPEN POND EVAPORATION

A solar pond is simply a pool of saltwater which collects and stores solar thermal energy. The high TDS stream from the tannery and the outlet concentration stream from the ambient air evaporator is sent to open ponds of evaporation The layers of solutions increase in concentration (and therefore density) with depth. Below a certain depth, the solution has a uniformly high salt concentration.

When the sun's rays contact the bottom of a shallow pool, they heat the water adjacent to the bottom. When water at the bottom of the pool is heated, it becomes less dense than the cooler water above it, and convection begins. Solar ponds heat water by impeding this convection. High concentration effluent at the bottom of the pond does not mix readily with the low concentration effluent above it, so when the bottom layer of water is heated, convection occurs separately in the bottom and top layers, with only mild mixing between the two. This greatly reduces heat loss, and allows for the high concentration effluent to get up to 90 °C while maintaining 30 °C low concentration. This hot, salty water can then be pumped away for use in electricity generation, often through a turbine of some sort.

Fig: 3.5 Open Pond Evaporation

3.6.1 Efficiency

The low efficiency of solar ponds is usually justified with the argument that the 'collector', being just a plastic-lined pond, might potentially result in a large-scale system that is of lower overall energy cost than a solar concentrating system.

3.7 DEMISTER

A demister is a device often fitted to vapour-liquid separator vessels to enhance the removal of liquid droplets entrained in a vapour stream. Here the demister is placed at the top of the evaporator. The salts present in the demister have to be cleaned by spraying clean water on top of it. This requires about 60 Liters/day of freshwater which adds to the effluent to be evaporated. Demisters may be a mesh type coalescer, vane pack or other structure intended to aggregate the mist into droplets that are heavy enough to separate from the vapor stream. Here when the air flows in to the evaporator, it comes largely in contact with the atomizer from which the sludge is sprayed at a high speed and carries away minute solid particles towards the top. The demister then separates the solid from the air reducing the residence time required to separate a given liquid droplet size. Demisters are often used where vapour quality is important in regard to entrained liquids particularly where separator equipment costs are high (e.g., high pressure systems) or where space or weight savings are advantageous.

Fig: 3.6 Demister Configurations

4. RESULTS AND DISCUSSIONS TABLE:

4.1 Tabulation for passing 600 LPH of Wastewater

Parameters	Run 1	Run 2	Run 3
DBT(^{O} C) at point 1	26	26	25.5
WBT(^{O} C) at point 1	24.5	24	24.5
DBT(^{O} C) at point 2	24	24	24
WBT(^{O} C) at point 2	23.5	23.6	23.8
Conductivity of solids at the Inlet(μS/Cm)	54.7	55.4	55.5
Conductivity of the solids at the outlet(μS/Cm)	55.8	56.7	57
Concentration of the solids at the Inlet(mg/l)	38290	38780	38850
Concentration of the solids at the Outlet(mg/l)	39060	39690	39900

TABLE: 4.2 Tabulation of Water Loss (600LPH)

Parameters	Run 1	Run2	Run 3
Total amount of sludge at the Inlet (kg/h)	660	660	660
Solids present in the sludge at Inlet (kg/h)	38.29	38.78	38.85
Amount of Water present at the Inlet (kg/h)	621.71	621.22	621.15
Total amount of sludge at the Outlet (kg/h)	640	640	640
Solids present in the sludge at the Outlet (kg/h)	39.06	39.69	39.90
Amount of Water present at the Outlet (kg/h)	600.94	600.31	600.10
Water Loss (kg/h)	20.77	20.91	21.05

4.1 CALCULATION FOR 600 LPH (Run 1)

4.1.1 Water Loss

(CONVERSION FACTOR 0.7) (Conc. via CONDUCTOMETER)

Total Inlet = 600 l/h x 0.980 kg/m^3
= 588 kg/h

Solid Inlet (TDS) = 54.7 x 0.7 x 1000(conc. * conv. Factor)
= 38290 mg/l
= 38290 mg/l x 600 l/h x 10^{-6} kg/mg
= 22.974 kg/h

Water Inlet = Total Inlet – Solid Inlet = 565.026 kg/h

Total Outlet (LPH) = 600 l/h x 0.970 kg/m^3

= 582 kg/h

Solid Outlet (TDS) = 55.8 x 0.7 x 1000

= 39060 mg/l

= 39060 mg/l x 600 l/h x 10^{-6} kg/mg

= 23.436 kg/h

Water Outlet (LPH) = Total Outlet – Solid Outlet

= 558.564 kg/h

Water Loss (LPH) = Water Inlet - Water Outlet = 565.026 - 558.564

= 6.498 kg/h

4.1.2 Height of Atomizer to be placed

Humidity at Inlet (Y_1') (Kg of H_2O / Kg of Dry Air) = 0.0170

Humidity at Outlet (Y_2') (Kg of H_2O / Kg of Dry Air) = 0.0175

Mass of Dry Air (m $_{dryair}$) (Kg / h) = Water Loss / (Y_2„-Y_1„)

= 6.498 / (0.0175 - 0.0170) = 12996

Ky (Mass Transfer Co- Efficient) = 1.12

Yas'(Saturation Humidity at DBT) (Kg of H_2O / Kg of Dry Air) = 0.022

Gs (Kg / s) = 12996 / 3600

= 3.61

(Z / Gs)*Ky = ln ((Yas„-Y_1„) / (Yas„-Y_2„))

(Z / 3.61)* 1.12 = ln ((0.022-0.0170) / (0.022-0.0175))

Height (Z) = 0.339 m

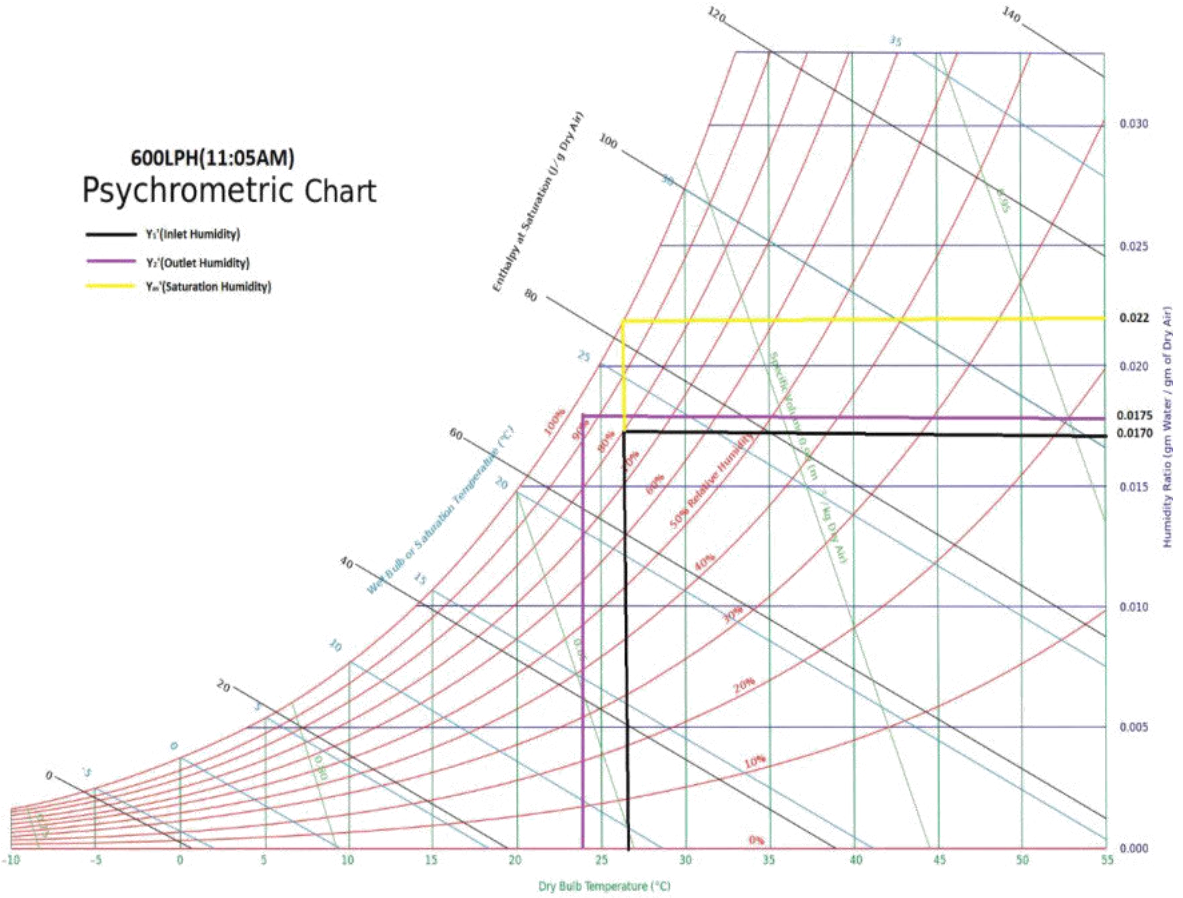

Fig: 4.1 Humidity using Psychrometric Chart for 600 LPH (Run 1)

TABLE: 4.3 Tabulation of Height of atomizer to be placed for 600 LPH

Parameters	Run1	Run 2	Run 3
Inlet DBT (^{o} C)	26	30	25.5
Y_1'	0.0170	0.0173	0.0175
Y_2'	0.0175	0.0178	0.018
m $_{\text{dry air}}$	12996	13092	13260
Yas'	0.0220	0.0215	0.0210
Ky	1.12	1.12	1.12
Z (m)	0.339	0.412	0.507

TABLE: 4.4 Tabulation for passing 800 LPH of Wastewater

Parameters	Run 1	Run 2	Run 3
DBT(^{O} C) at point 1	25.5	25.5	26
WBT(^{O} C) at point 1	24	23.9	24.5
DBT(^{O} C) at point 2	23.8	24	24
WBT(^{O} C) at point 2	23.5	23.5	23.5
Conductivity of solids at the Inlet(μS/Cm)	55.7	56	56.3
Conductivity of the solids at the outlet(μS/Cm)	56.2	56.4	58.7
Concentration of the solids at the Inlet(mg/l)	38990	39200	39410
Concentration of the solids at the Outlet(mg/l)	39340	39480	41090

TABLE: 4.5 Tabulation of Water Loss (800LPH)

Parameters	Run 1	Run 2	Run 3
Total amount of sludge at the Inlet (kg/h)	768	768	776
Solids present in the sludge at Inlet (kg/h)	31.192	31.36	31.528
Amount of Water present at the Inlet (kg/h)	736.808	736.64	744.472
Total amount of sludge at the Outlet (kg/h)	760	756	761.6
Solids present in the sludge at the Outlet (kg/h)	31.472	31.584	32.872
Amount of Water present at the Outlet (kg/h)	728.528	724.416	728.728
Water Loss (kg/h)	8.28	12.224	15.744

4.2 CALCULATION FOR 800LPH(Run 1)

4.2.1 Water Loss

(CONVERSION FACTOR 0.7) (Conc. via CONDUCTOMETER)

Total Inlet = 800 l/h x 0.960 kg/m^3
= 768 kg/h

Solid Inlet (TDS) = 55.7 x 0.7 x 1000(conc. * conv. Factor)
= 38990 mg/l
= 38990 mg/l x 800 l/h x 10^{-6} kg/mg
= 31.192 kg/h

Water Inlet = Total Inlet – Solid Inlet
= 736.808 kg/h

Total Outlet = 800 l/h x 0.950 kg/m^3
= 760 kg/h

Solid Outlet (TDS) = 55.8 x 0.7 x 1000

= 39340 mg/l

= 39340 mg/l x 800 l/h x 10^{-6} kg/mg
= 31.472 kg/h

Water Outlet = Total Outlet – Solid Outlet

= 728.528 kg/h

Water Loss = Water Inlet - Water Outlet

= 736.64 - 728.528

= 8.28 kg/h

4.2.2 Height of Atomizer to be placed

Humidity at Inlet (Y_1') (Kg of H_2O / Kg of Dry Air) = 0.0170

Humidity at Outlet (Y_2') (Kg of H_2O / Kg of Dry Air) = 0.0175

Mass of Dry Air (m_{dryair}) (Kg / h) = Water Loss / (Y_2„-Y_1„)

= 8.28 / (0.0175-0.017)

= 16560

Ky (Mass Transfer Co- Efficient) = 1.12

Yas'(Saturation Humidity at DBT)(Kg of H_2O / Kg of Dry Air) = 0.0225

Gs (Kg / s) = 16560 / 3600

= 4.6

(Z / Gs) * Ky = ln ((Yas„ - Y_1„) / (Yas„ - Y_2„))

(Z / 4.6)* 1.12 = ln ((0.0225 - 0.017) / (0.0225 - 0.0175))

Height (Z) = 0.391 m

TABLE: 4.6 Tabulation of Height of atomizer to be placed for 800 LPH

Parameters	Run 1	Run 2	Run 3
Inlet DBT(^{o} C)	25.5	25.5	25
Y1'	0.017	0.017	0.0165
Y2'	0.0175	0.0175	0.0170
$m_{dry\ air}$	16560	24.448	31488
Yas'	0.0225	0.0210	0.0215
Ky	1.12	1.12	1.12
Z (m)	0.391	0.809	0.8228

TABLE: 4.7 Tabulation for passing 1000 LPH of Wastewater

Parameters	Run 1	Run 2	Run 3
Inlet DBT(^{O} C)	26	30	26
Inlet WBT(^{O} C)	24.1	24.5	23.2
Outlet DBT(^{O} C)	24	26	23
Outlet WBT(^{O} C)	22.5	23.9	22.8
Conductivity of solids at the Inlet(μS/Cm)	56.9	56.3	60.3
Conductivity of the solids at the outlet(μS/Cm)	59.7	61.4	64.5
Concentration of the solids at the Inlet(mg/l)	39830	39410	42210
Concentration of the solids at the Outlet(mg/l)	41790	42980	45150

TABLE: 4.8 Tabulation of Water Loss (1000LPH)

Parameters	Run 1	Run 2	Run 3
Total amount of sludge at the Inlet (kg/h)	1010	1018	1013
Solids present in the sludge at Inlet (kg/h)	39.83	39.41	42.21
Amount of Water present at the Inlet (kg/h)	970.17	978.59	970.79
Total amount of sludge at the Outlet (kg/h)	980	983	979
Solids present in the sludge at the Outlet (kg/h)	41.79	42.98	45.15
Amount of Water present at the Outlet (kg/h)	938.21	940.02	933.85
Water Loss (kg/h)	31.96	38.57	36.94

4.3 CALCULATION FOR 1000LPH (Run 1)

4.3.1 Water Loss

(CONVERSION FACTOR 0.7) (Conc. via CONDUCTOMETER)

Total Inlet = 1000 l/h x 1.01 kg/m^3
= 1010 kg/h

Solid Inlet (TDS) = 56.9 x 0.7 x 1000(conc. * conv. Factor)
= 39830 mg/l
= 39830 mg/l x 1000 l/h x 10^{-6} kg/mg
= 39.83 kg/h

Water Inlet = Total Inlet – Solid Inlet
= 970.17 kg/h

Total Outlet = 1000 l/h x 0.980 kg/m^3 = 980 kg/h

Solid Outlet (TDS) = 59.7 x 0.7 x 1000(conc. * conv. Factor)

= 41790 mg/l

= 41790 mg/l x 1000 l/h x 10^{-6} kg/mg

= 41.79 kg/h

Water Outlet = Total Outlet – Solid Outlet

= 938.21 kg/h

Water Loss = Water Inlet - Water Outlet

= 970.17 – 938.21

= 31.96 kg/h

4.3.2 Height of Atomizer to be placed

Humidity at Inlet (Y_1') (Kg of H_2O / Kg of Dry Air) = 0.017

Humidity at Outlet (Y_2') (Kg of H_2O/Kg of Dry Air) = 0.018

Mass of Dry Air ($m_{mdryair}$) (Kg / h)= Water Loss / ($Y_{2„}$-Y_1')

= 31.96 / (0.018-0.017)

= 31960

Ky (Mass Transfer Co- Efficient) = 1.12

Yas„(Saturation Humidity at DBT) (Kg of H_2O / Kg of Dry Air) = 0.0245

Gs (Kg / s) = 31960 / 3600

= 8.878

(Z / Gs) * Ky = ln ((Yas„-$Y_{1„}$) / (Yas„-$Y_{2„}$))

(Z / 8.878) * 1.12 = ln ((0.0245-0.017) / (0.0245-0.018))

Height (Z) = 1.134 m

TABLE: 4.9 Tabulation of Height of atomizer to be placed for 1000 LPH

Parameters	Run 1	Run 2	Run 3
Inlet DBT(^{o} C)	26	30	26
Y_1'	0.017	0.017	0.0165
Y_2'	0.018	0.018	0.0175
$m_{\text{dry air}}$	31960	38570	36940
Yas'	0.0245	0.0275	0.0230
Ky	1.12	1.12	1.12
Z (m)	1.134	1.368	1.53

TABLE: 4.10 Tabulation for passing 1000 LPH of Wastewater

Parameters	Run 1	Run 2	Run 3
DBT(^{O} C) at point 1	32	32	30
WBT(^{O} C) at point 1	28	26.5	27
DBT(^{O} C) at point 2	30	28	28
WBT(^{O} C) at point 2	28	27	27.5
Conductivity of solids at the Inlet(μS/Cm)	54.7	54.1	53.8
Conductivity of the solids at the outlet(μS/Cm)	57.3	56.94	57.74
Concentration of the solids at the Inlet(mg/l)	38290	37870	37660
Concentration of the solids at the Outlet(mg/l)	40110	39858	40418

TABLE 4.11 Tabulation of Water Loss (1000 LPH)

Parameters	Run 1	Run 2	Run 3
Total amount of sludge at the Inlet (kg/h)	1002	1020	990
Solids present in the sludge at Inlet (kg/h)	38.29	37.87	37.66
Amount of Water present at the Inlet (kg/h)	963.71	982.13	952.34
Total amount of sludge at the Outlet (kg/h)	972	990	970
Solids present in the sludge at the Outlet (kg/h)	40.11	39.86	40.418
Amount of Water present at the Outlet (kg/h)	931.89	950.142	929.582
Water Loss (kg/h)	31.82	31.988	32.758

4.4 CALCULATION FOR 1000LPH (Run 1) WITH PREHEATER AND PARTITION

4.4.1 Water Loss

(CONVERSION FACTOR 0.7) (Conc. via CONDUCTOMETER)

Total Inlet = 1000 l/h x 1.002 kg/m^3
= 1002 kg/h

Solid Inlet (TDS) = 54.7 x 0.7 x 1000(conc. * conv. Factor)

= 38290 mg/l

= 38290 mg/l x 1000 l/h x 10^{-6} kg/mg
= 38.29 kg/h

Water Inlet = Total Inlet – Solid Inlet

= 1002 – 38.29= 963.71 kg/h

Total Outlet = 1000 l/h x 0.972 kg/m^3
= 972 kg/h

Solid Outlet = 57.3 x 0.7 x 1000(conc. * conv. Factor)

= 40110 mg/l

= 40110 mg/l x 1000 l/h x 10^{-6} kg/mg

= 40.11

Water Outlet = 931.89 kg/h

Water Los = Water Inlet - Water Outlet

= 963.71 – 931.89

= 31.82 kg/h

4.4.2 Calculation of Height of Atomizer to be placed

Humidity at Inlet (Y_1') (Kg of H_2O / Kg of Dry Air) = 0.024

Humidity at Outlet (Y_2') (Kg of H_2O/Kg of Dry Air) = 0.025

Mass of Dry Air (m_{dryair}) (Kg / h) = Water Loss / (Y_2„-Y_1')

= 31.82 / (0.025-0.024)

= 31820

Ky (Mass Transfer Co- Efficient) = 1.12

Yas„(Saturation Humidity at DBT) (Kg of H_2O / Kg of Dry Air) = 0.031 Gs (Kg / s)

= 31820 / 3600

= 8.838

(Z / Gs) * Ky = ln ((Yas„-Y1„) / (Yas„-Y2„))

(Z / 8.838) * 1.12 = ln ((0.031-0.024) / (0.031-0.025))

Height (Z) = 1.671 m

TABLE 4.12 Tabulation of Height of atomizer to be placed for 1000 LPH

Parameters	Run 1	Run 2	Run 3
Inlet DBT(^{o} C)	32	32	30
Y_1'	0.024	0.020	0.022
Y_2'	0.025	0.022	0.023
$m_{dry\ air}$	31820	15994	32758
Yas'	0.031	0.0303	0.0275
Ky	1.12	1.12	1.12
Z (m)	1.671	0.856	1.63

TABLE4.13 Tabulation for passing 1000 LPH with increased air flow rate

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
DBT at point 1 (^{o} C)	34.2	36	37.5	37.2	38.3	38.7	37
WBT at point 1 (^{o} C)	24.5	23.9	26.8	24	24.9	23.3	23.1
DBT (^{o} C) at point 2	28.9	30	30.1	27.8	29.3	28.7	28.3
WBT (^{o} C) at point 2	23.9	23.7	24.2	23.7	23.9	23.5	22.6
Conductivity of solids at the Inlet(µS/Cm)	59.1	58.9	60.5	61	59.61	57.66	57.16
Conductivity of the solids at the outlet(µS/Cm)	77.08	77.38	74.62	76.13	77.86	75.37	79.56
Concentration of the solids at the Inlet(mg/l)	41370	41230	42350	42700	41730	40360	40010
Concentration of the solids at the Outlet(mg/l)	53960	54170	52240	53290	54500	52760	55690

TABLE: 4.14 Tabulation of Water Loss (1000LPH) with increased air flow rate

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Total amount of sludge at the Inlet (kg/h)	1002	1035	1134.37	1044.87	1042.9	1044	1018.67
Solids present in the sludge at Inlet (kg/h)	41.37	41.23	42.35	42.70	41.73	40.36	40.01
Amount of Water present at the Inlet (kg/h)	960.63	993.77	1092.02	1002.17	1001.17	1003.64	978.65
Total amount of sludge at the Outlet (kg/h)	950	971.2	1101.30	1017.22	1007.01	1011.75	953.22
Solids present in the sludge at the Outlet (kg/h)	53.96	54.17	52.24	53.29	54.50	52.76	55.69
Amount of Water present at the Outlet (kg/h)	896.04	917.03	1049.06	963.93	952.51	950.99	897.53
Water Loss (kg/h)	64.59	76.67	42.96	38.24	48.66	52.65	81.12

4.5 CALCULATION FOR 1000LPH(Run 1)WITH INCREASED AIR FLOW RATE

4.5.1 Water Loss

(CONVERSION FACTOR 0.7) (Conc. via CONDUCTOMETER)

Total Inlet = 1000 l/h x 1.002 kg/m^3
= 1002 kg/h

Solid Inlet (TDS) = 59.1 x 0.7 x 1000(conc. * conv. Factor)
= 41370 mg/l
= 41370 mg/l x 1000 l/h x 10^{-6} kg/mg
= 41.37 kg/h

Water Inlet = Total Inlet – Solid Inlet
= 1002 – 41.37
= 960.63 kg/h

Total Outlet = 1000 l/h x 0.95 kg/m^3
= 950 kg/h

Solid Outlet = 62.8 x 0.7 x 1000(conc. * conv. Factor)
= 43960 mg/l

= 43960 mg/l x 1000 l/h x 10^{-6} kg/mg= 53.96 kg/h

Water Outlet = 896.04 kg/h

Water Loss = Water Inlet - Water Outlet

= 960.63 – 896.04= 64.59 kg/h

4.5.2 Calculation of Height of Atomizer to be placed

Humidity at Inlet (Y_1') (Kg of H_2O / Kg of Dry Air) = 0.0155

Humidity at Outlet (Y_2') (Kg of H_2O/Kg of Dry Air) = 0.017

Mass of Dry Air (m $_{dryair}$) (Kg / h) = Water Loss / (Y_2„-Y_1')

= 64.59 / (0.017-0.0155) = 43060

Y_{as}„(Saturation Humidity at DBT) (Kg of H_2O / Kg of Dry Air) = 0.038 Gs (Kg / s)

= 43060 / 3600 = 11.961

(Z / G_S) * K_y = ln ((Y_{as}„-Y_1„) / (Y_{as}„-Y_2„))

Height (Z) = 0.924 m

TABLE 4.15 Tabulation of Height of atomizer to be placed for 1000 LPH

With increased air flow rate

Parameters	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7
Inlet DBT(^{O} C)	34.2	36	37.5	37.2	38.3	38.7	37
Y_1'	0.0155	0.0148	0.0155	0.014	0.0145	0.012	0.013
Y_2'	0.017	0.017	0.0165	0.0175	0.017	0.016	0.0155
m $_{dry\ air}$	43060	34850	42960	10925	19464	13162	32488
Yas'	0.038	0.042	0.045	0.044	0.047	0.048	0.044
K_y	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Z (m)	0.924	0.914	0.3674	0.336	0.3863	0.5685	0.6766

5. SUMMARY AND CONCLUSION

The detailed study on the existing step was initially done to improve the performance. Based on this study various modifications were carried out to increase the efficiency of the setup and also the concentration variation was compared with various modifications.

The increased air capacity drafters were provided that allowed more mass of dry air to flow inside the setup to increase the solid concentrations. For 1000 LPH (standard setup flow rate), increased air capacity drafters were the best option in order to obtain higher outlet concentration. Higher water loss and concentration were obtained around 9 AM to 2 PM. After 2 PM evaporation rate is gradually decreasing due to variation in ambient humidity. Accordingly, flow rates can be adjusted with respect to humidity in order to obtain better evaporation.

When the preheater along with partition setup is employed, considerable effects were observed but restriction in the air flow was witnessed.

The higher efficiency or increase of concentration about 53950 mg/l was achieved by high capacity air draft fan modification whereas in existing and preheater setup it is achieved around 41392 mg/l and 40128.67 mg/l respectively.

TABLE 5.1 Comparisons for standard 1000 LPH flow rate

Parameters	Existing Setup	Steam passing and And Directional Flow	Increased Fan Capacity
Inlet Concentration	40483.33 mg/l	37940mg/l	41392mg/l
Outlet Concentration	43306.667mg/l	40128.667mg/l	53960mg/l

Further it is also suggested to carry out further modification as a Scope of Future Work:

Pressure gauge must be provided in order to obtain the inlet and outlet pressure to find the respective air densities for the calculation of pressure drop, which will used to calculate the optimum power required to run the drafter.

Variable speed drives can be installed based on the factors such as power supplied to fan, humidity and flow rates in order to obtain higher outlet concentrations.

Installation of Louvers shall also be studied to direct the air flow with backpressure considerations.

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APPENDICES

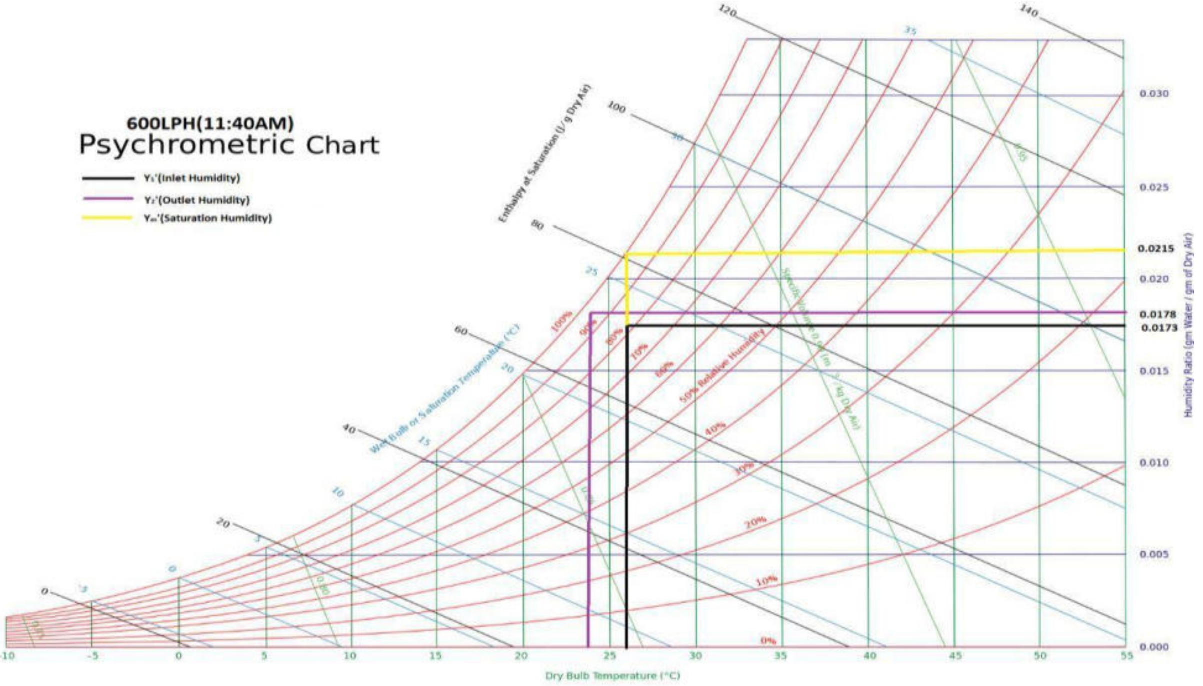

Fig: A.1 Humidity using Psychrometric Chart 600 LPH (Run 2)

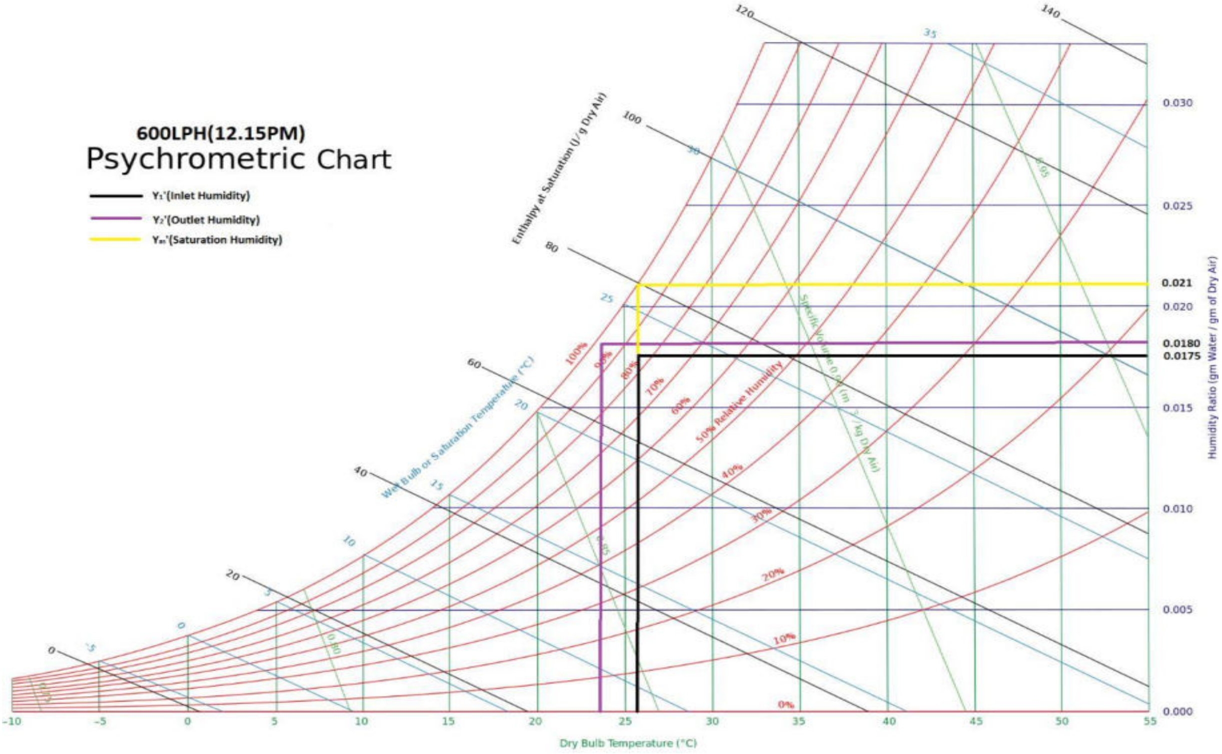

Fig: A.2 Humidity using Psychrometric Chart 600 LPH (Run 3)

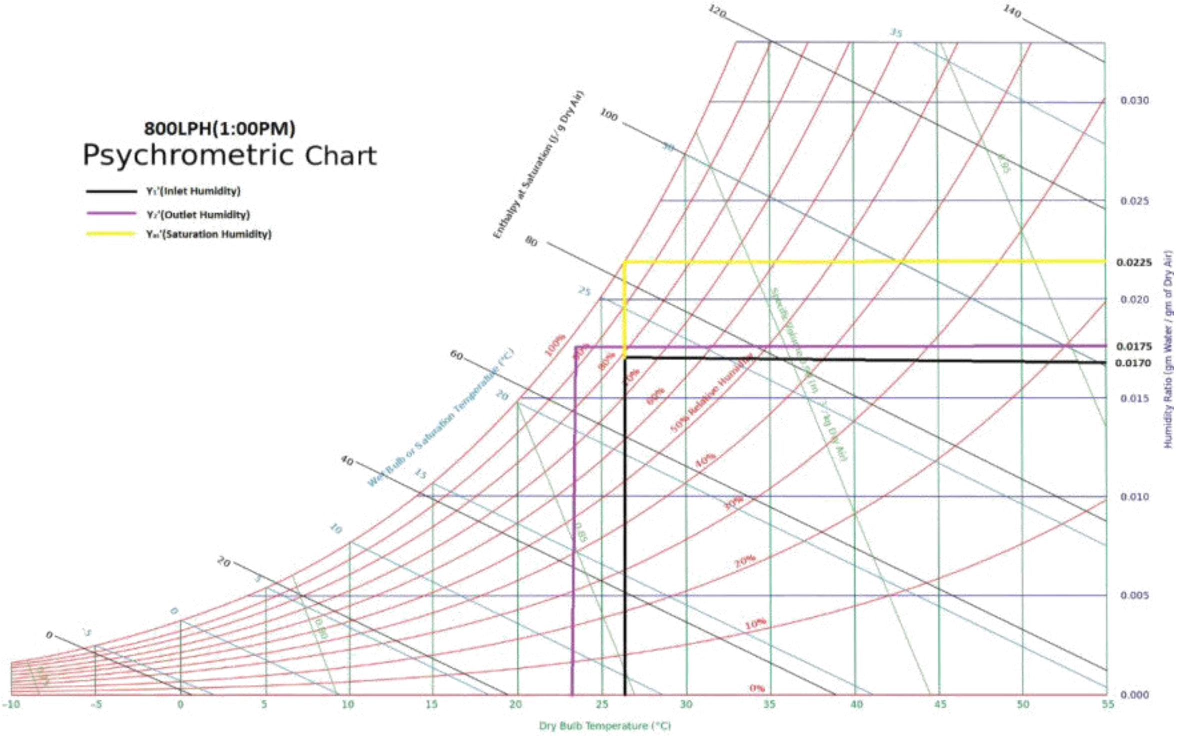

Fig: A.3 Humidity using Psychrometric Chart 800 LPH (Run 2)

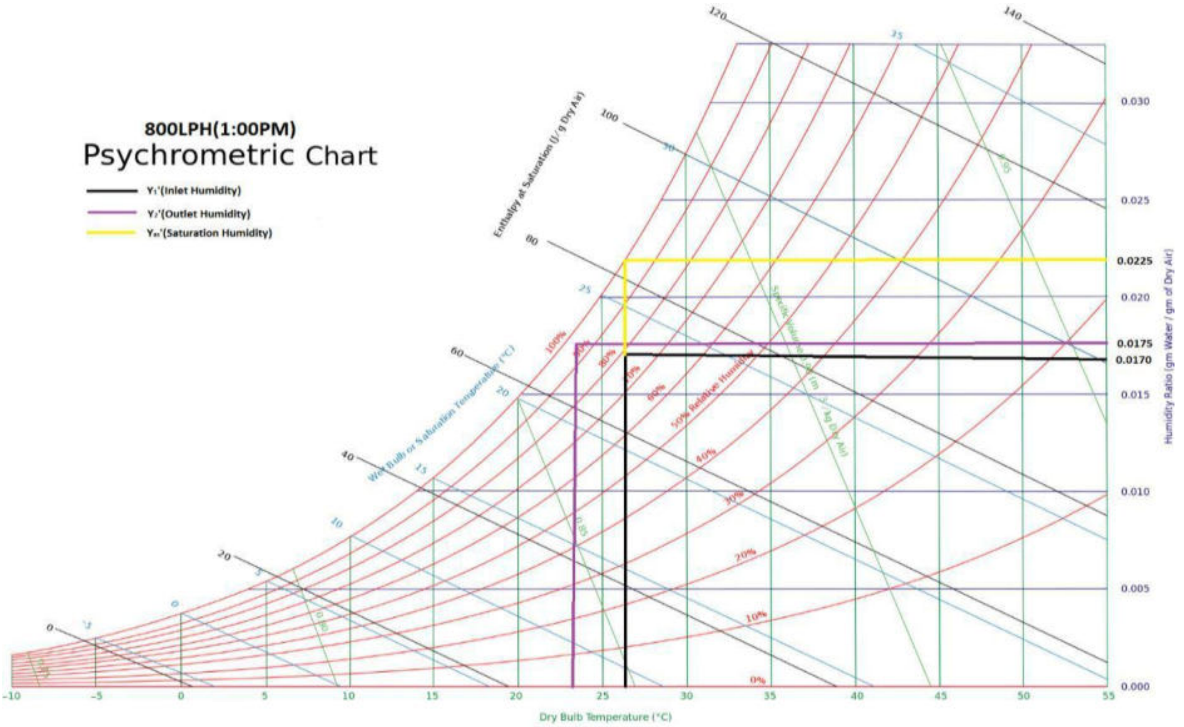

Fig: A.4 Humidity using Psychrometric Chart 800 LPH (Run 3)

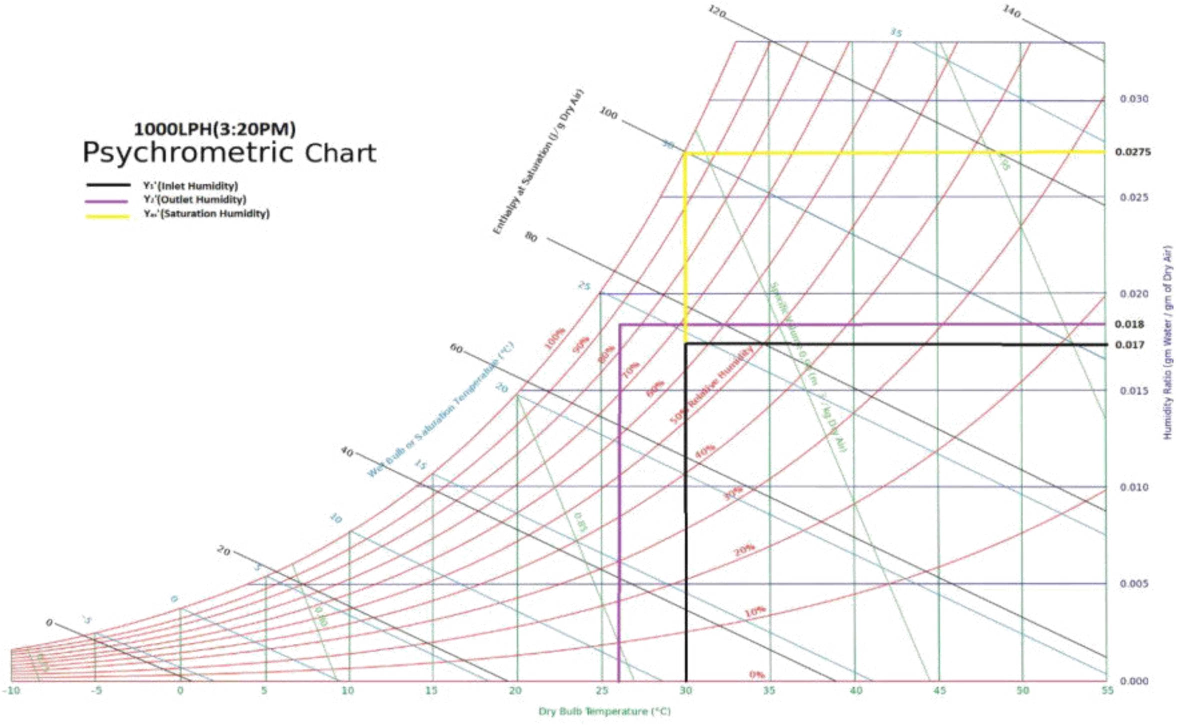

Fig: A.5 Humidity using Psychrometric Chart 1000 LPH (Run 2)

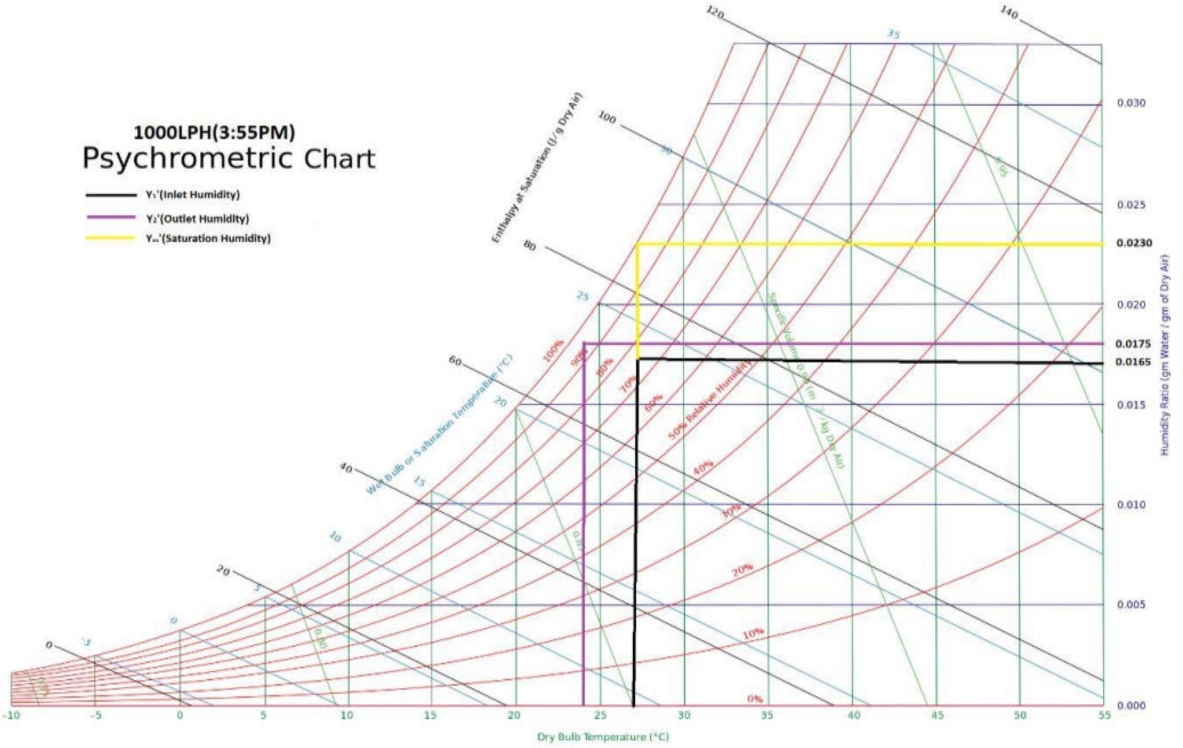

Fig: A.6 Humidity using Psychrometric Chart 1000 LPH (Run 3)

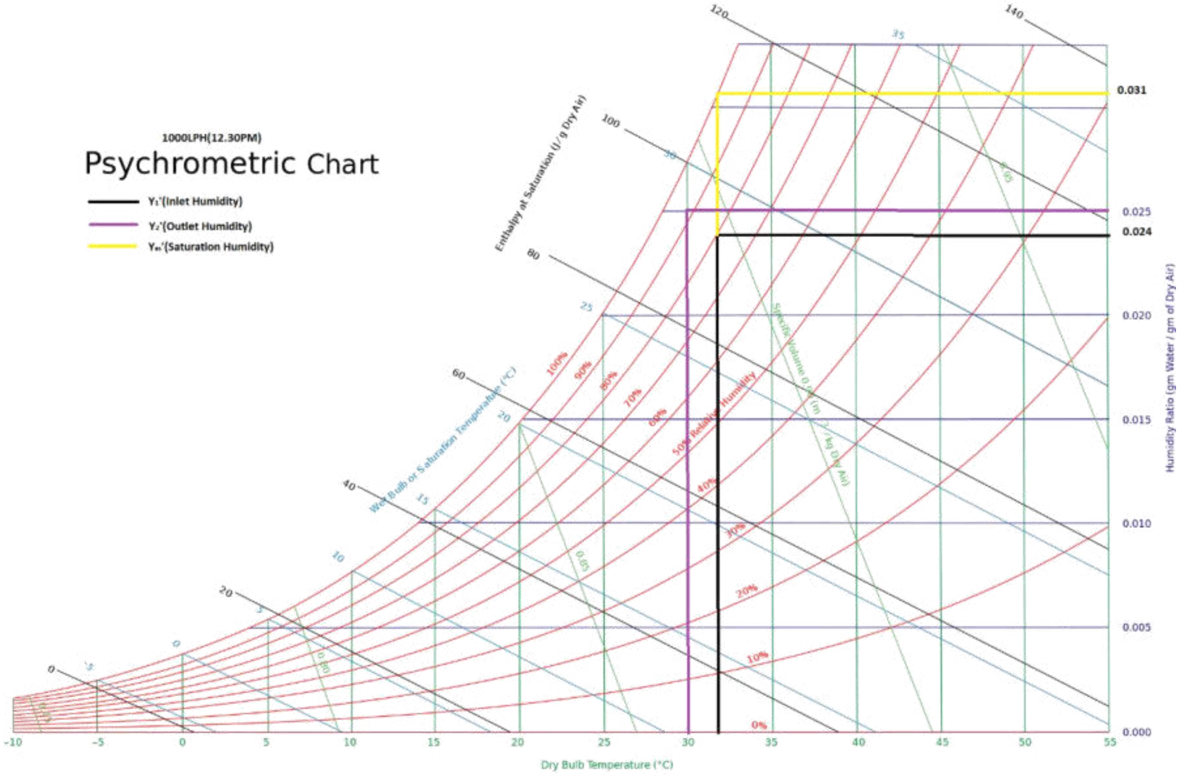

Fig: A.7 Humidity using Psychrometric Chart 1000 LPH (Run 1)

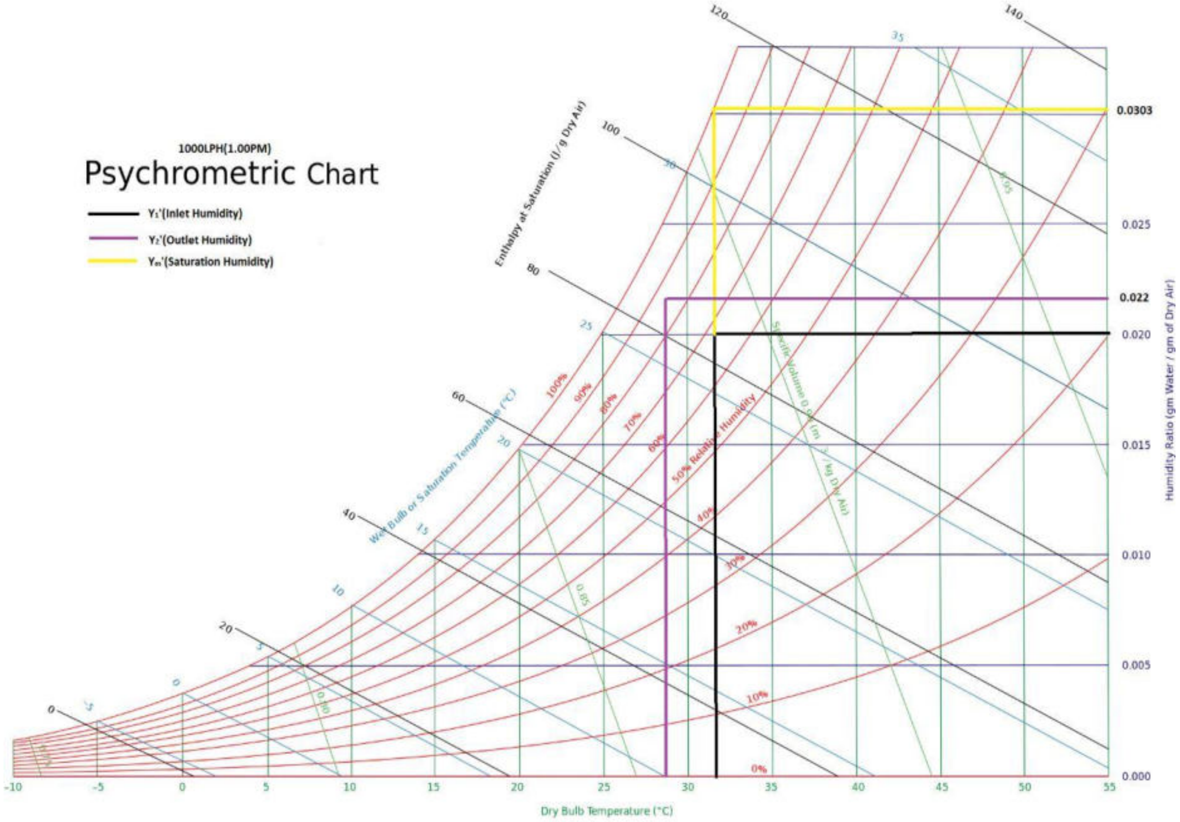

Fig: A.8 Humidity using Psychrometric Chart 1000 LPH (Run 2)

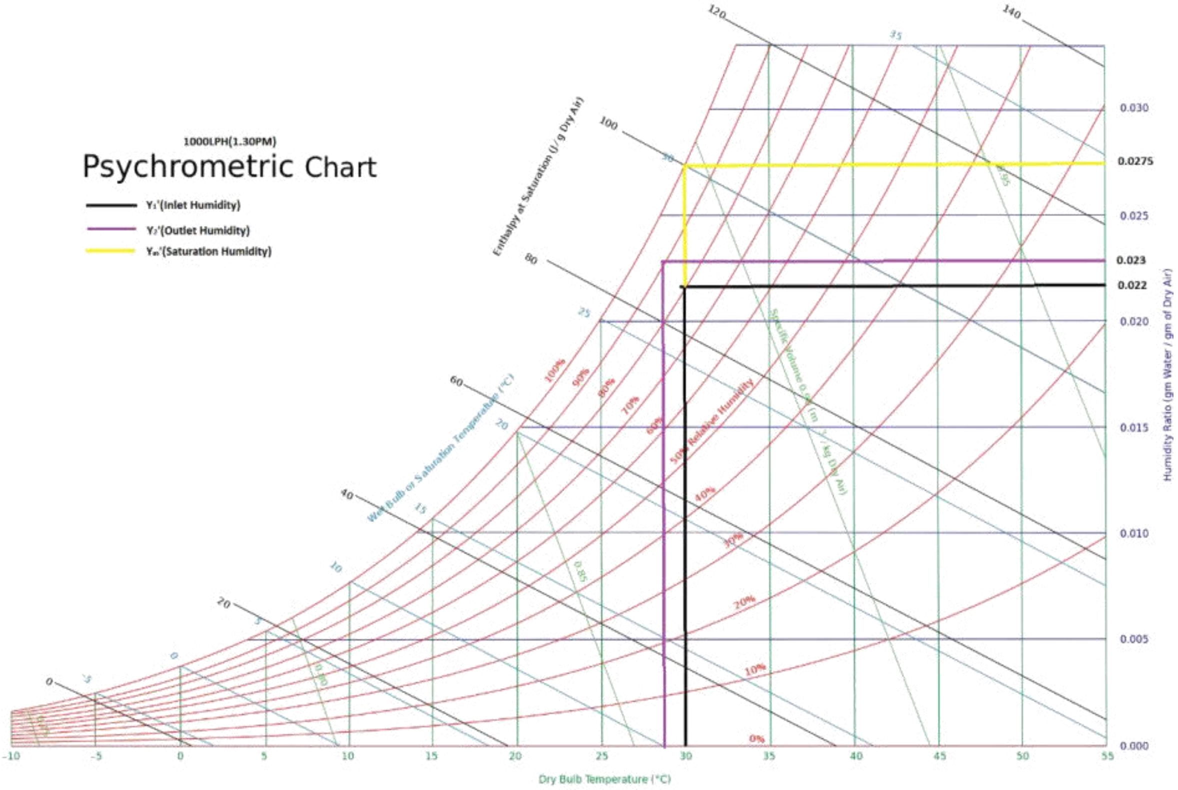

Fig: A.9 Humidity using Psychrometric Chart 1000 LPH (Run 3)

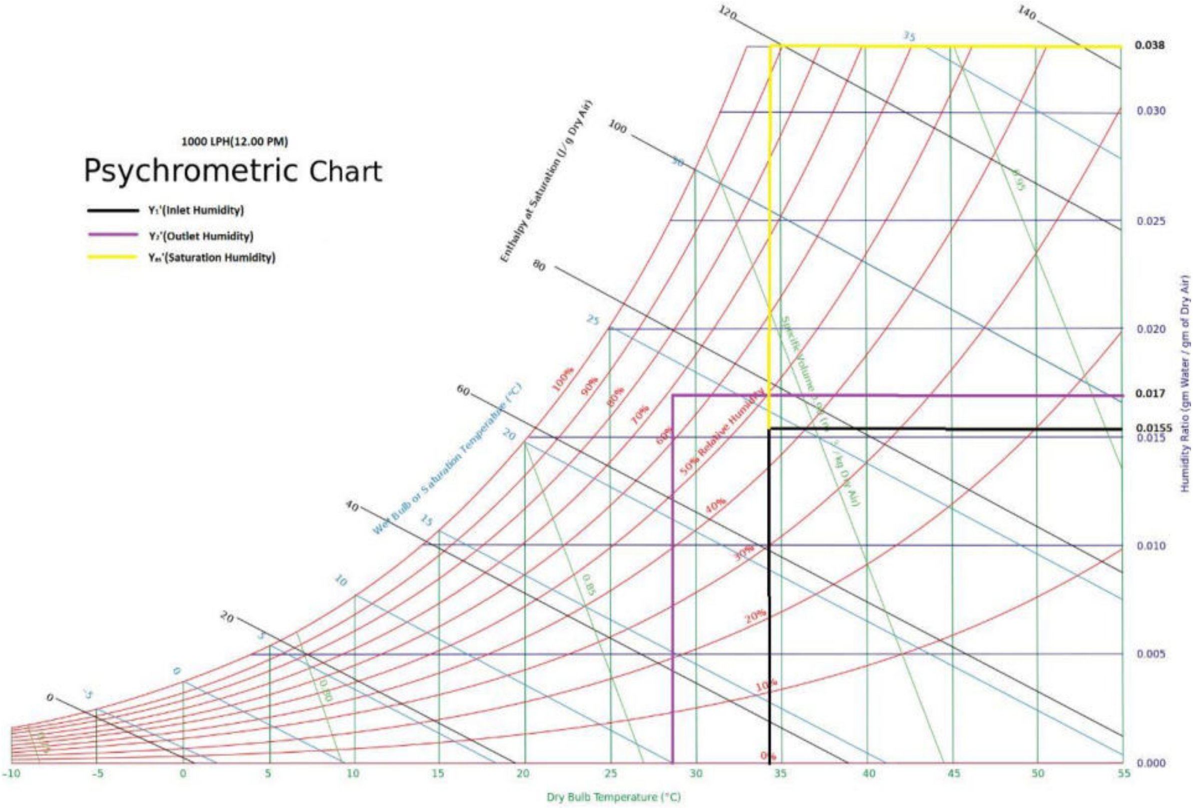

Fig: A.10 Humidity using Psychrometric Chart 1000 LPH (Run 1)

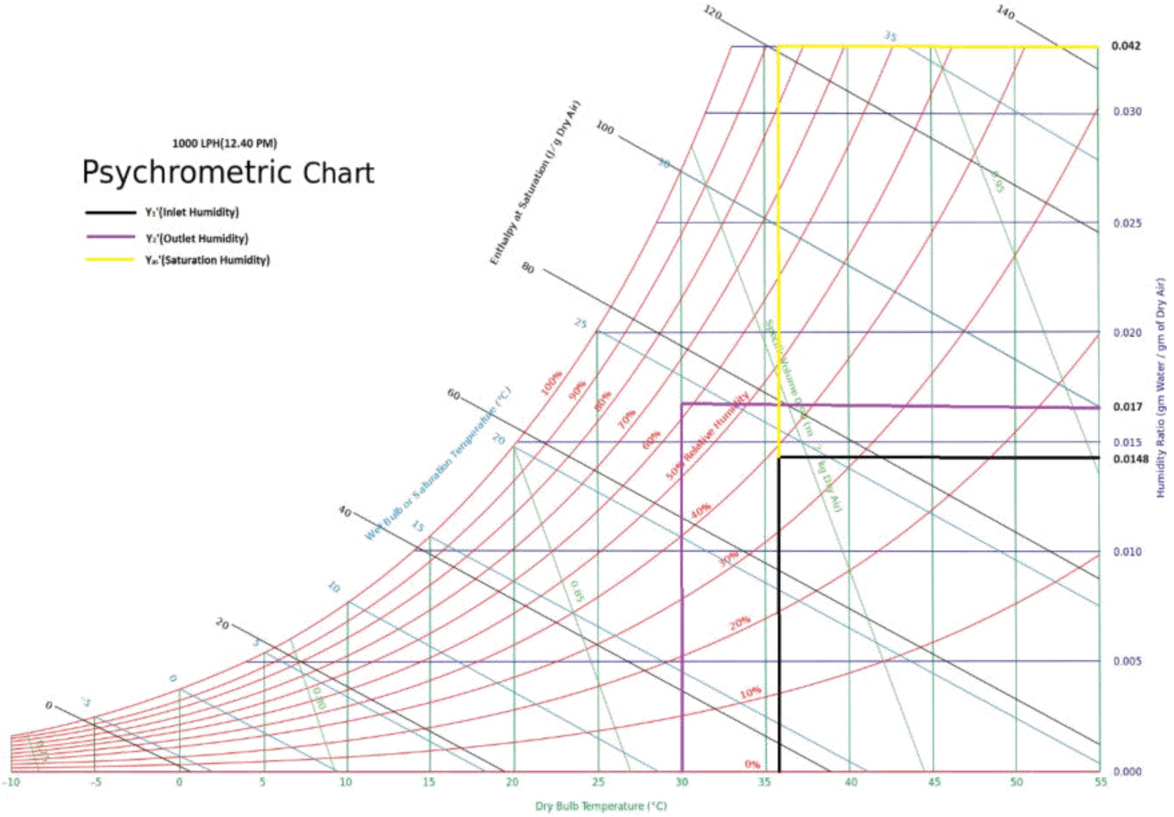

Fig: A.11 Humidity using Psychrometric Chart (1000 LPH (Run 2)

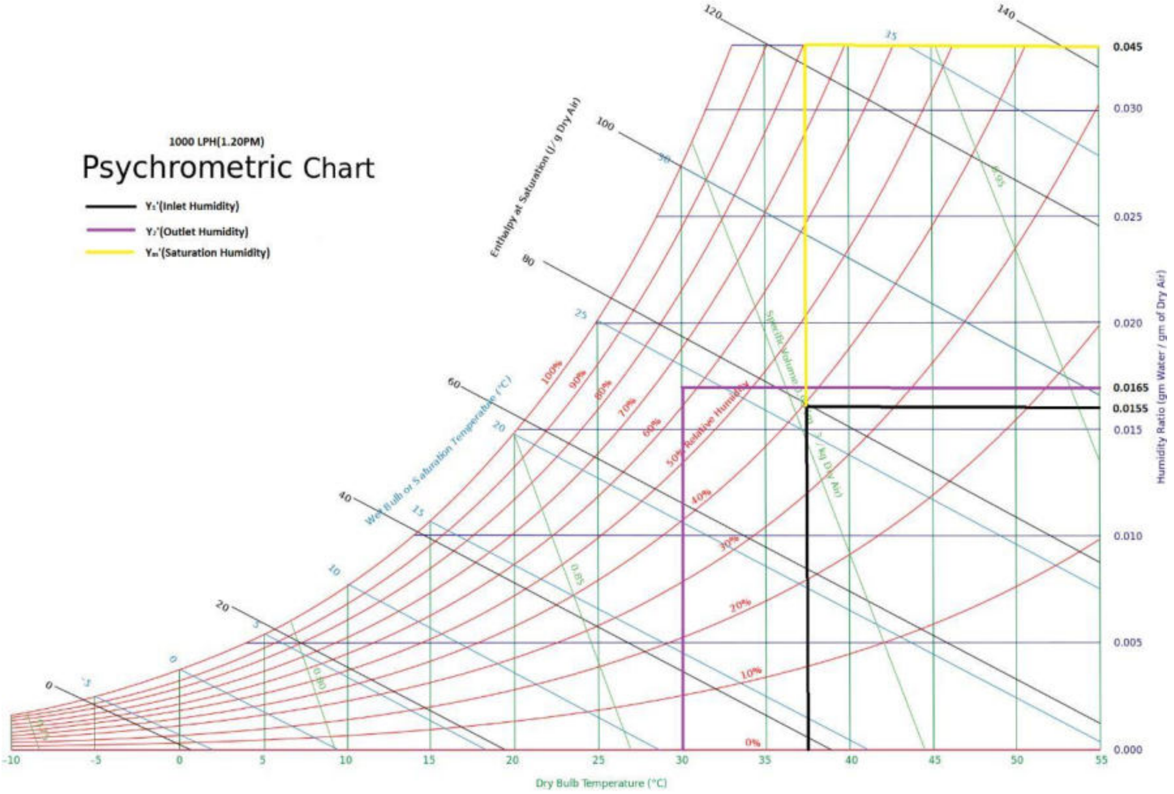

Fig: A.12 Humidity using Psychrometric Chart 1000 LPH (Run 3)

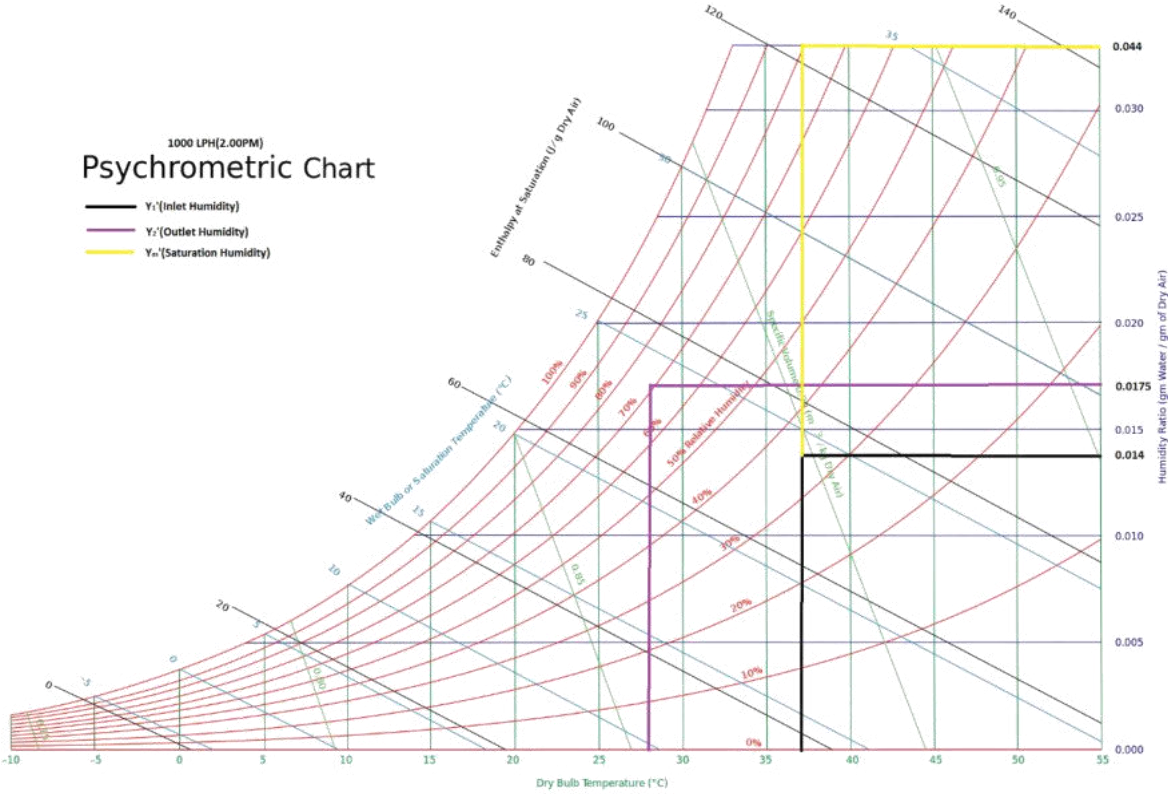

Fig: A.13 Humidity using Psychrometric Chart 1000 LPH (Run 4)

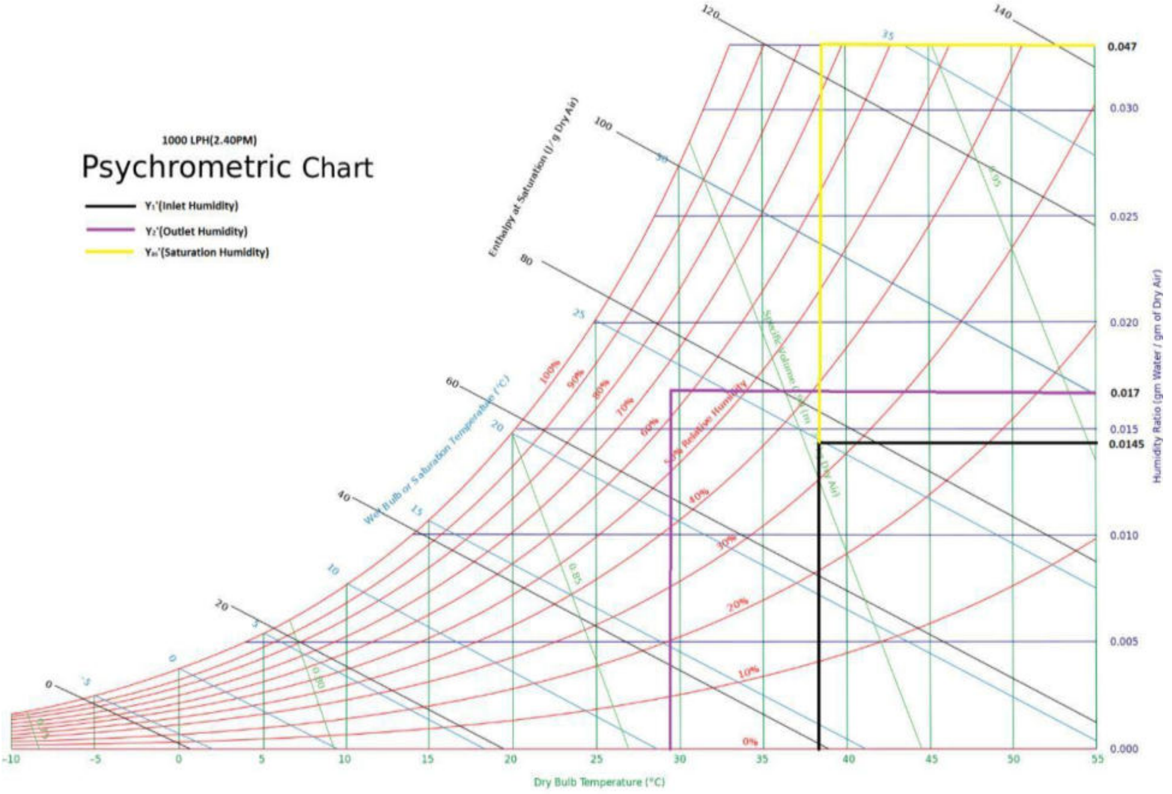

Fig: A.14 Humidity using Psychrometric Chart 1000 LPH (Run 5)

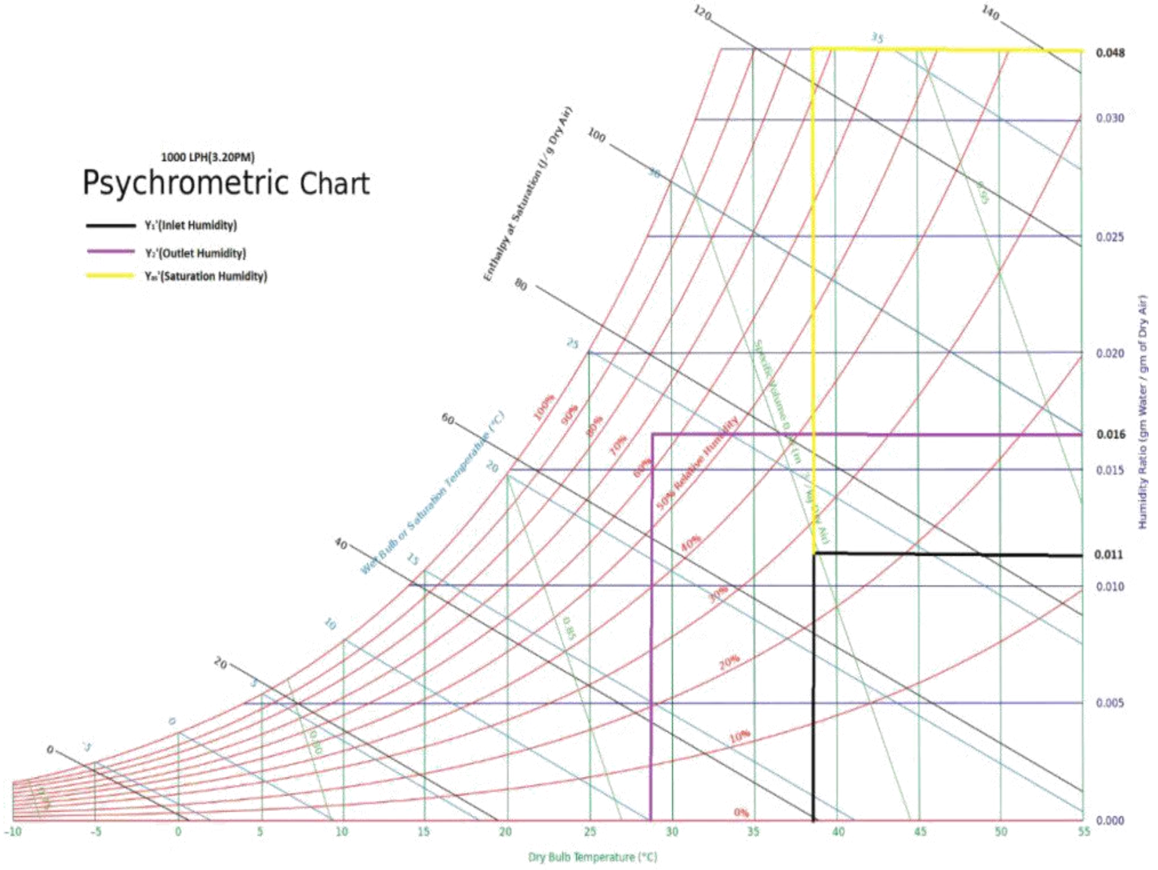

Fig: A.15 Humidity using Psychrometric Chart 1000 LPH (Run 6)

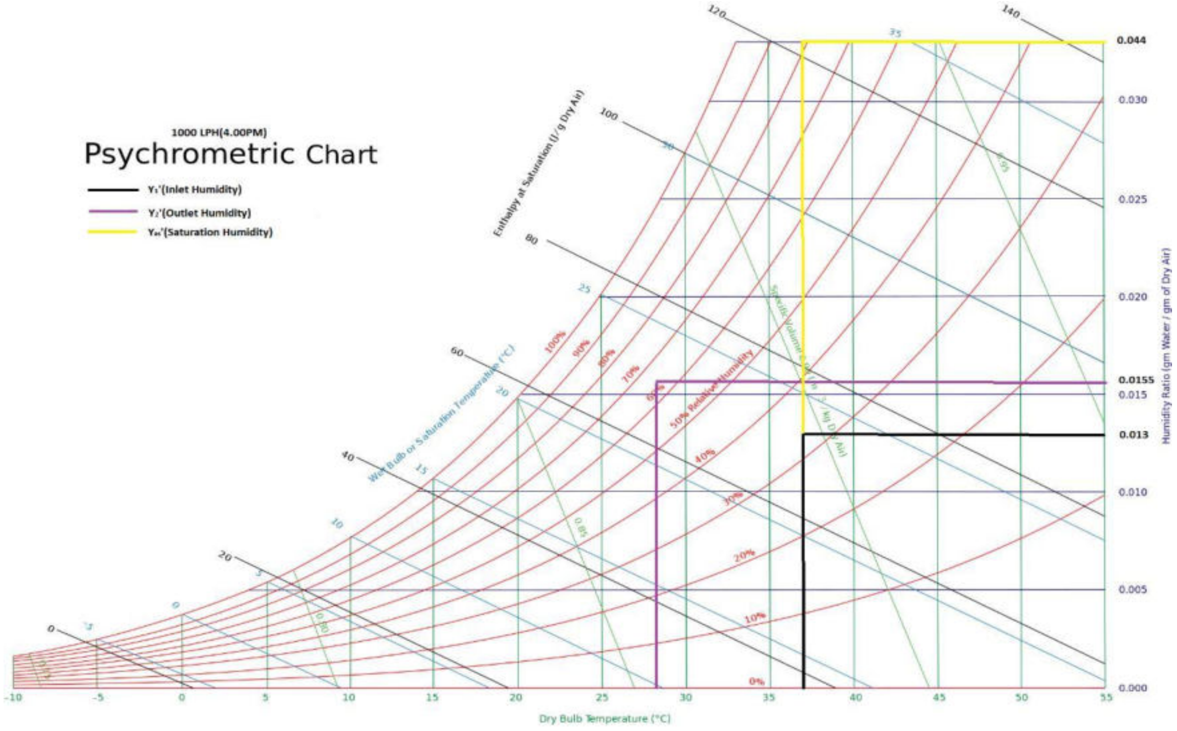

Fig: A.16 Humidity using Psychrometric Chart 1000 LPH (Run 7)