European Journal of Mechanical Engineering Research, 12(2),53-60, 2025

Print ISSN: 2055-6551(Print)

Online ISSN: 2055-656X(Online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development-UK

Evaporative Cooling Systems Adiabatic chillers

Ehab Nader Tuffaha
Mechanical Engineering
Saudi Jordanian Investment Fund-Jordan

doi: https://doi.org/10.37745/ejmer.2014/vol12n25360 Published December 30, 2025

Citation: Tuffaha E.N. (2025) Evaporative Cooling Systems Adiabatic chillers, *European Journal of Mechanical Engineering Research*, 12(2),53-60

Abstract: *The study trying to explain and utilize the adiabatic cooling principle in the chillers of high capacity in dry and hot environment. This methodology system designed to enhance the efficiency of cooling equipment by exploiting the principles of evaporative cooling. During the hot weather months units are under constant pressure to circulate enough cool air to the area where it is needed. but simply when air temperature increases, electricity consumption in air-conditioning units increases substantially and in addition to this process the cooling capacity of the air conditioning unit will decrease. The study aims to renovate the traditional refrigeration system, so that it can be developed to take advantage of the adiabatic evaporative cooling process without complicated changes neither a completely demolishing.*

Keyword: HVAC; adiabatic, evaporative, psychrometric

INTRODUCTION

Jordan as other amongst countries have a climate changes in a broad range of impacts, nowdays global warming is the most prominent challenges of the current era. Jordan is one of the most water-scarce countries in the world and is far below the international water poverty line, that's why we have to think how to manage the resources, and heating refregeration is affecting on water demands for the district cooling plants.

Basic thermodynamics statement that as a greater temperature difference between substances the faster heat flow, however an adiabatic or isenthalpic air-cooling process occurs during direct contact of unsaturated air with water. It is not a cold production process, since the initial heat content (enthalpy) of the air within that process stays unchanged.

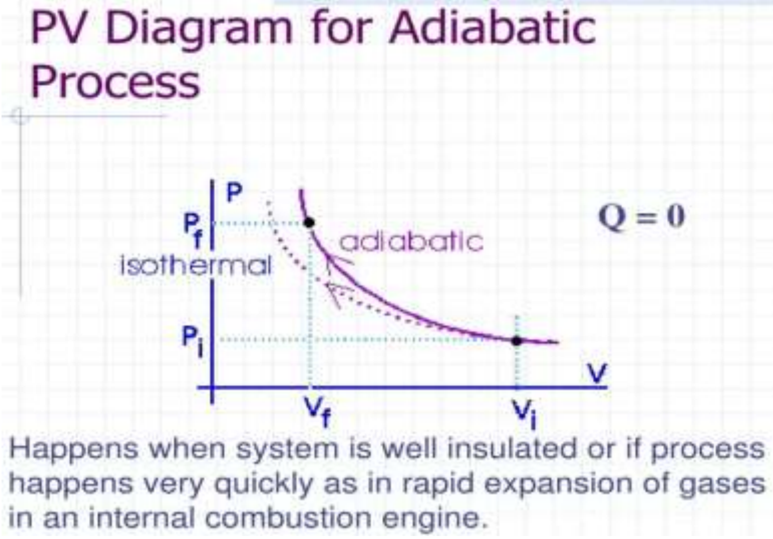

Figure -1: Illustration P-V diagram for adiabatic process.

Figure 1 illustrate the principle of adiabatic process as thermodynamic understanding.Let us go deeply in thermodynamic principles and reflect the idea in psychrometric chart however the first step let us verify the psychrometric parameters input data as per below in figure 2.

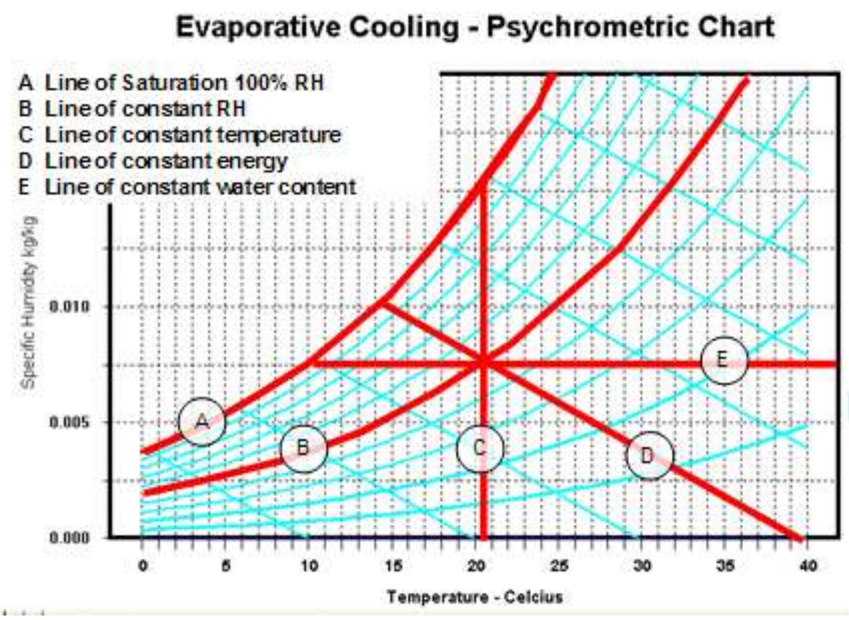

Figure -2: Evaporative cooling pscyrometric chart.

Air acts like a sponge to water, so let us explain that in psychometric chart, as we see in below figure 3, as the air takes up water it moves along the line of constant energy D but it's clearly the air also moving to reduce the dry bulb temperature C as it moving to more saturation lines.

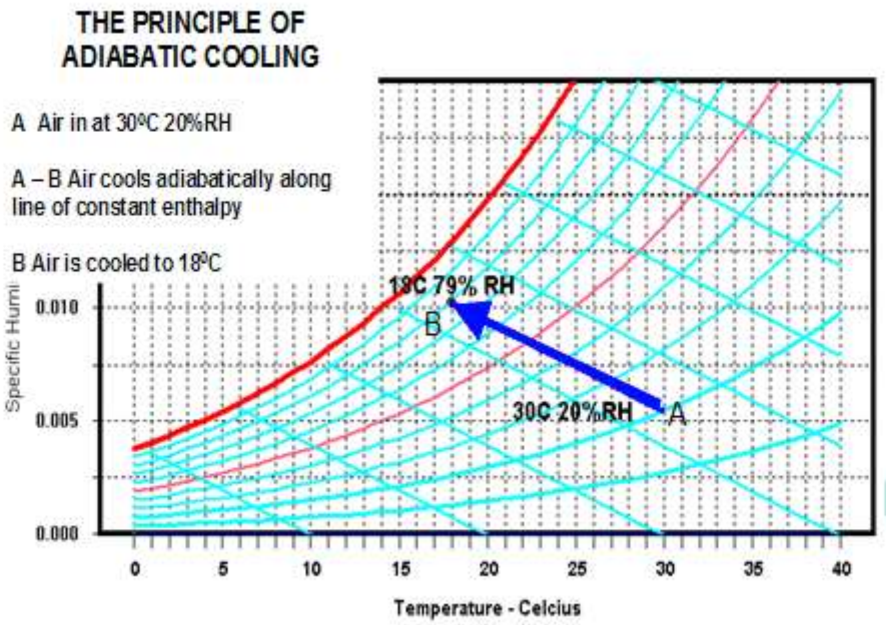

Figure -3: The principle of adiabatic cooling -Psychrometric chart**.**

LITRATURE REVIEW

The main point is to drive that the adaibatic evaporative cooling psychrometric process that involves the cooling of air without heat loss or gain. Sensible heat lost by the air is converted to latent heat in the added water vapor.

Referring to below Figure 4, let us explain the process in below example :

air at state point 1 (65 ° C dry bulb temperature and 57 °C wet bulb temperature) experiences a temperature drop of 3 °C as it passes through the 1.2-m wide stack of lumber. Determine the properties of the air at state point 2 and compare them with those at state point 1. If the air is flowing at a rate of 2 meters per second, determine the drying rate assuming that the volume of the stack of 2.5-cm-thick lumber is 2.5 m 3. The stack is 1.2 m wide x 3.6 m long, and the boards are separated by stickers 3.8 cm wide x 1.9 cm thick that are spaced 0.6 m apart.

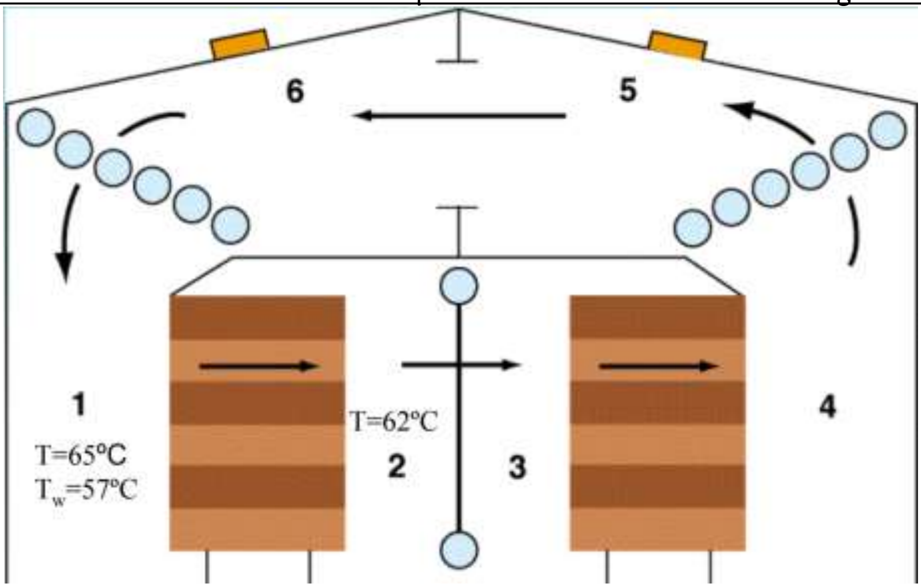

Figure -4: Litraure review example illustration.

Given: T1 = 65 °C; Tw1 = 57 ° C
Adiabatic cooling to T 2 = 62 ° C

Air flow rate = 2 m/s Volume of lumber = 2.5 m 3 Board thickness = 2.5 cm
Stack dimensions: 1.2 m wide x 3.6 m long Sticker dimensions: 3.8 cm wide x 1.9 cm thick Sticker spacing = 0.6 m Required: (a) Properties of the air at state point 2 relative to that at state point 1 (b) Drying rate.

Solution :

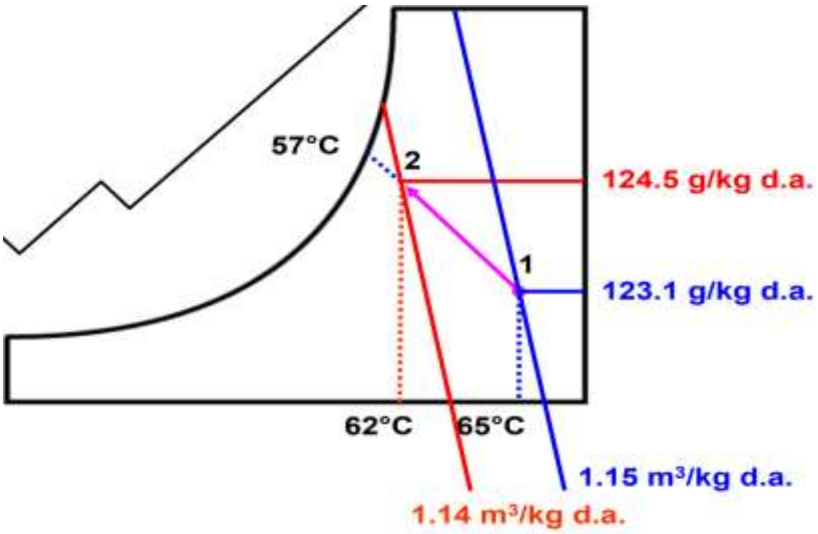

Figure -5: Illustration of the example in the psychrometric chart.

(a) At state point 1

T1 = 65 ° C Tw1 = 57 ° C Tdp1 = 56.3 ° C RH1 = 66.9% HR1 = 123.1 g/kg of dry air v1 = 1.15 m 3/kg of dry air h1 = 387.7 kJ/kg of dry air

At state point 2:

T 2 = 62 ° C Tw2 = 57 ° C Tdp2 = 56.5 ° C RH 2 = 77.3% HR 2 = 124.5 g/kg of dry air v 2 = 1.14 m 3/kg of dry air h 2 = 387.7 kJ/kg of dry air

(b) Drying rate = (ΔHR)(Wa)

Wa =VF/ v2 VF = (A) (air flow rate)

$$A = \left(\frac{V}{P_1 P_w B_1}\right)\left(P_1 S_1 - \frac{P_1 + S_s}{S_s} S_1 S_w\right)$$ equation 01a

$$A = \left(\frac{2.5}{3.6*1.2*0.025}\right)\left(3.6*0.019 - \frac{3.6+0.6}{0.6} 0.019*0.038\right)$$ equation 01b

A= 1.47 m2

$$VF = (A)(\text{air flow rate})$$ equation 02a

$$VF = (1.47\,m^3)\left(2\,\frac{m}{s}\right) = 2.9\,\frac{m^3}{s}$$ equation 02b

$$w_a = \frac{VF}{v_2}$$ equation 03a

$$w_a = \frac{2.9\,\frac{m^3}{s}}{1.14\,\frac{m^3}{\text{kg dry air}}} = 2.6\,\frac{\text{kg dry air}}{s}$$ equation 03b

$$\text{Drying rate} = (w_a)(\Delta HR)$$ equation 04a

$$\text{Drying rate} = \left(2.6\,\frac{\text{kg dry air}}{s}\right)\left(1.4\,\frac{g}{\text{kg dry air}}\right) = 3.6\,\frac{g}{s} = 13.0\,\frac{kg}{h}$$ equation 04b

European Journal of Mechanical Engineering Research, 12(2),53-60, 2025
Print ISSN: 2055-6551(Print)
Online ISSN: 2055-656X(Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

METHODOLGY

Adiabatic (evaporative) cooling provides energy-efficient cooling by making use of the natural change in temperature that occurs during the process of evaporation.

In a simple, direct diabatic system, a fan blows warm air against water-soaked pads. Some of the energy of the warmth in the air is imparted on the water. This evaporates the water in the pads, and lowers the temperature of the air.

Efficiency of the system

Based on the above explanation of adiabatic system ,the below is a study case for biggest project in Qatar, the project is in high temperature zone with high humidity in the coastal region, the aim from this case to proof that if such system doable with high efficiency in such proposed circumstance's it means it could be a high efficient system in dray and hot areas like Jordan and its neighbors.

Adiabatic Kit Performance Analysis:

The below figure 6 is the tabulation study from the view hospital in Doha with a total gross built up area of 91,185.00 sq.m., The project was planned to consist of 374 total bed units with 445 nos. car park facility.

Based on the below tabulation, the total cost 9 Nos. of Adiabatic System can be recovered in 2.7 year only.

The total cost of 9 Nos Air Cooled Chillers with Adiabatic System can be recovered in 28.6 years and can be applied to the following:

• It can pay for itself if the economic life span of chiller can be extended to 28.6 years with a good planned preventive maintenance (PPM)

• Or the total annual cost savings (QAR231,998.40) can be used as part to cover for the operating and maintenance expenses.

Studies show savings of up to 15% to 30% compared to traditional air-cooled condensers by reducing the power consumption and improving the chiller cpacity at high tempertures consequantly water flow will be reduced in operation process.

ADIABATIC AIR COOLED CHILLER PERFORMANCE TABULATION ANALYSIS						
Technical Description:	Ambient Temp per QCS	Summer Months Ambient Temperature, with Adiabatic System				
		May	June	July	August	September
	50 $^{\circ}$C	45 $^{\circ}$C	48 $^{\circ}$C	48 $^{\circ}$C	48 $^{\circ}$C	44 $^{\circ}$C
Air Entering Coil Temp, after passing through Adiabatic Mesh, $^{\circ}$C	N/A	36	39	39	39	35
Number of Duty Chillers	8	8	8	8	8	8
Cooling capacity for each chiller						
kW	1340	1550	1517	1517	1517	1561
Tons	381	440	431	431	431	443
Total capacity for 8 Duty Chillers, Tons	3045	3523	3448	3448	3448	3548
Power Input per Chiller, kW	576.8	456.9	479.9	479.9	479.9	449.5
Total Power Input for 8 Duty Chillers, kW	4614.4	3655.2	3839.2	3839.2	3839.2	3596
Comparative Total Power Consumption for 5 months at 10 Hrs operation per day, kW-Hr	**6,921,600**	**5,630,640**				
Savings in Power Consumptions during Summertime (5-Months Period), kW-Hr		**1,290,960**				
Operating Cost Savings in 5 Months due to the operation of Adiabatic Chillers, QAR		**284,011**				
Water Consumption per chiller/day @ 10 hrs operation of Adiabatic system, m^3/day	N/A	5.04	5.04	5.04	5.04	5.04
Total Water Consumption for the 8 Duty Chillers, m^3/month	N/A	1209.6	1209.6	1209.6	1209.6	1209.6
Total Water Consumption for 5 Summer Months, m^3		**6,048**				
Total Water Operating Cost due Kahramaa (@ QR8.60/m^3), QAR		**52,012.80**				
Net Operating Cost Savings Due to Adiabatic System, QAR:		**231,998.40**				
Total Cost of 9 Nos Adiabatic System:		**630,000.00**				
Payback Period to recover the cost of 9 Nos Adiabatic System, Years		**2.7**				
Total Cost of 9 Chillers with Adiabatic System (8 Duty + 1 Standby), QAR	=(180,000 x 9 x 3.70) + 630,000.00	**6,624,000.00**				
Payback Period to recover the cost of 9 Chillers with Adiabatic System, Years		**28.6**				

Figure -6: Tabulation of Adiabatic Kit Performance Analysis

Pros versus cons

Any system has a pros and cons based on the operation functionality, however the below are the most important advantages for such system:

– SAVINGS: Up to 30 % energy saving on conventional cooling system.

– ENVIRONMENTALLY FRIENDLY: Only water and air as cooling agent and low energy consumption, no CO2 emission.

– COST EFFECTIVE: Minimal maintenance requirements, minimal power infrastructure

– HYGIENIC: No still standing water, no algea, no legionella risk

The disadvantages are:

Direct diabatic systems can be very efficient – however, they also add humidity to the air, which isn't acceptable in data centre and telecom environments. Too much moisture can corrode sensitive components, and even cause short circuits.

CONCLUSION

The system is effiecinet and can increase the EER of the rfregiration ssytem.

Suggestions

As the direct evaporative system is not recommended to the data center, it's worth to suggest using the indirect evaporating system.

Indirect adiabatic cooling is a means of gaining the efficiencies of evaporative cooling without adding moisture to the air. A large percentage of the cost of operating a data center goes towards cooling and conditioning the air around these sensitive components, and the efficiencies gained by use of environmentally friendly evaporative cooling can lower those costs dramatically.

An indirect adiabatic cooler draws in and humidifies outside air to lower its temperature. The air is taken to a heat exchanger, and immediately exhausted. Indoor air – which never mixes with the outdoor air – is also brought to the heat exchanger, where the temperature of the indoor air is lowered without changing its humidity.

REFERENCES

- Heat and Mass Transfer, Fundamentals and Applications, Fourth Editionby Yunus A. Çengel and Afshin J. Ghajar.
  McGraw-Hill, 2011 ISBN:007-3398128.
- Engineering heat and mass transfer by Mahesh M.Rathore from university Science press 113, golden house, daryaganj-new delhi-110002
- Fundamentals of Heat and Mass transfer by M.Thirumaleshwar Pearson Publication panchasheel
- Fundamentals of Engineering Heat and Mass transfer by R.C. Sachdeva New age international
- Ron Zevenhoven Åbo Akademi University Thermal and Flow Engineering Laboratory / Värme- och strömningsteknik tel. (02 215)3223 ; ron.zevenhoven@abo.fi.
- MEP concept design report for the view hospital, REV. 01 Page 1 DH2019-RPT-MEP-0006.