**Analysis of an Air Conditioner using both Water Mist and Air for Cooling in Condenser**

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***Abstract***—*This paper considers how the performance can be improved, when the water mist system is coupled with the air cooled conditioner as a pre-cool for condenser inlet air to increase the cooling capacity, and decrease the compressor power consumption .A theoretical investigation has been carried out to study the thermal performance of a water mist assisted air conditioner under ambient temperatures ranging from 25℃ to 45℃. The influence of condenser and evaporator inlet air temperatures on the cooling capacity and power consumption has been investigated and presented. A mathematical model of the existing system was developed. The model was validated using experimental data recorded from the system. Subsequently, the model served as a tool to evaluate alternative system design and operating strategies that lead to optimum system performance. Evaporative cooling can reduce the air temperature from its dry bulb to wet bulb temperature. Therefore, it is possible to improve the energy efficiency of air-cooled Air conditioners by installing water mist system to pre-cool the outdoor air before entering condensers. In very dry climates, evaporative coolers, sometimes referred to as swamp coolers or desert coolers, are popular for improving coolness during hot weather. An evaporative cooler is a device that draws outside air through a wet pad, such as a large*[*sponge*](https://en.wikipedia.org/wiki/Sponge_%28tool%29)*soaked with water. The*[*sensible heat*](https://en.wikipedia.org/wiki/Sensible_heat)*of the incoming air, as measured by a*[*dry bulb thermometer*](https://en.wikipedia.org/wiki/Dry-bulb_temperature)*, is reduced. The temperature of the incoming air is reduced, but it is also more humid, so the*[*total heat*](https://en.wikipedia.org/wiki/Total_heat)*(sensible heat plus latent heat) is unchanged. Some of the sensible heat of the entering air is converted to latent heat by the evaporation of water in the wet cooler pads. If the entering air is dry enough, the results can be quite substantial.The influence of condenser and evaporator inlet air temperatures on the cooling capacity and power consumption has been investigated and presented. It has been found that due to the coupling of water mist with air cooled condenser, the cooling capacity of the air-cooled,air conditioner can be increased up to 17.5%, and the compressor power consumption can be reduced up to 15.5%. Thus, it is concluded that the application of water mist condenser, inlet air pre-cooling could increase the COP by up to 37%, especially when the ambient relative humidity is low[10].*

***Keywords— Thermal performance, water mist, air cooled condenser, air conditioner.***

1. **INTRODUCTION**

Air conditioning (often referred to as A/C or AC) is the process of altering the properties of [air](https://en.wikipedia.org/wiki/Air) (primarily [temperature](https://en.wikipedia.org/wiki/Temperature) and [humidity](https://en.wikipedia.org/wiki/Humidity)) to more comfortable conditions, typically with the aim of distributing the conditioned air to an occupied space such as a building or a vehicle to improve [thermal comfort](https://en.wikipedia.org/wiki/Thermal_comfort) and [indoor air quality](https://en.wikipedia.org/wiki/Indoor_air_quality). In common use, an air conditioner is a device that lowers the air temperature. The [cooling](https://en.wikipedia.org/wiki/Cooling_%28disambiguation%29) is typically achieved through a [refrigeration cycle](https://en.wikipedia.org/wiki/Refrigeration_cycle)

 The use of water mist in decreasing the air temperature entering the condenser will definitely increase the efficiency of heat exchange at the condenser and so increase efficiency of the condenser and the coefficient of performance (COP) of the air conditioning unit.A mathematical model of the existing system was developed. The model was validated using experimental data recorded from the system. Subsequently, the model served as a tool to evaluate alternative system design and operating strategies that lead to optimum system performance. Evaporative cooling can reduce the air temperature from its dry bulb to wet bulb temperature. Therefore, it is possible to improve the energy efficiency of air-cooled Air conditioners by installing water mist system to pre-cool the outdoor air before entering condensers. In very dry climates, evaporative coolers, sometimes referred to as swamp coolers or desert coolers, are popular for improving coolness during hot weather. An evaporative cooler is a device that draws outside air through a wet pad, such as a large [sponge](https://en.wikipedia.org/wiki/Sponge_%28tool%29) soaked with water. The [sensible heat](https://en.wikipedia.org/wiki/Sensible_heat) of the incoming air, as measured by a [dry bulb thermometer](https://en.wikipedia.org/wiki/Dry-bulb_temperature), is reduced. The temperature of the incoming air is reduced, but it is also more humid, so the [total heat](https://en.wikipedia.org/wiki/Total_heat) (sensible heat plus latent heat) is unchanged. Some of the sensible heat of the entering air is converted to latent heat by the evaporation of water in the wet cooler pads. If the entering air is dry enough, the results can be quite substantial.Refrigeration is the cooling effect of the process of extracting heat from a lower temperature heat source, a substance or cooling medium and transferring it to a higher temperature heat sink, probably atmospheric air, or water, to maintain the temperature of the heat source below that of the surroundings. The most common refrigeration systems are vapourcompression systems. The use of water mist in decreasing the air temperature entering the condenser will definitely increase the efficiency of heat exchange at the condenser and so increase efficiency of the condenser and the coefficient of performance (COP) of the air conditioning unit (ASHRAE, 2009 [1,2])here are two ways using the condensate water: one is to use it as water resource: one is as the supply forunits of the cooling tower. Another is to use it as sanitary water in public places, such as the airport lounges [2-3].

1. **LITERATURE REVIEW**

Water-spray mist cooling system is used to assess its performance, which is based on the pre-cooling air entering the condensers to decrease compressor power consumption of air-cooled chillers with a nominal capacity of 600 kW. It mainly consists of atomization nozzles, water pipe work, a filter assembly, mounting brackets and a high pressure pump with around 70 bars of pressure. Based on the experimental data obtained from the measurements under ambient temperatures ranging from 25℃ to 39℃, the reduction in air temperature were 5 to 20℃. The energy efficiency ratio (EER) increased by a 13.5%, while an increase of 5.9% in the cooling capacity was obtained [3]

The chiller performance can be improved by using water mist to pre-cool ambient air entering the condensers to decrease compressor power. A simulation analysis on an air-cooled chiller equipped with a water mist pre-cooling system under head pressure control shows that applying water mist pre cooling enables the coefficient of performance (COP) to increase. They concluded that the application of water mist pre-cooling could increase the COP in various degrees by up to 30%, especially when the relative humidity is low. Furthermore incase of using a water mist system, the chiller power could reduce by 16.2% or 15.8% [6].

It is possible to improve the energy efficiency of air-cooled condensers by installing water mist system to pre-cool the outdoor air before entering condensers. The water mist pre-cooling system is not a new concept, and has been applied successfully in the industries [5].

However, the application of water-mist system associated with a chiller system is not common, and a limited number of studies are found on the performance of chillers with water mist system. High energy costs are compelling air conditioner manufacturers to develop more efficient systems. The air conditioning system disclosed herein does not require inordinate heat exchanger size or new compressor technology to significantly reduce energy costs, while improving the efficiency of the system and the ability of the system to cool thecomfort Zone in a building. Further, the system does not require a remote cooling tower or other sources of a largevolume of Water. The system does not discharge Waste Waterand thus conserves resources.

1. **THEORETICAL ANALYSIS**

When the water mist system is coupled with the air conditioner, the temperature of the air at the inlet of the air-cooled condenser will decrease compared the temperature of the ambient air, as well the condensing temperature and condensing pressure will decrease accordingly, as shown in Figure (1).

The refrigeration cycle of the air conditioner with water mist system is changed from the cycle 1-2-3-4-1 to 1’-2’-3’-4’-1’. As the condensing pressure decreases, the work of the compressor will also decrease. However, the cooling capacity may be increase, so the COP of the chiller system will increase. Theoretically, air-cooled condenser coupled with a water mist system will improve the air conditioner efficiency, but it will depend on the ambient climatic conditions, cooling load, etc.



Refrigeration specific enthalpy, h (kj/kg)

*Fig.1:Vapour compression refrigeration cycle.*

1. **MATHMATICAL FORMULATION**

**Air Conditioner with air cooled condenser**

The measured operating data for the air-cooled air conditioner included the power of compressor, WCP; the power of refrigeration cycle, WRP, which equal to the power of compressor plus the power of fan, cooled air supply temperature, Tea,s, cooled air return temperature, Tea,r; evaporating temperature, Tev and condensing temperature, Tcd of refrigeration cycle. The cooling capacity of the air conditioner, QE is:

QE = 𝑚𝑎.(hea,r – hea,s ) … (1)

Where ma is the cooled air mass flow rate, Ca is the specific heat capacity of air, Where: hea,r, hea,s are enthalpies of the air at evaporator inlet and outlet, respectively (kJ/kg).

Heat rejection, QR was calculated by Eq. (2). The heat rejection airflow, Va was determined by Eq. (3), where Tca,l is the temperature of air leaving the condenser.

QR = QE + WCP…(2)

𝑉𝑎 = 𝑄𝑅/(ρaCa (Tca,1 − Tca,e)) … (3)

The air conditioner COP is expressed as cooling capacity, QE over power consumption WCP, as follow:

COP = QE/ WCP … (4)

For any given cooling capacity, QE, compressor power, WCP and heat rejection, QR will vary according to the condensing temperature, Tcd.[10]

**Air conditioner with water mist**

While the water mist system operates,(with reference to fig. 1)

Wair cooling=$P\_{1}V\_{1}\frac{n}{n-1}\left[\left(\frac{P\_{2}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]$

Wwater cooling=$P\_{1}V\_{1}\frac{n}{n-1}\left[\left(\frac{P\_{2}^{"}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]$

% saving = $\frac{W\_{air}-W\_{water}}{W\_{air}}$

= $\frac{\left[\left(\frac{P\_{2}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]-\left[\left(\frac{P\_{2}^{"}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]}{\left[\left(\frac{P\_{2}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]}$

=$\left[1-\frac{\left[\left(\frac{P\_{2}^{"}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]}{\left[\left(\frac{P\_{2}}{P\_{1}}\right)^{\frac{n-1}{n}}-1\right]}\right]$\*100%

In terms of temperature at compressor outlet

% saving= $\left[1-\left(\frac{\frac{T\_{2}^{"}}{T\_{1}}-1}{\frac{T\_{2}}{T\_{1}}-1}\right)\right]$\*100

=$\left[1-\left(\frac{T\_{2}^{"}-T\_{1}}{T\_{2}-T\_{1}}\right)\right]$\*100

Work required by condenser fan (air-side)

Wf,comp=$\frac{V\_{a}ΔP\_{a}A\_{f}}{η\_{f}}$

Where,

Va= velocity of air,

ΔPa= Pressure drop,

Af= Frontal area,

𝜼f=Fan efficiency.

As of now evaporators are not considered as the part of the study but we will wor on the optimisation of the tube thickness of the evaporator.

C.O.P.=$\frac{Q\_{E}}{W\_{comp}+W\_{condenser fan}+W\_{evaporatoe fan}+W\_{pump}}$

(As the pump work is negligible so, by ignoring the pump work, we have,

C.O.P.=$\frac{Q\_{E}}{W\_{comp}+W\_{condenser fan}+W\_{evaporatoe fan}}$

Seasonal C.O.P.=$\frac{\sum\_{}^{}Q\_{E}\left[t\right]}{\sum\_{}^{}W\left[t\right]}$

Wcomp= $P\_{1}V\_{1}\frac{n}{n-1}\left[\frac{P\_{2}}{P\_{1}}-1\right]$

If $\frac{P\_{2}}{P\_{1}}=r$

Wcomp(in Kw)=$ mRT\_{1}\frac{n}{n-1}\left[r^{\frac{n}{n-1}}-1\right]$ Kw

Energy of one hr. = $mRT\_{1}\frac{n}{n-1}\left[r^{\frac{n}{n-1}}-1\right]$ Kwhr

Cost of one hr. = $mRT\_{1}\frac{n}{n-1}\left[r^{\frac{n}{n-1}}-1\right]\*C$ RS.

Where, C is the cost of 1Kwhr.

Running cost of water per hr. = $\frac{ρQgH}{η\_{p}}=\frac{m\_{w}gH}{η\_{p}}$

Where,

Q = Discharge required.

mw= Mass flow rate of water.

$η\_{p}$= Pump efficiency.

H = Head produced by the pump.

g = Acceleration due to gravity.

$ρ$ = Density of water.

Cost of running pump for 1 hr. = $\frac{m\_{w}g H}{1000}\*C$

Now the heat lost by the refrigerant, water and air is equal to the heat gain by water vapour.

mwcpw(Δtw)=mref(h2-h3)

mw=mref(h2-h3)$\frac{m\_{ref}\left(h\_{2}-h\_{3}\right)}{c\_{pw}\left(Δt\_{w}\right)}$

Get h2,h3 in terms of r or make calculations for various readings.

ΔP=$\frac{fG^{2}L}{ρ}$ in both superheated and subcooled region.

f=$\frac{64}{Re\_{D}}$ if ReD<2000µ

$\frac{1}{f^{\frac{1}{2}}}=-2log\_{10}\left[\frac{\frac{E}{D}}{3.7}+\frac{2.5l}{Re\_{D}f^{\frac{1}{2}}}\right]$if ReD>2000

1. **RESULTS AND DISCUSSIONS**

 The use of water mist in decreasing the air temperature entering the condenser will definitely decrease the condensing temperature of the refrigeration cycle.The condenser inlet air temperature affects the performance of the refrigeration cycle of air conditioner. As, mentioned, the decrease of condenser inlet air temperature, which will definitely decrease in condensing temperature, consequently the condensing pressure of the cycle was decreased. As the condensing pressure decreases the power required by the compressor is also decreases and the further subcooling of the liquid refrigerant result in the huge saving of power consumption, increases the life of the components of an air conditioning unit.

1. **CONCLUSIVE REMARKS**

The theoretical study gave an idea on how the water mist system can be used as an evaporative pre-cooler to improve the efficiency under different weather and cooling load conditions. So, it can be concluded that: - The power consumption of the compressor was decreasedand the cooling capacity was increased. As the temperature of air entering the condenser decreases, the COP of the air conditioner was increases.

In the present research paper, the potential of applying mist precooling have been investigated for air-cooledair conditioners. The cooling effect will be better and energy savings from water mist pre-cooling would be more significant if the air conditioner operate in a hot and arid outdoor environment

In this study, the potential of applying mist pre cooling have been investigated for air-cooled air conditioner. The validity of the performance of the entire air conditioning system model, which is integrated the air conditioner model and water mist model was checked by comparing the modeled results with the operating data of the air conditioner. The cooling effect will be better and energy savings from water mist pre-cooling would be more significant if the air conditioner operate in a hot and arid outdoor environment. The theoretical study gave an idea on how the water mist system can be used as an evaporative pre-cooler to improve the efficiency under different weather and cooling load conditions. So, it can be concluded that: - The power consumption of the compressor was decreased and the cooling capacity was increased. As the temperature of air entering the condenser decreases, the COP of the air conditioner was increases.

**NOMENCLATURE**

Symbol DefinitionsUnits

Caspecific heat of air kJ/kg oC

henthalpykJ/kg

mmass flow rate kg/s

T temperature°C

QEcooling capacitykw

QRheat rejectionkw

Vavolume rate of airm3/s

Wcompressor workkw

ρdensitykg/m3

**Subscripts**

a air

db dry bulb

ea,r return air to evaporator

ea,s supply air from evaporator

ca,e entering air to condenser

ca,l leaving air from condenser

cd condensing

ev evaporation

mist water mist

**Abbreviations**

COP coefficient of performance

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