IMPROVING THE THERMAL PERFORMANCE OF COOLING TOWERS BY CONDITIONING OF AIR

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ABSTRACT

Up to the present, attempts at improving the performance of cooling towers have been focused on the design of the components such as the packing, nozzles, fans, etc. This investigation has been carried out to assess the viability of a new and novel approach, which involves conditioning the inlet air to the cooling tower in order to reduce the wet-bulb temperature, which is the principal external parameter that affects performance.

The wet-bulb temperature of the air entering the cooling tower determines operating temperature levels throughout a water-cooled plant, process or system. It is very important to have the cold water temperature low enough to exchange heat or to condense vapours at the optimum temperature level.

The investigation of performance involved the development of a suite of integrated computer models which were used along with real-time plant data to assess the performance improvement achievable with the proposed air conditioning system.

The results of the analysis indicated the feasibility of this new and novel approach. However, significant further work will be required before the concept can be implemented in reality.

DEDICATION

This project is dedicated to GOD ALMIGHTY

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a	Contact area/tower volume (m^2/m^3) (area of effective transfer surface per unit of tower packing volume)
A	Absorption factor
c	Cooling tower mass transfer constant
C	Specific heat (kJ/kg K)
C_p	Specific heat at constant pressure (kJ/kg K)
CR	Circulation ratio (liters TEG/kg H_2O)
E_a	Absorption efficiency
Exp	Exponential function
G	Air rate [kg/(m^2.s)] (mass of air flow per unit plan area of packing)
h	Specific enthalpy (kJ/kg)
H	Enthalpy (kJ)
dh	Change in air enthalpy (kJ/kg)
k	Equilibrium constant
K	Mass transfer coefficient kg/[(m^2.s. (kg/kg)][1]
l	Glycol circulation (moles/unit time)
L	Water rate [kg/(m^2.s)] (mass of water flow per unit plan area of packing)
$\dot{m}$	Mass flow rate
MW	Molecular weight (kmol/kg)

[1] Coefficient of mass transfer defined in terms of difference in absolute humidity. That is kilogram per second per square meter per kilogram water per kilogram dry air.

n Cooling tower mass transfer exponent

N Number of theoretical trays

NTU Number of transfer units

LNG Liquefied natural gas

P System pressure (Pa)

$\dot{q}$ Volumetric flow rate (m^3/h)

Q Heat transferred in cooling tower from water to air (kW)

t Temperature (°C)

T Temperature (K)

dT Cooling tower temperature range (K)

TEG Triethylene glycol

UA Overall heat transfer coefficient – area product (W/K)

$\dot{v}$ Gas flow rate (moles/unit time)

v Specific volume (m^3/kg)

V Active cooling volume/plan area (m^3/m^2)
(effective packing volume per unit area of packing)

w Mass of water per standard volumetric flow rate of gas ($kg/10^6$ std m^3)

W Work (kW)

x Mol fraction of water in lean glycol

X Weight percent TEG (wt%)

y mol fraction of water in gas

GREEK SYMBOLS

ε Effectiveness

γ Activity coefficient for water in TEG-water system

η Cooling efficiency of tower

λ Average latent heat of vaporisation of water vapour (kJ/kg)

ρ Density (kg/m³)

ω Humidity ratio or absolute humidity (kg/kg da)

μ Mean

SUBSCRIPTS:

1 Inlet

2 Outlet

a Air

d Design

dehyd Dehydrated

g Saturation

in Inlet

n molar

out Outlet

Ref Reference

s Water Vapour

std Standard condition

t Test

TEG Glycol

Undehyd Undehydrated

w water

wb Wet-bulb

GLOSSARY OF TERMS

Term	Definition
Absorption process	The attraction and retention of vapours (water) by liquids (glycol) from a gas (air) stream.
Air flow	Total quantity of air, including associated water vapour.
Approach	Difference between exit water temperature (from cooling tower) and the inlet air wet-bulb temperature.
Cell	Smallest subdivision of a cooling tower bounded by exterior walls and partition walls which can function as an independent unit as regards air and water flow.
Cold water basin	A device at the bottom of the cooling tower to receive cold (exit) water from the tower, and direct its flow to the suction line of the circulating pump.
Cooling Range	Difference between the inlet water temperature and the exit water temperature of the cooling tower.
Drift eliminator	A system of baffles located at the exit of the tower, designed to reduce the quantity of entrained water in the exit air.
Drift loss	Water lost from the cooling tower as liquid droplets entrained in the outlet air.
Effective volume	The volume within which space the circulating water is in intimate contact with the air flowing through the tower.
Fan power	Power input to the fan drive assembly excluding power losses in the driver.

Heat flux	The average heat transfer rate through an heat exchanger tube, to the fluid per unit tube surface area.
Heat load	Rate of heat removal from water in the cooling tower.
Lean glycol	Glycol which has been regenerated and has a low water content.
Louvres	Members installed in a tower wall tp provide openings through which air enters the tower; usually installed at an angle to the direction of air flow.
Make-up water	Water added to the circulating water system to replace water loss from the system by evaporation, drift, blowdown and leakage.
Packing (cooling tower)	Material placed within the cooling tower to increase heat and mass transfer between the circulating water and the air flowing through the tower.
Packing (glycol absorber)	Material installed in the absorber, still column or stripping column that provides large surface area for intermingling liquid and vapour to facilitate mass transfer during absorption, distillation or stripping.
Purge (or Blowdown)	Water discharged from the system to control concentration of salts or other impurities in the circulating water.
Recirculation	Portion of the exit air that re-enters the cooling tower.
Reflux	Condensed liquid which flows back down a column to maximise separation efficiency.
Rich glycol	Glycol which has absorbed water and thus has a high water content.
Spray nozzle	Used in a pressure distribution system to break up the flow of the circulating water

	into droplets, and effect uniform spreading of the water over the wetted area of the tower.
Standard (temperature and pressure)	Unit of ideal gas volume at reference conditions of 101.3250kPa and 15 °C. Abbreviated: std m^3
Stripping gas	Gas that is contacted with glycol to help remove water from the glycol.
Unit circulation rate (circulation ratio)	Volumetric or mass flow rate of lean glycol per mass flow rate of water removed (absorbed).
Water loading	Inlet water flow expressed in quantity per unit of plan packing area of tower.