Reducing Air Cooler Size in Design Stage by Using a Chilling System

This technical paper will describe a practical way of how to decrease design ACHE or ACC size by using a fogging system to reduce air temperature during those critical warm days or for peak loads. The advantages of designing a smaller ACHE are the fact that it will reduce the cost of the project considerably, reduce overall noise level of the project and will also reduce plot area as well.

When designing new process equipments such as Air Cooled Heat exchangers (ACHEs) or air cooled condensers (ACC's), one must always decide what ambient air temperature to use. Ambient air temperature will greatly affect ACHE size.

There is always the trade-off between high capital expenditure (high ambient air temperature) or limitations in production during the hot summer days if one decides to use lower ambient air temperatures in the design stage.

The choice is even made so much harder as in a large portion of the world, the warm days are limited to a certain number of days of the year (2-4 months), and therefore, one builds an ACHE or ACC that is also able to cope with these relatively limited number of hot days in order not to be limited in production during those warm days.

Other plants also only need their units to be running at peak loads for a limited number of days a year which necessitates to design a large unit only used for a couple of days or weeks.

We will look at one case study of an existing 5 bay bank of Air-Cooled Heat Exchangers (ACHEs), namely a C3/C4 splitter condenser unit located in a European Refinery.

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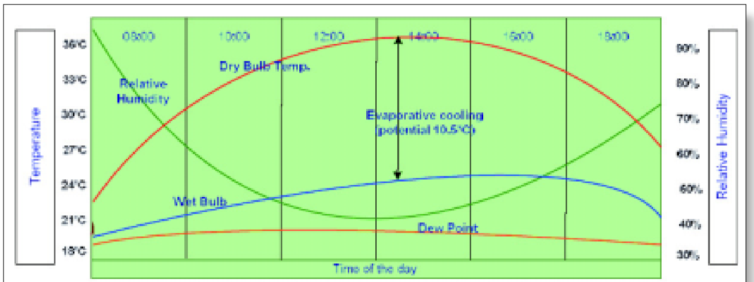
How does a proper chilling system work?

A proper chilling (also called fogging, misting, peak cooling) system is a high pressure fogging system used to influence ambient climatic conditions. By evaporating billions of micro fine droplets in the inlet air of an ACHE or ACC, adiabatic cooling is attained and the evaporative effect results in a drop in inlet air temperature, resulting in an increase in efficiency of the ACHE or ACC. The evaporative cooling system effect on an ACHE or ACC will have a direct positive effect on Process production. A proper chilling system can reduce air temperature by as much as 12*C in dry climates (Steppes & desert) and up to 10*C in continental, Mediterranean and temperate climates. Illustration of adiabatic cooling through fogging system is shown in Graph 1.



Graph 1

A proper chilling system is also designed and installed in such a way that all of the water sprayed in the air is completely evaporated before reaching the mechanicals and/or finned tube bundle as illustrated in Figures 1 and 2. This is attained by using special nozzles and high pressure (70- 100 Bar) in order to create microscopic droplet sizes (20-25 μ). By doing so, the evaporation time is reduced to almost nothing (almost instant evaporation) and will therefore allow for a system with maximum efficiency, minimum water waste and no damage of your mechanicals and/or finned tube bundle.

Figure 1 & 2. Illustration of proper chilling system where all the "fog" is evaporated before reaching the finned tube bundle on an induced draft air cooled heat exchanger unit.

Other things to keep in mind when designing a proper chilling system is to take into consideration the following factors:

- Evaporation time which is determined by the droplet size and air temperature
- Face velocity of the air beneath the fan for a forced draft unit and beneath the bundle for an induced draft unit
- Distance of fogging system and finned tube bundle and/or mechanicals (motors/fans & drives)
- Wind factor (to be eliminated by using special wind screens)
- Regulation of system by using multiple stage system with or without connection to weather station

A high pressure fogging consists of the following items

- A high pressure motor pump unit (up to 120 bars) skid mounted with SS316L plunger pump with 3 ceramic plungers, high pressure release valve, pressure regulator, low pressure sensor, pulsation dampener, V-belt drive reduction system and electrical motor (ex proof if provided in Ex zone);
- A water filter system using cartridge filters (up to 5μ) (one filter of 20μ and the other of 5μ);
- A pressure control (provided with our motor pump units) ;
- A network of SS316L tubing inter-connected by SS316L compression fittings (Parker) ;
- A drainage system to purge the lines during winter operation;
- A grid of SS316L tubing with custom inserted SS316L atomization nozzles (fully dismountable) inter-connected by SS316L compression fittings (Parker)

In order to make sure that the wind does not blow away the fog/mist, a wind screen system should be installed at the height of the nozzle lines. This must be done at least at the side of the prevailing wind direction such as illustrated in the pictures below. This will also have a positive effect on the air cooler or air

Figure 3

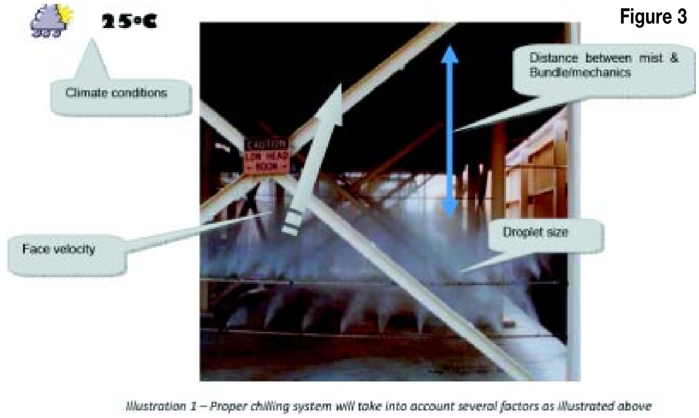


Illustration 1 – Proper chilling system will take into account several factors as illustrated above

Figure 4 & 5. Illustration of wind screens in order to make sure that the wind does not blow away a portion of the mist in the atmosphere

cooled condenser performance as it eliminates the negative effects of cross winds creating back pressure underneath the fan or under the finned tube bundle for an induced draft unit.

Case study on C3/C4 splitter condenser at Northern European Refinery

The base design air-cooled heat exchanger (ACHE) described in this paper is a grade mounted, carbon steel induced draft item built to the API-661 Standard. The ACHE has a thermal duty of 9875 KW condensing propane at an ambient design air temperature of 35oC. The item consists of 5 individual bays with 12.2 m (40.0 ft) long 25.4 mm (1.0 in) OD carbon steel tubes with extended surface. The extended surface consists of extruded aluminum fins 15.9 mm (0.625 in) high spaced at 433 fins per meter. The tubes are spaced in an equilateral tube pitch of 63.5 mm (2.5 in). Header is plug type with 3 passes. The individual bays are 6.08 m (20 ft) wide. For each bay, there are two finned tube bundles. Height from the bottom of the tube bundle frame to grade is 7 m (23 ft).

The base mechanical fan drive systems consists of 15 kW, 50 HZ, single speed motors, Banded V-belt speed reduction, and 4.27 m (14 ft) aluminum fans with 6 blades.

Each bay has two mechanical drive systems with the entire item containing ten such systems.

In order to design the fogging system, we used a minimum relative humidity (RH) of 40%. This low RH is realistic as the system is used in the peak hours of the day. A strong inverse relationship exists between the Dry Bulb Temperature and RH, which is more pronounced during the hot summer days. Whenever the ambient temperatures are high, the coincident RH is always lower. By doing so, we can obtain the following new ambient air temperatures based on system requirements (using a multi stage system).

What does this mean in terms of designing a new ACHE with fogging system?

In this comparison, we have compared a few factors that are important in terms of air cooler design which are:

1. Number of bays required

The number of bays required for each thermal duty has been calculated by using in-house thermal rating program of Air Cooled Heat Exchanger manufacturing company Decometa located in Belgium. All parameters such as tube side data, air side data, construction and mechanical equipment have been kept identical except for design air temperature and relative humidity. We have used the following temperatures with corresponding relative humidity for each case

- Case 1 without fogging system Design air 35.0°C with 50% RH
- Case 2 fogging system 5°C Design air 30.0°C with 60% RH
- Case 3 fogging system 10.5°C Design air 24.5°C with 90% RH

2. Noise level

In order to evaluate the overall noise level, we have assumed:

- exact same type of blade profile, fan diameter, number of blades, inlet conditions
- exact same type of tip speed of fan
- exact same type of drive and motor (absorbed power)
- Dimensions of bay (14991 mm x 6079 mm)
  - Reflection parameters (gravel)
  - Distance to periphery
  - Number of fans per bay (2)

3. Plot area

This data is the overall dimensions of the unit as a whole for each case.

4. Cost

In order to evaluate the overall cost of a new unit for each case, we have estimated:

- Cost per bay (bay is fully identical for each case in terms of finned tube bundle, motor size, fan diameter/

10.5°C cooling system (3 stage system)

Without fogging system	T [°C]	35.0°C	30°C	24°C
	HR [%]	40%	50%	60%
Total Airflow		786 m3/s	786 m3/s	786 m3/s
Water consumption [m³/h]		13.73 m³/h	9.15 m³/h	4.58 m³/h
Number of stages		3 stages	2 stages	1 stage
With fogging system	T [°C]	24.5°C	23.1°C	20.6°C
	HR [%]	94.7%	90.5%	82.6%

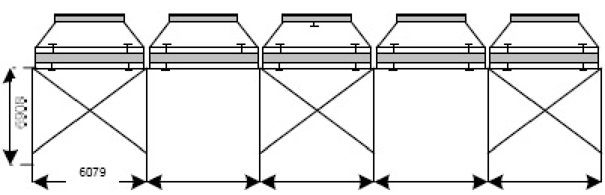
5°C cooling system (2 stage system)

Without fogging system	T [°C]	35.0°C	30°C	24°C
	HR [%]	40%	50%	60%
Total Airflow		786 m3/s	786 m3/s	786 m3/s
Water consumption [m³/h]		6.53 m³/h	6.53 m³/h	3.27 m³/h
Number of Nozzles		2 stages	2 stages	1 stage
With fogging system	T [°C]	30.0°C	25.1°C	21.6°C
	HR [%]	60.5%	76.5%	75.4%

type, motor size, etc.)
- Erection & commissioning cost per bay
- Electrical installation per bay and cost of electrical installation of motor/pump units for fogging system
- Cost of design, supply, installation and start up of HP fogging system for cases 2 & 3
- Prices are Ex Works for air cooled heat exchangers unit and Duty Delivery Paid for the fogging systems
- Cost index has been calculated by taking into account all the costs mentioned above

Results of simulations

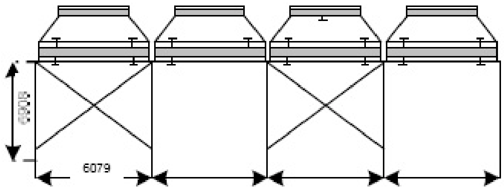
Case 1 - Without fogging system



C3/C4 splitter condenser with thermal duty of 9875 KW
35.0oC design air temperature (**AS BUILT**)
5 identical bays with a total of 10 bundles and 10 fans (2 fans/bundles per bay)

SPL noise level at 2.5 m from the unit periphery	60.7 dB(A)
Plot area	14991 mm x 30995 mm
Cost index	1

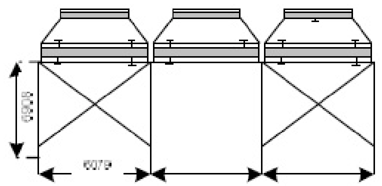
Case 2 - With 5oC fogging system



C3/C4 splitter condenser with thermal duty of 9875 KW
30.0^{o}C design air temperature

4 identical bays with a total of 8 bundles and 8 fans (2 fans/bundles per bay)	**Gain versus AS BUILT**
SPL noise level at 2.5 m from the unit periphery 60.0 dB(A)	**- 0.7 dB(A)**
Plot area 14991 mm x 24766 mm	**-20%**
Cost index (included HP fogging system) 0.9	**-10%**

Case 3 - With 10.5oC fogging system



C3/C4 splitter condenser with thermal duty of 9875 KW
24.5^{o}C design air temperature

3 identical bays with a total of 3 bundles and 3 fans (2 fans/bundles per bay)	**Gain versus AS BUILT**
SPL noise level at 2.5 m from the unit periphery 58.6 dB(A)	**-2.1 dB(A)**
Plot area 14991 mm x 18537 mm	**-40%**
Cost index (included HP fogging system) 0.82	**-18%**

Summary

As presented in the cases herein, it can be very advantageous to evaluate the possible integration of a fogging system in the design stage of an air cooler project. This can resolve a few frequently occurring problems such as very stringent noise level criteria and limited plot space issues.

Furthermore, it reduces the initial cost considerably making it also possible at no extra cost for the project to use more reliable mechanical equipment such as gearboxes, better bearings in order to compensate for the extra humidity in the air caused by a fogging system. Eventually motors can be protected by a thin metal box/sheet to protect it from the higher humidity.

When one takes into account a fogging system in the design stage, it is much easier to install a properly working system then retrofitting afterwards reducing the cost of installation of a fogging system drastically. Furthermore, we can then guarantee almost 100% evaporation of the fog/mist before reaching mechanicals/finned tube bundle.

It is however important to stress out that a fogging system should properly be operated, which is the responsibility of the operator. Operation of the system will determine whether a system will wear down equipment slightly or not.

Another factor to keep in mind is that the best units suited for such a system are the light product condensers (especially Air Cooled Steam Condensers!) where the thermal resistance is almost fully on the air side and not on the tube side.

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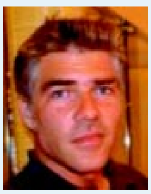

This publication thanks Mr. Marc Ellmer, owner and CEO of ELFLOW BV, for providing this paper which was presented at the Hydrocarbon Asia Operating & Engineering Convention 2010, which was held in Kuala Lumpur, Malaysia, on 20 & 21 July 2010. Mr. Ellner attended the Technical University of Delft and Higher Economical School of Rotterdam both located in the Netherlands. After having spent half a year as a trainee at Hudson Products Corporation (Houston, Texas) in 1997, Mr. Ellmer returned to Europe to create his own company named ELFLOW BV. In 2006, he joined the GEA group to create and manage for GEA BTT a service company called GEA Airflow Services SAS, which he left 2 years later in order to expand his own company ELFLOW BV in the field of chilling systems, wind screens, air filter systems and cooling tower optimization programs.