Auxiliary Power Saving In Air Cooled Heat Exchanger by Fans

Parag Mishra¹, Dr Manoj Arya²

¹Department of Mechanical Engineering, Radharaman Institute of Research & Technology, Bhopal, MP, India
²Department of Mechanical Engineering, MANIT Bhopal, MP, India

ABSTRACT

A heat exchanger is a heat transfer device that exchanges heat between two or more process fluids. A heat exchanger is used for transfer of internal thermal energy between two or more fluids available at different temperatures. In most heat exchanger fluids are separated by a heat-transfer surface, and ideally they do not mix. Heat exchangers have widespread industrial and domestic applications. Today’s heat exchangers must meet a variety of highly demanding requirements. In terms of performance, they have to ensure maximum heat transfer while keeping size to a minimum. Furthermore, the durability of heat exchangers must be extremely high, providing trouble-free performance throughout its service life at low manufacturing costs. The obvious advantage of an air cooler is that it does not require water, which means that equipment requiring cooling need not be near a supply of cooling water. In addition, the problems associated with treatment and disposal of water have become more costly with government regulations and environmental concerns. The air-cooled heat exchanger provides a means of transferring the heat from the fluid or gas into ambient air, without environmental concerns, or without great ongoing cost. This is made possible by the large variety of aluminum-based materials and product forms that empower system designers and manufacturers with multiple options for significant design improvement and cost reduction. Aluminum, in its various forms, offers clear possibilities to achieve these goals and is also well positioned to meet the challenges of the increasing market demands for cost effective, energy-efficient products and new customized, innovative applications.

INTRODUCTION

An air cooled heat exchanger, or ACHE, is simply a pressure vessel which cools a circulating fluid within finned tubes by forcing ambient air over the exterior of the tubes. The Air-cooled heat exchanger is a device for rejecting heat from a fluid or gas directly to ambient air. When cooling both fluids and gases, there are two sources readily available, with a relatively low cost, to transfer heat to…air and water. A heat exchanger consists of heat-exchanging elements such as a core or matrix containing the heat-transfer surface, and fluid distribution elements such as headers or tanks, inlet and outlet nozzles or pipes, etc. Usually, there are no moving parts in the heat exchanger; however, there are exceptions, such as a rotary regenerator in which the matrix is driven to rotate at some design speed. The heat-transfer surface is in direct contact with fluids through which heat is transferred by conduction. The portion of the surface that separates the fluids is referred to as the primary or direct contact surface. To increase heat-transfer area, secondary surfaces known as fins may be attached to the primary surface.

FANS

The air-cooled heat exchanger is controlled by two factors, the tube bundle size and configuration, and the ability to move air across the surface area that the bundle provides. Therefore, a major consideration of air cooler manufactures is not only the selection of the proper fan, but also the design of plenums to force the air across the surface area. The common means of moving air across the air cooler bundle is an axial flow, propeller type fan that either pushes (forced draft) the air across the bundle or pulls (induced draft) it across.

Even distribution of the air across the tube bundle is critical for uniform heat transfer. This is normally achieved by adequate fan to bundle coverage and controlling the static pressure loss across the bundle. A good design practice, and API661 requirement, is to maintain a forty percent (40%) coverage of the face area of the tube bundle to the area of the fan. Coverage’s of less than this will allow for lower airflows on the outer surfaces of the tube bundle, and can
result in poor performance. In addition, the distance from the fan to the coil can be critical. Again, good design practice requires an air dispersion angle of forty five percent (45%). The angle is measured from the outlet side of the fan ring to the center of the depth of the coil. This distance will allow the air to disperse, rather than channel directly through the bundle in front of the fan.

In horizontal configurations, the face coverage and air dispersion angle control the plenum size. On vertical configurations, many times the forty five percent dispersion angle is more difficult, since the overall size of the cooler is affected. Therefore, the designer must compensate for this design flaw by other means. This can be accomplished by additional air flow from the fan, resulting in more air flow than required directly in front of the fan, with the outside surfaces at the design velocity. It can also be accomplished by adding additional surface area to the coils affected. On vertical coolers with vertical air discharge, the designer also has to deal with the problem of discharging the air from the cooler, without causing additional pressure losses to the fan. Careful design of the size of the discharge plenum must be undertaken to assure the air can discharge the cooler.

Fans can vary in size from 2 to 20 feet in diameter, and can have from 2 to 16 blades. Common sizes are in one-foot increments, but can be supplied in any diameter desired. Generally the blades are aluminum, but other materials are available, including steel, fiberglass, reinforced plastic and wood. Normally the blades of the air cooler have a profile that allows an even distribution of air across the length of the blade. This can be accommodated for by a blade that has a wide chord width at the tip, and tapers to a narrow chord at the tip. In addition, most blades have a twist that compensates for the slower velocity at the portion of the blade closer to the center of the fan. This helps produce a more uniform, efficient air velocity pressure.

Heat Exchanger Fan Selection

Fan Engineering Nomenclature

ACFM - Actual cubic feet per minute of air moved by the fan.

Actual Conditions - Resistances related to actual inlet or outlet temperature and fan elevation above mean sea level compared to standard conditions.

Air Density - Air density at the plane of the fan based on standard or actual conditions.

Beam Passing Frequency - Number of times per revolution that one fan blade passes over a beam or strut thought of as “how the structure interacts with the fan blade” expressed in cycles/sec (Hz).

Blade Natural Frequency - Frequency at which a blade freely vibrates when struck in cycles/sec (Hz).

Blade Passing Frequency - Number of times per revolution that a fan tip passes a point on the fan ring expressed in cycles/sec (Hz) thought of as “how the fan interacts with the structure”.

Brake Horsepower - (BHP) - Net power required by the fan at actual conditions to perform the required design work.

Chord - Straight line distance between the leading and trailing airfoil edges.

Fan Diameter - Width/distance between opposite blade tips.

Fan Laws - Set of laws that predict performance changes if one or more parameters are changed from one fan or operating condition to another. These laws govern airflow, pressure, capability and power required among many other parameters.

Fan Ring Diameter - Inside diameter of fan housing at the plane of fan.

First Mode Resonant Frequency - Frequency at which a blade freely vibrates when struck (“natural” frequency) in cycles/sec (Hertz).

Forced Draft ACHE - Fan is located below the heat transfer surface forcing ambient air through the bundle.

Harmonic Frequency - Integer multiples of fan RPM and expressed as 1x, 2x and 3x fan speed in cycles/second (Hz). Harmonic frequency is checked against resonant frequencies to prevent vibration and fatigue.

Induced Draft ACHE - Fan is located above the heat transfer surface drawing ambient air through the bundle. The fan is exposed to the heated exhaust air.

Leading Edge - Thicker portion of the airfoil that is the first part of the blade to meet the air.
Net Free Area - Net area at the plane of the fan through which all air must pass. Usually based on the nominal fan diameter minus seal disc area or hub diameter. Note that blade area is not considered.

Pitch Angle - Blade tip angle below the horizontal required to do the design work and move air upward. Hudson fans all rotate clockwise looking into the airflow.

Static Efficiency - Fan efficiency based on static pressure and fan brake horsepower at the same density.

Static Pressure - Sum of all the system resistances against which the fan must work, expressed in inches of H₂O.

This is the useful work required from the fan. (Velocity pressure excluded).

Tip Clearance - Distance between the tip blade and the fan ring or housing, sometimes expressed as a percent of the fan diameter.

Tip Speed - Peripheral speed of the fan tip expressed in feet per minute.

Total Efficiency - Fan efficiency based on the total pressure and fan brake horsepower at the same density for standard or actual conditions.

Fan Selection - Horsepower Requirements: The fan diameter must assure that the area occupied by the fan is at least 40 percent of the bundle face area. The fan diameter must be 6 inches less than the bundle width. Fan performance curves are used to select the optimum number of blades and pitch angle as well as the horsepower.

To calculate the required horsepower for the fan driver:

Motor Shaft Horsepower = Actual ft³/min (at fan) - Total Pressure Loss (inches water) 6356 - Fan (System) Efficiency - Speed Reducer Efficiency

The actual volume at the fan is calculated by multiplying the standard volume of air (by the density of standard air (0.075 lb/ft³) divided by the density of air at the fan. From this relationship it can be seen that the ratio of the fan horsepower required for a forced draft unit to that required for an induced draft unit is approximately equal to the ratio of the exit air density to the inlet air density, which is in turn equal to the ratio of absolute air temperatures (t1 + 460) / (t2 + 460). The total pressure difference across the fan is equal to the sum of the velocity pressure for the selected fan diameter, the static pressure loss through the bundle, and other losses in the aerodynamic system. Fan diameters are selected to give good air distribution and usually result in velocity pressures of approximately 0.1 inch of water. The design of the fan, the air plenum chamber, and the fan housing, (in particular fan tip clearance), can materially affect system efficiency, which is always lower than shown on fan curves based on idealized wind tunnel tests. Industrial axial flow fans in properly designed ACHEs have fan (system) efficiencies of approximately 75%, based on total pressure. Poorly designed ACHEs may have system efficiencies as low as 40%. Speed reducers usually have about 95% mechanical efficiency. The value of driver output horsepower from the equation above must be divided by the motor efficiency to determine input power.
Auxiliary Power Saving in Air Cooled Heat Exchanger  Input Data for heat exchanger design-

<table>
<thead>
<tr>
<th>Flow (1000 kg/hr)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>27.7810</td>
<td>27.7810</td>
<td>27.7810</td>
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<td>91.212</td>
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<tr>
<td>Temp In (deg c)</td>
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<td>107</td>
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<td>Temp out (deg c)</td>
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<tr>
<td>Pressure In (kg/cm²A)</td>
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<td>39.37</td>
<td>70.88</td>
<td>4.602</td>
<td>4.602</td>
</tr>
<tr>
<td>Pressure drop (kg/cm²)</td>
<td>.714</td>
<td>.714</td>
<td>.714</td>
<td>.816</td>
<td>.612</td>
</tr>
</tbody>
</table>

Data is obtained from HTRI Software (From input data)
Data is obtained from HTRI Software (From input data)

Calculations –

Flow Rate,

\[
Q = m \times C_P \times (T_i - T_o)
\]

\[
5.3473 \times 10^6 = m \times 0.2409 (63.79 - 47.2)
\]

(From output summary, \( Q = 5.3473 \text{ metric million kcal/hr} \))

\[
m = 1.338 \times 10^6 \text{ kg/hr}
\]

HTRI Software summary report is based on experimental data & Air side correction factor (benefit factor varies from 10 to 20%)

\[
m = 1338 \times 1000 \text{ kg/hr}
\]

by dividing correction factor 1.179

\[
m = 1338/1.179
\]

\[
m = 1134.86 \times 1000 \text{ kg/hr}
\]

Number of fans calculation –

As per API 661, fan coverage area to the bundle face area must be greater than 40% fan coverage of area

From Summary report

\[
L = 16.5 \text{m}
\]

\[
B = 5.3 \text{m}
\]

So,

\[
\frac{\pi \times d^2}{4} = L \times B
\]

\[
D = 16.68 = 17 \text{m}
\]

Hence , number of fans= \( d/b = 3.21 \)

Therefore, number of fans = 4
Cofimco Fan Selection Software

By feeding the data into the software, we obtained the following data,
Moore fan selection software

By feeding the data into the software, we obtained the following data:

### Costing Of Fans

Cost of Moore Fan = USD 900/ per fan = 900 x 55 = Rs. 49500/-

Cost of Cofimco Fan = Euro 868/ Per Fan = 868 x 69 = Rs. 59892/-
Total Number of fans = 4
Therefore, Cost of Moore Fan = 1,98,000
Cost of Cofimco Fan = 2,39,568

CONCLUSION & RESULT

Auxiliary Power saving in fans –

Power Consumption per fan –
Power Consumption in Cofimco fan = 23.6 kw
Power Consumption in Moore fan = 28.49 kw

And,
Cofimco fan consumes less power than Moore fan = 28.49 - 23.6 = 4.89 kw
Therefore, Power Saving in Cofimco fan = 4.89 kw
Total Number of fans = 4

Therefore, Total Power Saving = 19.56 kw

Both the Fan manufacturer use the Aluminum for fan blade, but power consumption is different due to the following reason:-

1. Cofimco fans blade are more flexible as compare to Moore blade Due to flexible blade cofimco fans are easy to absorb jerk during running condition as well as longer life as compare to Moore fans.
2. Weight of Cofimco Fans(128Kg) are less than Moore fans(145Kg).
3. There are 7 number of fan blades in Cofimco fan& Number of fan blades in Moore fan are 11.

Total Power Saving = 19.56 KW = 19560 W

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