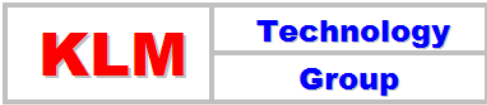


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		REV 01 – February 2015
KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru. Malaysia	Kolmetz Handbook Of Process Equipment Design Fin Fan Air Cooler Selection and Sizing (ENGINEERING DESIGN GUIDELINE)	Co Authors Rev 01 - Mela Widiawati
		Author / Editor Karl Kolmetz

KLM Technology Group has developed; 1) Process Engineering Equipment Design Guidelines, 2) Equipment Design Software, 3) Project Engineering Standards and Specifications, and 4) Unit Operations Manuals. Each has many hours of engineering development.

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INTRODUCTION

Scope

This engineering design guideline covers the selection and sizing methods for air cooled heat exchanger which are commonly used in the typical industrial processes. It assist engineers, operations personnel and maintenance personnel to understand the basic designs of the different types of air cooled heat exchangers, and increases their knowledge in selection and sizing.

An Air-Cooled Heat Exchanger is a device for rejecting heat from a fluid directly to the ambient air. This is in contrast to rejecting heat to water and then rejecting it to air, as with a shell and tube heat exchanger and a wet cooling tower system.

The obvious advantages 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. 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 such as water supply and treatment.

A fin-fan is a type of heat exchanger that forces air over a set of coils to cool the process. It is also referred to as an air cooled heat exchanger. Fin fan heat exchangers are generally used where a process system generates heat which must be removed, but for which there is no local use. In fin-fan heat exchanger, air is forced in cross-flow across tubes carrying processing fluid.

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General Design Consideration

Air-cooled heat exchangers should be located so that the hot air emitted is not a hazard or an inconvenience to personnel or has an adverse effect on the operation of adjacent equipment.

The air-cooled heat exchanger may be either a forced-draft exchanger or an induced draft exchanger and may include the components and any auxiliaries such as ladders, walkways and platforms.

Air cooled exchangers are classed as forced draft when the tube section is located on the discharge side of the fan, and as induced draft when the tube section is located on the suction side of the fan.

The applications for air cooled heat exchangers cover a wide range of industries and product, however generally they are used to cooler gases and liquids when the outlet temperature required is greater than the surrounding ambient air temperature.

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Table 1. The Advantages and Disadvantages of Each Model

Forced Draft		Induced Draft	
Advantages	Disadvantages	Advantages	Disadvantages
Lower horsepower requirement due to tower inlet air temperatures	Less uniform distribution of air over the bundle.	Better distribution of air across the bundle.	Higher horsepower since fan is in outlet air stream.
Better accessibility of fans and bearings.	Increased possibility of air recirculation.	Less possibility of hot air recirculation.	Mechanical equipment subjected to higher temperatures.
Better accessibility of bundles for replacement.	Low natural draft capability on fan failure.	Better process control since plenum covers 60% of bundle face area, blocking it from sun and rain.	Fans are less accessible for maintenance.
Accommodates higher process inlet temperatures.	Exposure of coils to sun, rain, etc.	Increased capacity with fan off due to natural draft stack effect.	Plenums must be removed to replace bundles.

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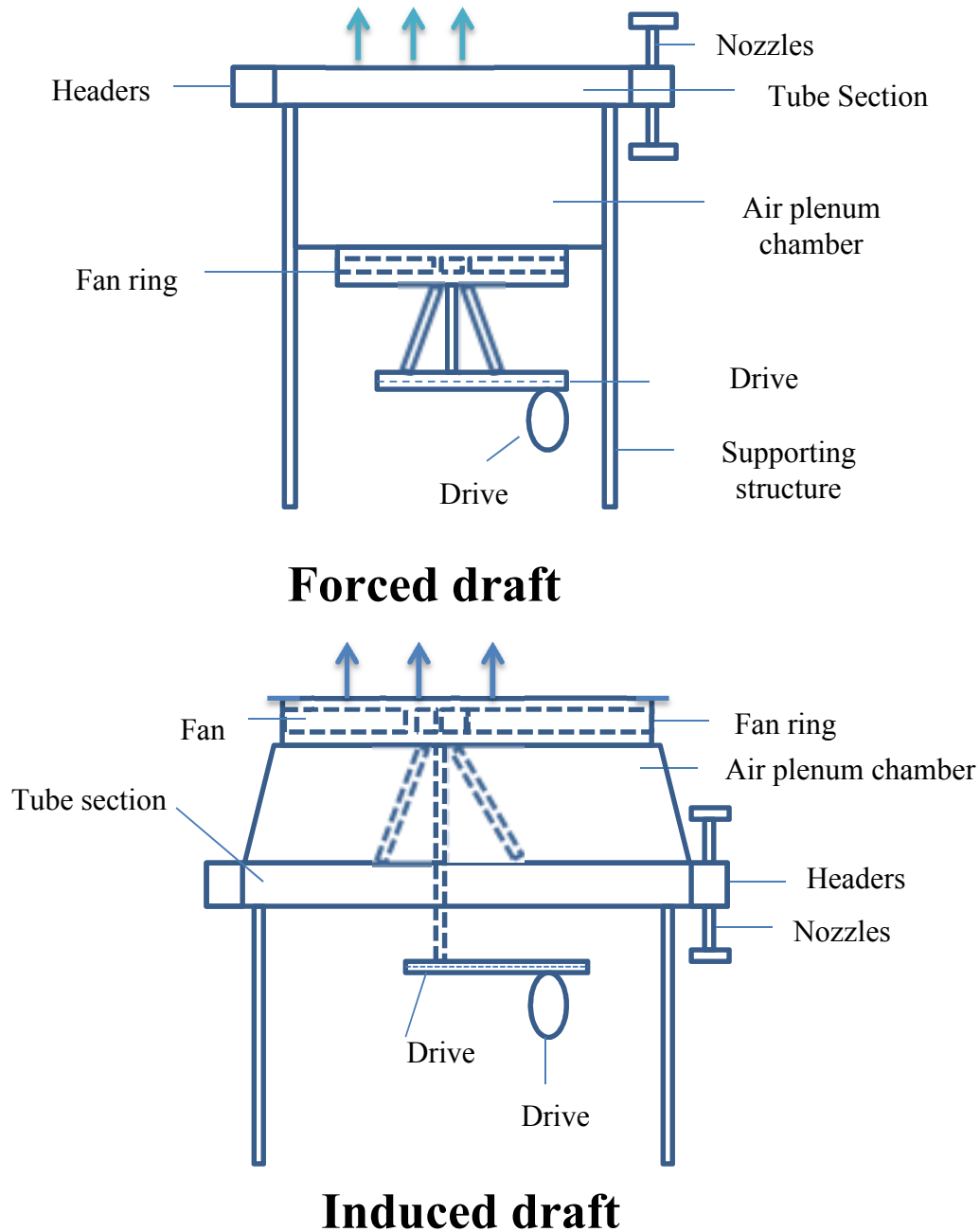


Figure 1. Typical Side Elevation of Air Coolers

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Fan sizes range from 3 ft to 28 ft diameter. However, 14 ft to 16 ft diameter is the largest diameter normally used. Fan drivers may be electric motors, steam turbines, hydraulic motors, or gas-gasoline engines. A speed reducer, such as a V-belt drive or reduction gear box, is necessary to match the driver output speed to the relatively slow speed of the axial flow fan. Fan tip speeds are normally 12,000 ft/min or less. General practice is to use V-belt drives up to about 30 bhp and gear drives at higher power. Individual driver size usually limited to 50 hp.

Two fan bays are popular, since this provides a degree of safety against fan or driver failure and also a method control by fan staging. Fan coverage is the ratio of the projected area of the fan to the face of the section served by the fan. Good practice is to keep this ratio above 0.40 whenever possible because higher ratios improve air distribution across the face of the tube section. Face area is the plan area of the heat transfer surface available to air flow at the face of the section.

The basic heat transfer relationships that exist for shell and tube exchangers also apply to the design of an air-cooled heat exchanger. However, there are more parameters to be considered in the design of an air cooled heat exchanger.

Since the air cooled heat exchanger is exposed to changing climatic conditions, problems of control of the air cooler become relevant. A decision must be made as to what the actual ambient air temperature to be used for the design.

Some of the governing factors in the design of the air cooler are:

- Tube diameter,
- Tube length,
- Fin height,
- Number of tube rows,
- Number of passes,
- Face area,
- Horsepower availability,
- Plot area.

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Fin fan coolers are also known as air cooled heat exchanger. There are variety of fin types that can be considered dependent upon the environment and design conditions.

The following factors should be considered when selecting a fin type:

- Design temperature
- Corrosive properties of the air
- Temperature cycling frequency
- Cleaning method and frequency
- Type of fouling debris in air
- Isolation of cooler

In the fin fan coolers the ambient air used as the cooling media to cool. The main hot fluid which is used in tube side. All the tubes in the coolers are finned tubes only. The finned tubes are having more contact surface hence the fin fan cooler is one the best closed circuit and water saveable cooling systems.

Fan selection at design conditions shall ensure that at rated speed the fan can provide, by an increase in blade angle, a 10% increase in air flow with a corresponding pressure increase. Since this requirement is to prevent stall and inefficient operation of the fan, the resulting increased power requirement need got govern the driver rating.

Fans and fan hubs

- Two or more fans aligned in the direction of tube length shall be provided for each bay, except that single-fan arrangements may be used if agreed by the purchaser.
- Fans shall be of the axial flow type.
- Each fan shall be located such that its dispersion angle shall not exceed 45° at the bundle centreline.
- The fan tip speed shall not exceed the maximum value specified by the fan manufacturer for the selected fan type. Fan type speed shall not exceed 60 m/s (12000 ft/min) unless approved by the purchaser. In no case shall the fan tip speed exceed 80 m/s (16000 ft/min). Noise limitations may require lower speeds.
- The radial clearance between the fan tip and the fan orifice ring.

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Table 2. Radial Clearances

Fan diameter		Radial clearance	
M	Ft	Minimum	Maximum
w 1,0 and u 3,0	w 3 and u 9	6 mm (1/4 inch)	13 mm (1/2 inch)
>3,0 and u 3,5	(>9 and u 11)	6 mm (1/4 inch)	16 mm (5/8 inch)
>3,5	(>11)	6 mm (1/4 inch)	19 mm (3/4 inch)

Each fan assembly shall be balanced by one of the following means:

- a. Dynamic balancing as an assembly
- b. Dynamic balancing of the hub and static moment-balancing of the blades.

For fans having a diameter larger than 1,5 m (5 ft), individual fan blades shall be manually adjustable for varying blade pitch. The use of automatic control for varying the blade pitch shall be as specified by the purchaser.

Fans equipped for pneumatically-actuated, automatically-controlled pitch adjustment of blades shall comply with following.

- a. If a single controller operates more than one actuator, the purchaser shall provide an isolating valve in the control signal line for each actuator, to allow maintenance.
- b. The pneumatic actuator may be equipped with a positioned or a bias relay.
- c. If provided, the positioned or bias relay shall be designed to operate on a 20 kPa gauge (3 psig to 15 psig) pneumatic control signal. Each change in the control signal shall result in a corresponding change in the fan blade pitch. The operating range of the positioned shall be adjusted so that the maximum pitch obtained is equal to the selected design blade angle setting. The fan manufacturer shall set maximum and minimum blade pitch limit stops. Unless otherwise specified by the purchaser, the minimum blade pitch limit shall result in an essentially zero air flow.
- d. The vendor shall furnish a flexible tubing connection approximately 300 mm (12 inches) long for connection to the purchaser's control-air line. The tubing shall connect to a rigid steel or alloy pipe or tube that terminates outside the fan enclosure. A terminal fitting for connection to the purchaser's control-air line shall be DN 8 (NPS 1/4). Pipe threads shall be taper pipe threads.
- e. The purchaser shall specify the direction of change of the fan pitch with loss of control-air pressure.

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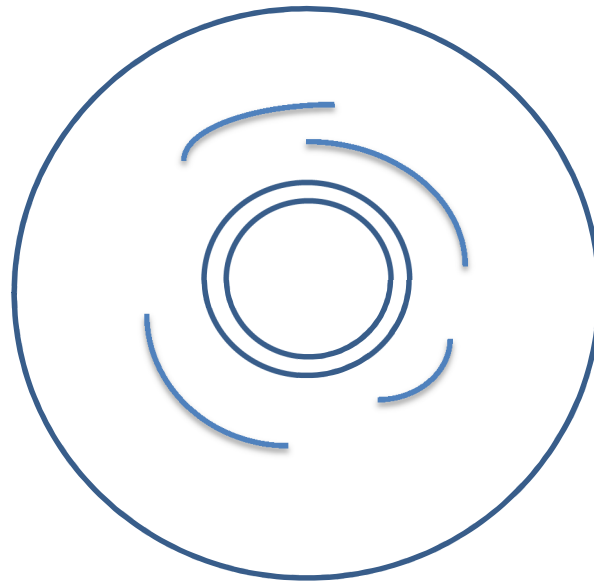


Figure 6. Plain Fin

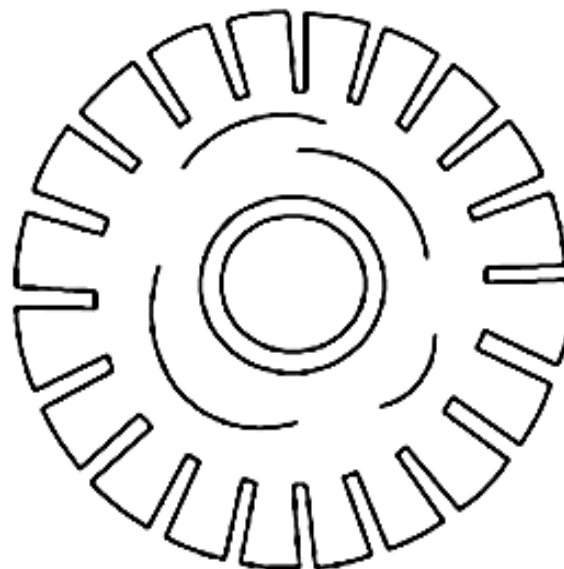


Figure 7. Serrated Fin

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Fins are normally helical wound aluminium fins. Aluminium material is used for reasons of good thermal conductivity and economy of fabrication. The normal aluminium material used is 1100-00 due to its relatively low cost and superior thermal conductivity. Fin can be produced from other material including copper, steel and stainless steel.

Copper is normally used in offshore or marine environments when the airside environment is corrosive enough to justify the cost increase associated with copper material. Steel and stainless steel is normally used for very high temperature applications.

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DEFINITIONS

Ambient Temperature – a term which refers to the temperature in a room, or the temperature which surrounds an object under discussion.

Bare Tube Face – Outside surface of prime tubes based on length measured between outside face of header tube sheets in square meters.

Bay – One or more K-Fin sections, mounted on a self-supported structure complete with mechanical equipment.

Bearing – is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts.

Brazing – is a metal joining process whereby a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action.

Condensing – is the change of the physical state of matter from gas phase into liquid phase, and is the reverse of evaporation.

Evaporation – is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance.

Evaporative Cooler – is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems which use vapour compression or absorption refrigeration cycles.

Extrusion – is a process used to create objects of a fixed cross-sectional profile.

Finned Tube Surface – Total outside surface (exposed to air) based on length of tubes measured between outside face of header tube sheets in square meters.

Forced Draft Type – Designed with tube bundles located on the discharge side of the fan.

Fouling – the accumulation of unwanted material on solid surfaces to the detriment of function. Fouling is usually distinguished from other surface growth phenomena in that it occurs on a surface of a component, system or plant performing a defined and useful function, and that the fouling process impedes or interferes with this function.

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Induced Draft Type – Designed with tube bundles located on the suction side of the fan.

Nozzle – is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exist (or enters) an enclosed chamber or pipe.

Pressure Drop – is defined as the difference in pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube.

Reynolds Number – a dimensionless quantity that is used to help predict similar flow situations. The Reynolds number is defined as the ration of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions.

Section – Assembly of two headers, finned tubes and side channels.

Tube Bundle – Assembly of headers, tubes and frames.

Velocity – is the rate of change of the displacement, the difference between the final and initial position of an object. Velocity is an important concept in kinematics, the branch of classical mechanics which describes the motion of bodies.

Viscosity – a measure of its resistance to gradual deformation by shear stress or tensile stress. For liquids, it corresponds to the informal concept of thickness.

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NOMENCLATURE

A	Heat transfer surface area
A_{con}	Contact area between fin and tube wall
A_{face}	Tube bundle face area
A_{fins}	Surface area of fins
A_i	Inside surface area, ft ²
A_m	Mean surface area, ft ²
A_o	Outside surface area, ft ²
A_{prime}	Prime surface area
A_{tot}	Total external surface area of finned tube
a_o	Outside surface area per unit length, ft
B_c	Baffle cut % of shell diameter, %
BR	Boiling rabfe (dew-bubble points), °F
BWG	Birmingham wire gage
b	<i>Fin height</i>
C	Two-phase pressure drop constant
C_b	Bundle bypass constant
C_{p1}	Heat capacity, hot fluid, Btu/lb.°F
C_{p2}	Heat capacity, cold fluid, Btu/lb.°F
D	Tube diameter, general, ft
D_f	Outer fin diameter
D_{fan}	Fan diameter
D_i	Internal diameter of tube
E_f	Fan efficiency (0.6-0.7, typical)
F	MTD correction factor
F_b	Bundle convection factor
F_c	Mixture correction factor
FSP	Fan static pressure
G	Mass Flux
G_n	Mass flux in nozzle
g	Gravitational acceleration
g_c	Unit conversion factor
h_i	Tube side heat transfer coefficient
h_o	Air side heat transfer coefficient
LMTD	Log mean temperature difference, °F
M	Molecular weight of air
m	Fin parameter
\dot{m}	Mass flow rate
\dot{m}_{air}	Mass flow rate of air

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\dot{m}_i	Mass flow rate of tube side fluid
N_f	Number of fans
N_R	Modified Reynolds number (in.lb/(sq ft. S. Cp)
N_u	Nusselt number
r_1	Inner radius of fin
r_2	Outer radius of fin
V	Fluid velocity
V_{face}	Air face velocity
$V_{face, ave}$	Air face velocity based on average air temperature
\dot{W}	Width of tube bundle
\dot{W}_{fan}	Fan brake power
\dot{W}_{motor}	Power delivered by motor
\dot{W}_{used}	Power used by motor

These design guideline are believed to be as accurate as possible, but are very general and not for specific design cases. They were designed for engineers to do preliminary designs and process specification sheets. The final design must always be guaranteed for the service selected by the manufacturing vendor, but these guidelines will greatly reduce the amount of up front engineering hours that are required to develop the final design. The guidelines are a training tool for young engineers or a resource for engineers with experience.

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