KLM Technology Group Practical Engineering Guidelines for Processing Plant Solutions	KLM Technology Group **Engineering Solutions** **www.klmtechgroup.com**	**Rev: 01** **REV 01 –FEB 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** **AIR COOLED FIN FAN HEAT EXCHANGER SELECTION, SIZING AND TROUBLESHOOTING** **(ENGINEERING DESIGN GUIDELINES)**	Co Authors Rev 01 - Mela Widiawati Author / Editor Karl Kolmetz

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TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURE

INTRODUCTION

Scope

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

An Air-Cooled Heat Exchanger is a device for rejecting heat from a fluid directly to 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.

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.

Table 1. The Advantages and Disadvantages of Each Model

Forced Draft		Induced Draft	
Advantages	Disadvantages	Advantages	Disadvantages
Lower horsepower requirement due tower inlet air temperatures	Less uniform distribution of air over the bundle.	Better distribution of air across the bundle.	Higher horse power 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 sum, rain, etc.	Increased capacity with fan off due to natural draft stack effect.	Plenums must be removed to replaced bundles.

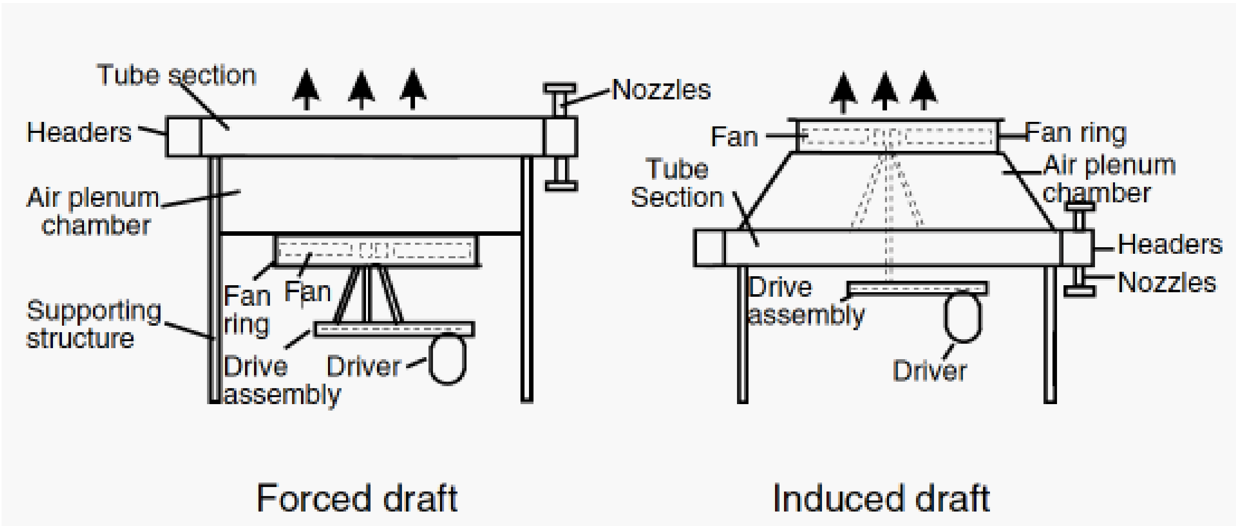
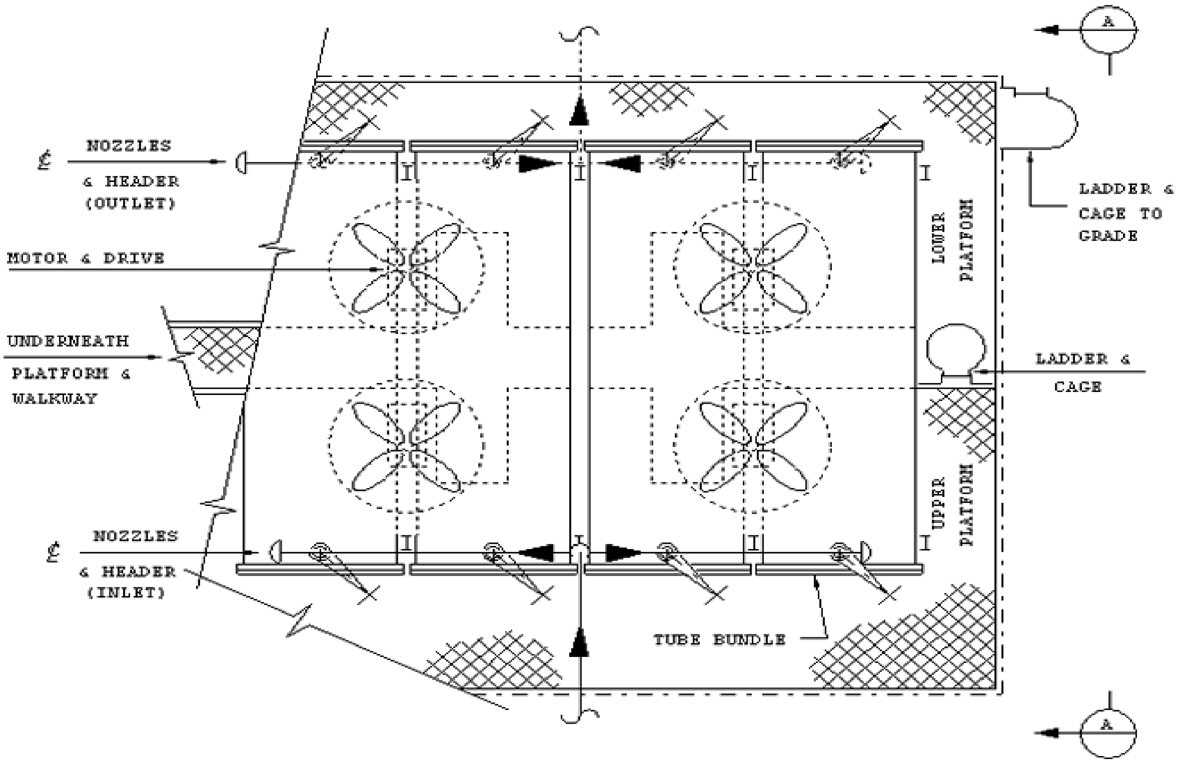


Figure 1. Typical Side Elevation of Air Coolers


NOZZLES
& HEADER
(OUTLET)
MOTOR & DRIVE
UNDERNEATH
PLATFORM &
WALKWAY
NOZZLES
& HEADER
(INLET)
LADDER &
CAGE TO
GRADE
LOWER
PLATFORM
LADDER &
CAGE
UPPER
PLATFORM
TUBE BUNDLE
A
A

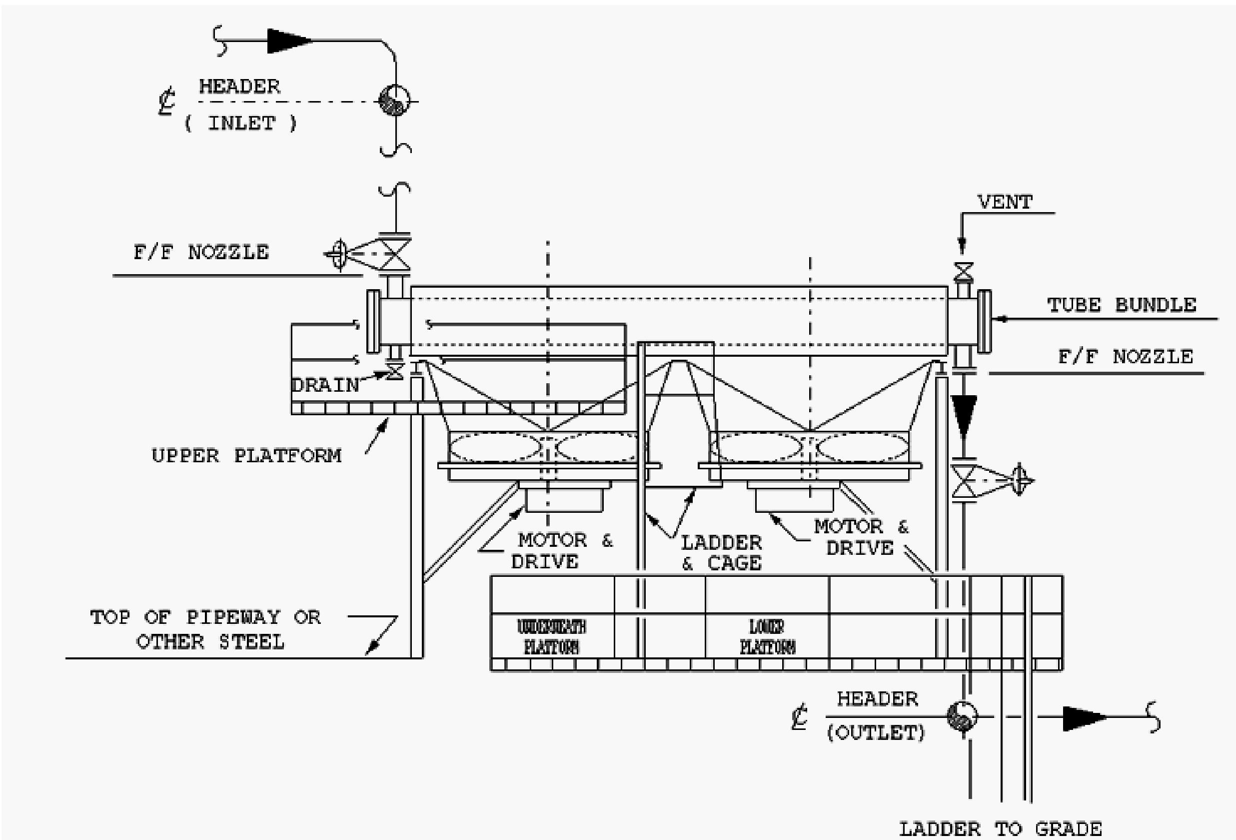


Figure 2. Typical Forced Draft Plan

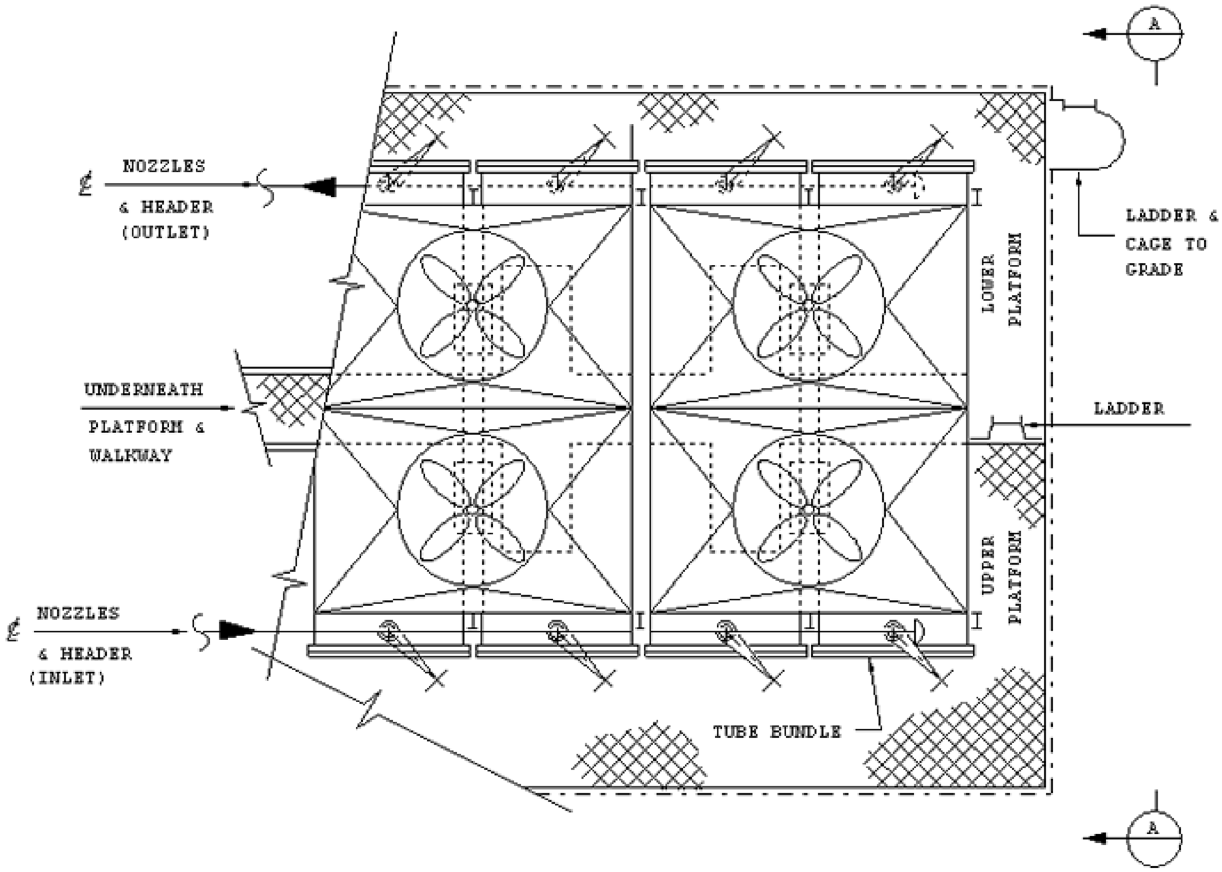


Figure 3. Typical Induced Draft Plan

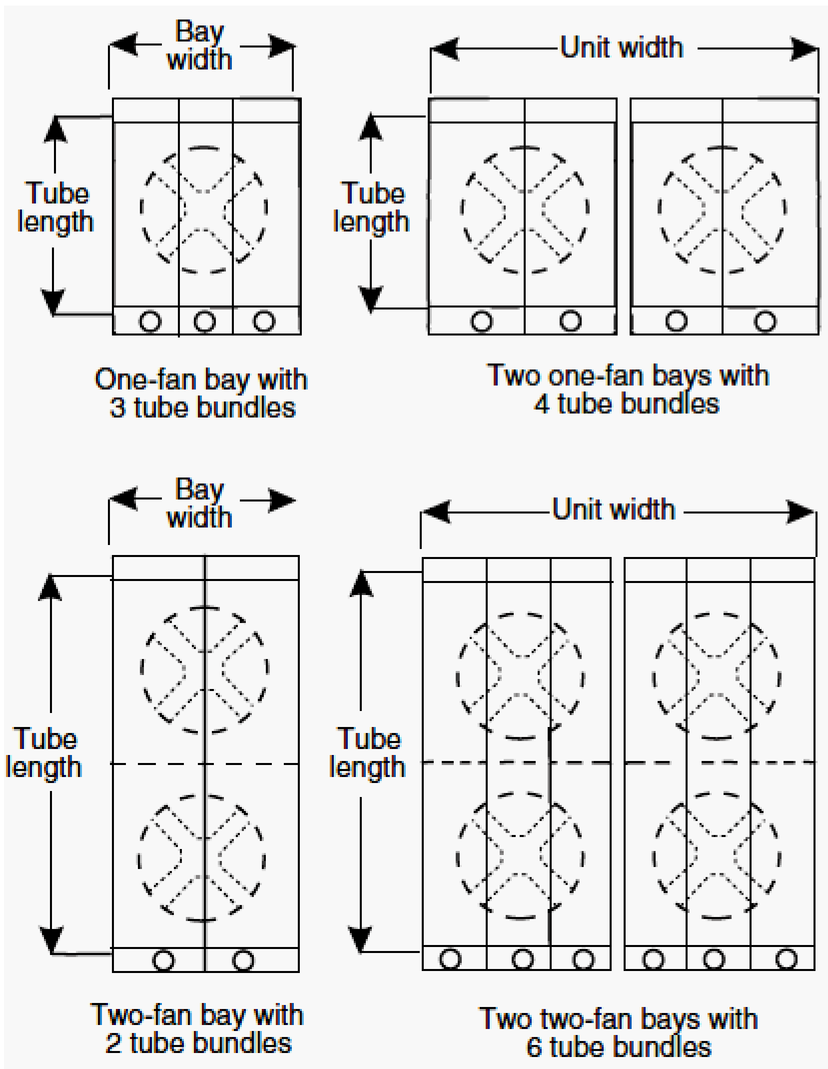


Figure 4. Some Typical Configurations of Fan Bays in Air-Cooled Heat Exchangers

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.

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^o 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.

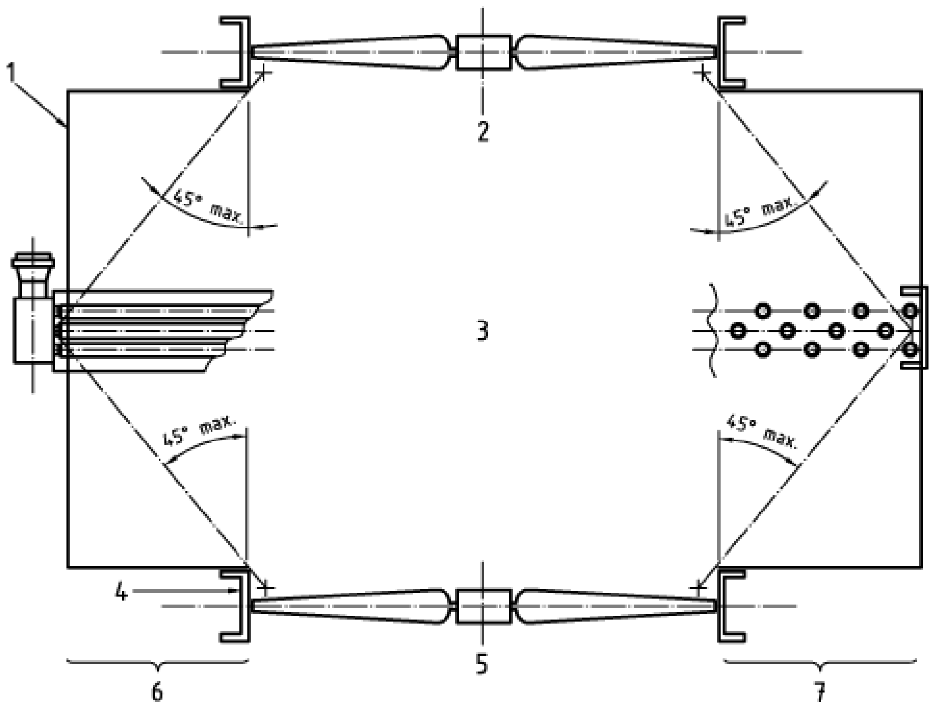


Figure 5. Fan Dispersion Angle

Note

1. Plenum
2. Induced draught
3. Centreline of bundle
4. Fan ring
5. Forced draught
6. Side
7. Front

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:

Dynamic balancing as an assembly
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.

1. 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.

2. The pneumatic actuator may be equipped with a positioned or a bias relay.

3. 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.

4. 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 ¼). Pipe threads shall be taper pipe threads.

5. The purchaser shall specify the direction of change of the fan pitch with loss of control-air pressure.

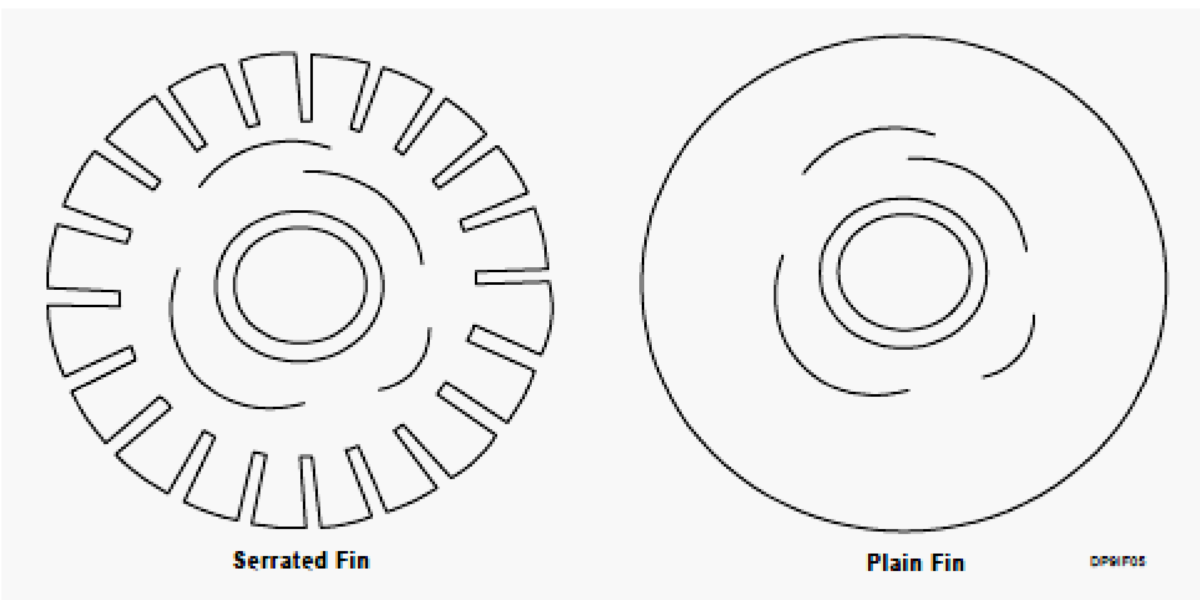


Figure 6. Serrated and Plain Fins

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. Coper 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.

Fin Types for Finned Tube Heat Exchanger

Fin can be attached to the tubes in a number of ways:

Plate Fin

In the plate fin design, tube holes are pressed in thin sheets of metal, where tube are inserted and then expanded. This highly efficient fin type provides a very large surface area that helps evenly distribute heat. The fins can be waffled or rippled for greater efficiency. The fin thickness can be varied from thin in situations where cost is important and clean-ability is not an issue to thick fins an applications where ruggedness and clean-ability are important.

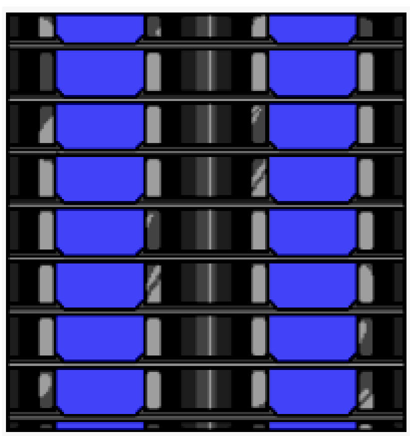


Figure 7. Plate Fin

L-footed Tension wound

The most common fin type utilized in the air-cooled heat exchanger design is the L-footed tension wound aluminium fin. The fin is produced by wrapping an aluminium strip, which is footed at the base, around the tube.

The L-Footed Fin has a lip at the base which is tension wound around the tubes. This increases the contact area and increases the heat transfer contact area between the tube and the fin and decreases the exposed joint at the fin base.

The tension wound fin has the fins wrapped tightly around the tube and stapled or welded at the ends to hold the form. Tension wound fins can also be solder-coated to help increase corrosion resistance. Tension wound fin works especially well with fins and tubes that are made of the same material.

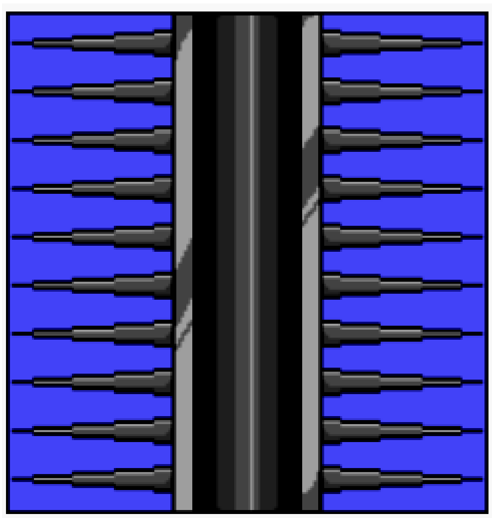


Figure 8. L Footed Tension Wound a

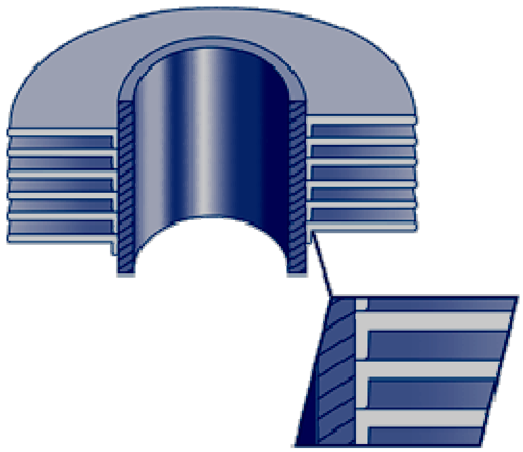


Figure 9. L Footed Tension b

Embedded

In high temperature applications, an embedded process is employed to attach the fin to the tube wall. In this process, a groove is actually cut into the tube, the fin strip inserted, and the tube material then “plowed” back against the fin to bond in to the tube. They can withstand higher temperatures, and are very durable. Embedded fins are best suited for applications that involve high temperatures or thermal cycling and where the fin side will be subjected to frequent cleaning. Separation of the fin and tube due corrosion or temperature differentials are not a factor with the fin type.

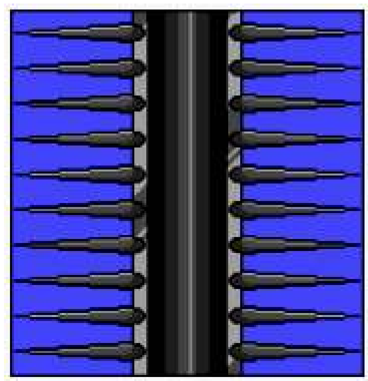


Figure 10. Embedded

Extruded

Extruded, or integral Fins are created by sliding a liner tube inside a thick-walled tube and then sending this assembly through a press which extrudes the fin from the thick walled tube in a cold worked process. The outer tube is pressed into a fin pattern while creating a mechanical bond between the outer (finned) tube and the liner tube. Since the fins are one piece there is no exposed bi-metal joint at the base of the fin. The liner tube can also be chosen to best suit the tubeside fluids as only a small area of the liner tube is exposed to the gas side.

For applications where atmospheric corrosion is critical, the extruded fin tube provides the best protection.

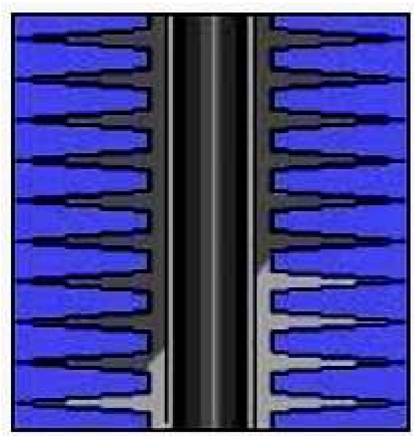


Figure 11. Extruded

Other

There are several other types of fin that are similar to the above fin types:

Double L-footed fin

This fin is similar to L-tension in that it is produced in much the same manner. In this process, a foot is formed on both sides of the upright portion of the fin, providing an overlapping of the fin. This provides a higher protection for the tube against atmospheric corrosion. This fin type is also referred to as an overlapped fin.

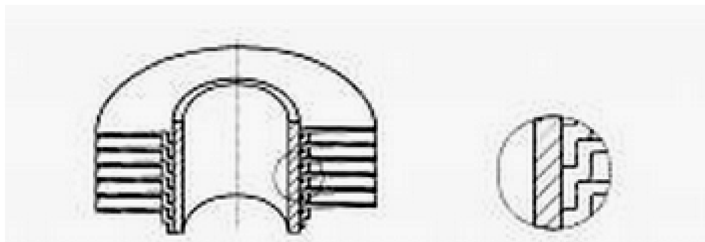


Figure 12. Double L with overlapped metal strip wounded on the core tube.

Knurled L-footed fin

Again, this process is very similar to the L-footed tension wound fin, but utilizes knurling between the tube and the fin, and reduces the likelihood of a corrosion film between the two.

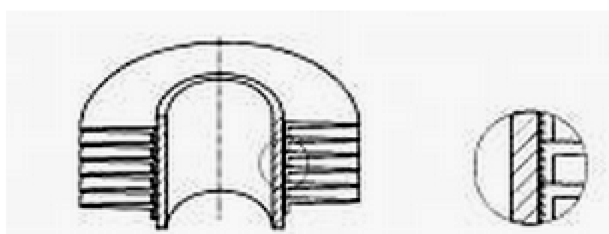


Figure 13. Knurled L with metal strip wounded on the core tube with knurled surface.

L-footed fins with slits cut into the fin

By cutting a slit into the fin, more air turbulence can be created, due to the interruption of the air boundary layer.

Common materials of construction for headers are firebox quality carbon steel, SA-515-70, SA-516-70. Tubes are generally SA-214 (ERW), SA-179 (SMLS), or carbon steel.

Louvers are generally carbon steel, or aluminium with carbon steel construction being the most general and most economical. Fins are normally aluminium. Both stainless

DEFINITIONS

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.

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.

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

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

Tube Bundle – Assembly of headers, tubes and frames.

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), ^oF
BWG	Birmingham wire gage
b	*Fin height*
C	Two-phase pressure drop constant
C_b	Bundle bypass constant
C_{p1}	Heat capacity, hot fluid, Btu/lb.^oF
C_{p2}	Heat capacity, cold fluid, Btu/lb.^oF
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
Gn	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
$\dot{m}_i$	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