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1 Basic scope of document

This document defines the basic design and requirements for air-cooled heat exchangers. It provides necessary guidelines to use BC standard specification and help to deal with Client requirements. This document is not mandatory but shall be used as guideline for purchasing the air-cooled heat exchangers. Deviation from this document may be required on case-to-case basis depending on Customer specifications and availabilities.

2 Basic of air coolers

Air coolers are used in cooling circuits where the preferred cooling media, viz. water is either not available or not in abundant quantities. In BCA related plant applications, air coolers are mainly used for cooling the cooling water, although, in a few cases these coolers are also used for cooling the gas being compressed, lube oil in upstream applications.
Air coolers, as the name suggests, use the ambient air to cool the hot medium, be it gas, oil or water. Since, the cooling system uses the ambient air for cooling the heat transfer is poor as compared to that with water coolers. Therefore, naturally require more surface area than a water-cooled heat exchanger for the same duty. Use of fins is primary means of increasing the heat transfer area for air cooled heat exchangers.

The main parts of an air-cooled heat exchanger are:

- One or more bundles of heat transfer surface.
- An air moving device such as a fan.
- Unless it is a natural draft, power transmission device eg motor or gas engine to run the fan

- A plenum between the bundle or bundles of heat transfer surface and the fan or blower.
- A support structure high enough to allow air to enter below the air cooled heat exchanger at a reasonable rate.
- Optional fan and / or header maintenance access platforms, walkways and ladders.
- Optional louvers for controlling outlet temperature of hot fluid by adjusting air flow.
- Optional protection devices for the unit. E.g. Screens (hail, insects or lint) based on requirement and vibration switches for fan driver.

3 Sizing of air coolers

As ambient air is used the design air temperature, specified by the client, is the most important sizing factor for air coolers. According to API661 the air temperature that is exceeded for 40 h per year should be used for critical processes. The size of cooler is also affected by the difference between the ambient air temperature and the desired outlet temperature of process medium. The temperature difference 10 K is typical and recommended. The lower value will lead bigger size air cooler with more hear exchange surface area.

2 x 100% fans or 3 x 50% fans is a option from API 614 for lube oil system. And It is a additional requirement that over standard API 661, and only be supply when Client's special. Spare fan is used to allow one fan motor failure when compressor continuous operation. It means 200% or 150% cost because of more fan and more tubes.

Because of substantial cost impact (Size of the air cooler) most important is to clarify the design temperature of the air used for the thermal calculation. In some cases, clients allow using for hot summer case the additional installed spare fan (e.g. 3 x 50%). It is also important to specify and consider the minimum air ambient temperature.

In many compressor data sheets used during tender phase the design temperature for the air coolers is given, in some data sheets the air temperature is not clearly defined. The design ambient temperature of air cooler should be defined by Sales & AE and Client in quotation phase. If not clearly definition, the design ambient temperature is typically defined to maximum ambient temp minus 5 C.

The basic heat transfer equations that apply to shell and tube heat exchangers also apply to air cooled heat exchangers.

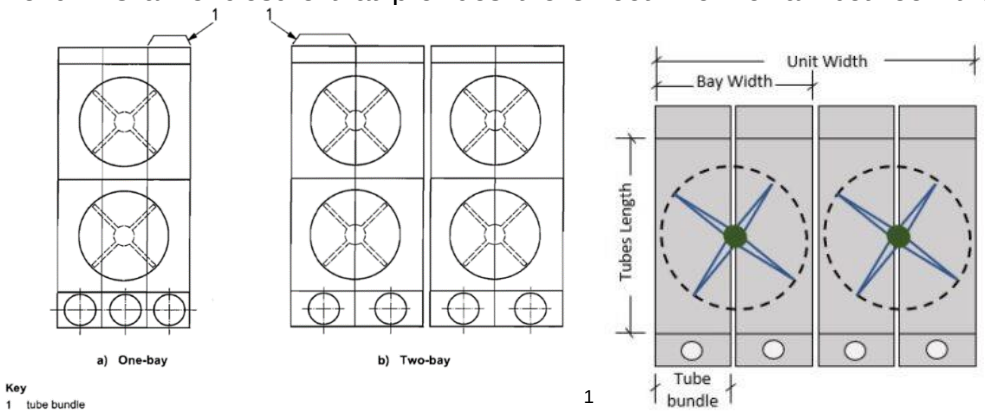
$$Q[kW] = \dot{m}[kg/s] \cdot cp[kJ/kgK] \cdot \Delta T[K] \qquad Q = A_0[m^2] \cdot U\left[\frac{kW}{m^2 \cdot K}\right] \cdot \Delta t_m[K]$$

Where:
Q = heat exchanged
m = mass flow
c_p = specific heat capacity
ΔT= terminal temperature difference
A_0= effective heat transfer surface
U=heat transfer ratio
Δt_m = mean temperature difference

4 Arrangement of air coolers

Definitions:

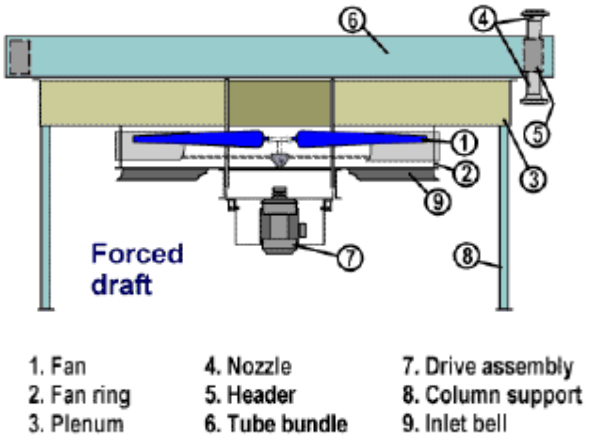
- Bay: One or more tube bundles, serviced by one or more fans, including the structure, plenum and other attendant equipment
- Unit/Item: One or more tube bundles for an individual service.
- Tube bundle: Assembly of headers, tubes, frames, tube supports.
- Plenum is an enclosure that provides the smooth flow of air between the fan and bundle.

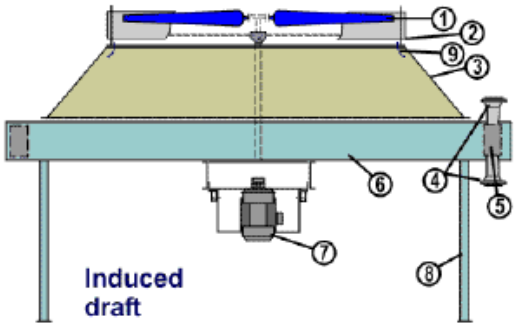


Although, natural draft could be a possibility, it is seldom used for being very inefficient. Either induced draft fans or forced draft fans are commonly used solutions. Each type of draft system has its advantages and disadvantages which need to be considered. Forced draft has been mostly used in BC projects. Normally coolers from India, middle east where power is more priority than operating costs, here forced drafted is priority.
If power has less priority than operating costs, then induced draft are preferred choice.
Temperature gradient, outlet hot fluid temperature, air ambient temp these design parameters decide the type of draft. Most of the time forced draft is preferred due to better heat transfer

Normally, the air cooled heat exchangers are laid horizontally with the air entering at bottom below the tube bundle and leaving upwards. Depending on the position of the fan it is differed between forced draft and induced draft

[1] Definition and figure, API Standard 661, Sixth Edition, February 2006





1. Fan
2. Fan ring
3. Plenum
4. Nozzle
5. Header
6. Tube bundle
7. Drive assembly
8. Column support
9. Inlet bell

Advantages of forced draft

- Better access to mechanical components and therefore less costs for platforms, walkways and ladders
- Slightly lower fan power
- Fan is located in cold air stream
- Adaptable for warm air recirculation during freezing conditions
- Louver installed on the top of bundle can control fluid outlet temperature by adjust air flow.

Advantages of induced draft

- Lower risk of air recirculation to intake
- Less effect from sun
- Some protection against sudden additional cooling due to rain
- Low risk of increase air-side fouling because of sand and dust.

5 Design Requirements

General design requirements:

- Provision for lateral movement of tube bundles has to be considered. API 661 defines as a standard 6mm lateral displacement in both directions or 12.7mm in one direction.
- Thermal expansion of tubes needs to be allowed
- Corrosion allowance on CS components, if not specified API 661 applies 3mm.
- For high temperature differences (> 110 K) in multi-pass bundles U-tube construction, split headers or other restraint relief is needed.
- Tube side fouling factor has to be respected according the fluid inside the tubes.
- Usually there is no fouling factor used for the air side but if the client location is dusty airside fouling needs to consider as 0.0001 - 0.0002 based on light to severe dusty/Sand laden site.
- If the compression is multi-stage , the process gas pressure drop through air cooler must less than the allowable maximum pressure loss of interstage.

5.1 Header

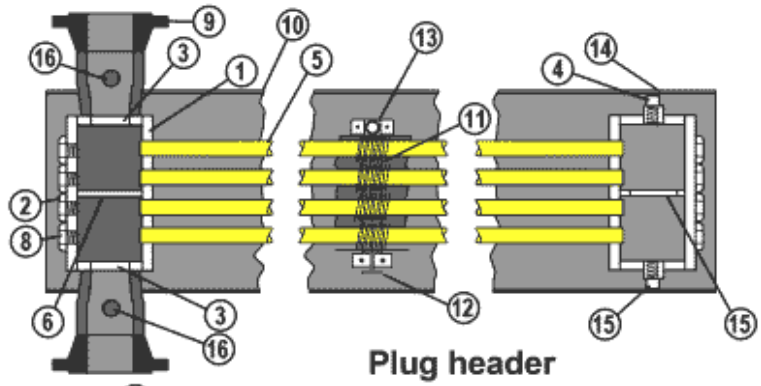
There are main four header types: pipe manifold header (cylindrical), removable cover plate, removable bonnet and plug header. As per API 661, the welded plug type headers need to have holes drilled and threaded opposite each tube for maintenance and are therefore more expensive. But plug type headers are required by API 661 when pressures exceed 3000 kPa gauge (435 psig) and/or for hydrogen service.

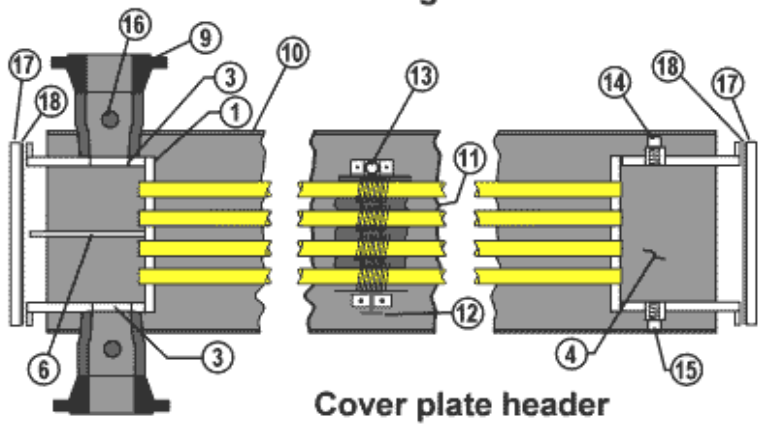
The following illustrations show the different header types:

5.1.1 Pipe-manifold header (cylindrical)

Cylindrical header is a additional design in API 661. It is recommended to use for design pressure over 140 barg or Client's request, such as serviced in highly toxic case.



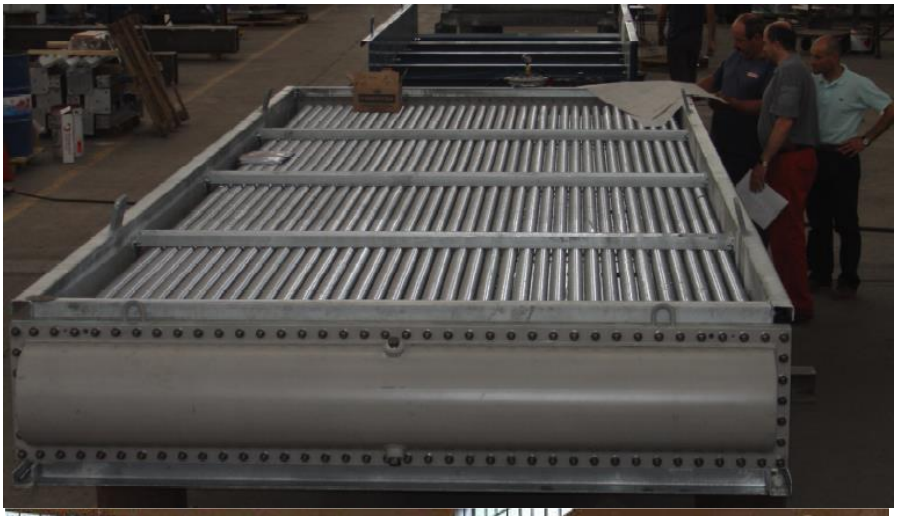




1. Tube sheet
2. Plug sheet
3. Top and bottom plates
4. End plate
5. Tube
6. Pass partition
7. Stiffener
8. Plug
9. Nozzle
10. Side frame
11. Tube spacer
12. Tube support cross-member
13. Tube keeper
14. Vent
15. Drain
16. Instrument connection
17. Cover plate
18. Gasket

Typical construction of tube bundles with plug and cover plate headers

Header type:
Removable bonnet



Header type:
Plugged (acc. to API 661)



5.2 Tube and tube-to-tubesheet joints

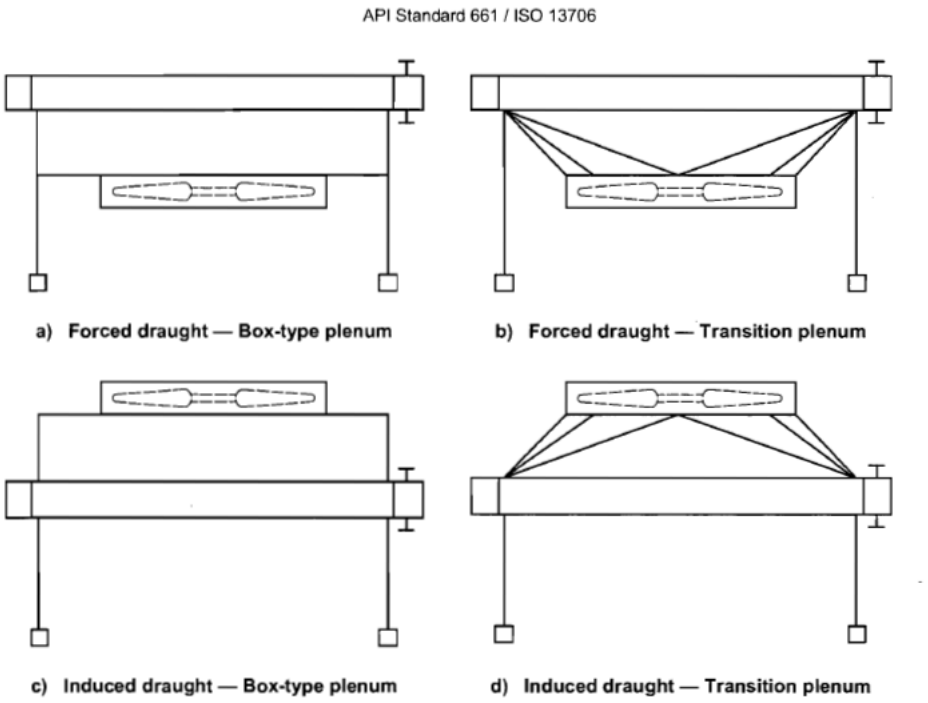
According to API 661 the outside diameter of cylindrical tubes should be at least 25.4mm. Carbon steel tubes have a minimum required wall thickness of 2.11 mm (0.0833 in). The maximum length of tube shall be specified by Client. For a finned tube, the total unfinned length between tube sheets after assembly shall not exceed 1.5 times the thickness of one tube sheet.

The shell & tube white book (TDO_2011219) explains the different kind of tube-to-tube sheet connections. These connections can also be applied to air coolers but need to be discussed in detail with the supplier / manufacturer of the air cooler. Mostly the gas air cooler manufacturer applies rolled-in with 2 expansion grooves solutions for the tube-to-tubesheet (header) joint. 2 grooves are only be provided for tubesheet thickness 25 mm and greater according to API 661. The tubesheets are less than 25 mm in thickness for low design pressure, such as lube oil air cooler and cycle water air cooler. As per API 661 tube hole grooving can be used for all tubesheet holes for expanded joints in tubesheets less than 25mm (1 inch) thick shall be machined with one groove approximately 3 mm

(1/8 in.) wide and 0.4mm (1/64 in.) deep A second groove shall be provided for tubesheets 25 mm(1in.) or greater in thickness.

5.3 Plenums

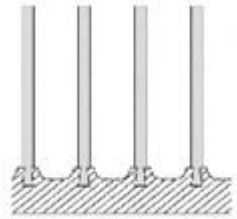
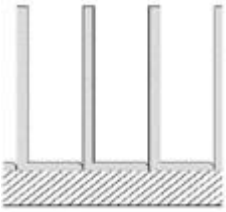
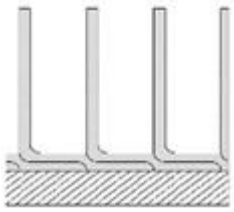
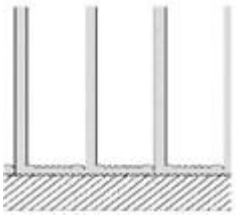
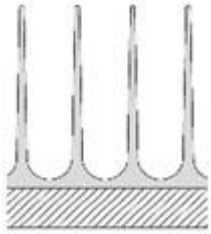
Plenums can be box type or transition type. The transition type gives the best distribution of air over the bundles but is almost exclusively used with induced draft because hanging a machinery mount from a transition forced draft plenum presents structural difficulties.



5.4 Fins

In air coolers normally finned tubes are used to increase the heat exchanger area. The different types and the methods to attach the fins influence the heat transfer. The fins may be generated by extruding the aluminium tubes or by helically wrapping a strip of aluminium to embed it in a pre-cut helical groove on the tube. Sometimes serrations are cut in fins which cause interruption in the air boundary layer thereby increasing the turbulence and hence, the heat transfer. Typically the fin material is aluminium. Main selection criteria are corrosion protection, heat transfer and manufacturing costs.

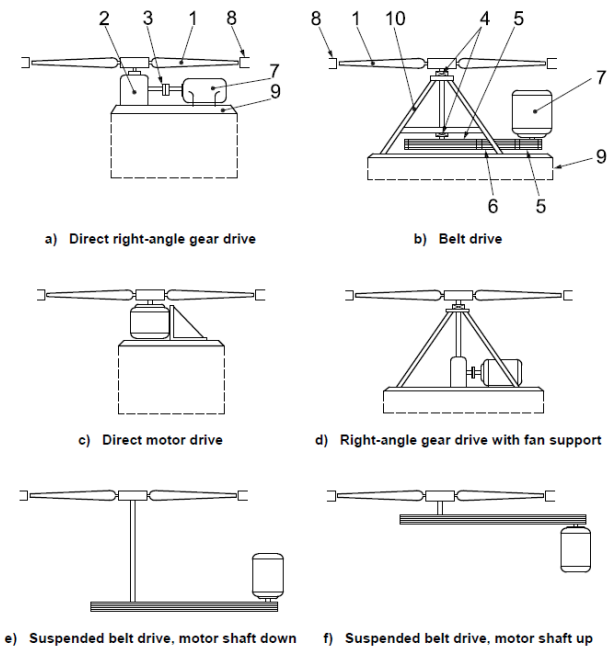
Fin types[2]

	G-fin or embedded fin	Maximum process temperature 400°C (750°F).
	L-fin or footed fin	Maximum process temperature 130°C (270°F). cheap Option
	LL-fin or overlapped footed fin	Maximum process temperature 130°C (270°F).
	KL-fin or knurled footed fin	Maximum process temperature 200°C (390°F).
	Extruded-fin	Maximum process temperature 300°C (570°F).Good Efficiency

5.5 Fans and Drives

Typical axial fans with following drive arrangements are used:

[2] Figure: http://www.beca-engineering.com/Products/FinnedTubes.html, 2.10.2015



Key

1	fan	6	belt drive
2	gear box	7	motor
3	coupling	8	fan ring
4	bearing	9	base plate
5	sheave	10	fan support

Figure 8 — Typical Drive Arrangements

3

The drive transmission type f is a typically type and used for forced draft.

Providing a vibration monitor (switch or transmitter) for each fan is in standard scope of compressor package. Vibration switch of Robertshaw make is preferred.It is recommended whenever possible to use direct driven fans. This may result in higher costs for the motor as it needs to be a low speed motor (noise of fan) but may also reduce the life cycle costs and there will be no strange noise of V-Belts.
Variable speed fans (speed frequency controlled, SFC) or automatic variable pitch AVP fans may be used for better process control. Also during night when air temperature is lower if stringent nosie limitations are applied air flow rate could be reduced by variable speed fans.
The occupied fan area should be in range of 40% - 70% of the bundle face area.
Certain installations demand higher degree of redundancy and ask for 2x100% and 3x50% fans in lube oil cooler as per API 614.
This means that in a bay with three fans the duty is performed by only two fans in case that one fan fails.
The operation of fans makes the air cooler noisy and needs to be considered as a design parameter in specifying the coolers to remain within the contractual noise limits specified for the installation.

[3] Figure: API Standard 661, Seventh edition 2018

As the pressure increase of axial fans is limited a typical air face velocity of 3-3.5 m/s should not be exceeded.

6 Further requirements

6.1 Control Philosophy

The fans are controlled based on the given outlet set point temperature of the fluid.The fluid outlet temperature must be monitor at downstream of cooler, not at the outlet of a temperature control valve. To avoid a lot of start & stop of the fan motors the set point shall be chosen according the real ambient temperature on site suitable for the process. Below table shall give an example how the fan control could be realized.

Note: The 3rd fan, even if the cooler is designed with 2x50% for operation and 1x50% in spare, shall also be implemented in the control system as last order. In case the 1st fan or 2nd fan is not working the 3rd fan will then automatically switch on for its programmed range.

A hysteresis of 5°C shall be implemented to avoid several start / stop.

- Example: 1st fan is on at 50°C. At this moment the fluid is rapidly cooled down to 46-47°C. To switch off the fan again minimum 45°C fluid temperature shall be achieved in order to release the off function for the fan even if the temperature controller reaches the off % value.

If 2 fans are working.

TAG-No (FAN or Motor)	Description	ON	OFF
XY-123A (W)	1st Fan of cooler *TAG*	50%	20%
XY-123B (W)	2nd Fan of cooler *TAG*	90%	60%
XY-123C (S)	3rd Fan of cooler *TAG*	105%	60%

If 3 fans are working.

TAG-No (FAN or Motor)	Description	ON	OFF
XY-123A (W)	1st Fan of cooler *TAG*	50%	20%
XY-123B (W)	2nd Fan of cooler *TAG*	70%	40%
XY-123C (W)	3rd Fan of cooler *TAG*	90%	70%

All temperature set points shall be higher than hydrate temperature that is from analysis based on gas composition and specified by process controlling requirement.

Additional to the set point the fans will have a priority assignment. The fan with the lowest priority will start first.

TAG-No (FAN or Motor)	Description	Priority		
XY-123A	1st Fan of cooler *TAG*	1		
XY-123B	2nd Fan of cooler *TAG*		2	
XY-123C	3rd Fan of cooler *TAG*			3

6.2 Surface treatment

- Preservation accord. to KV 5028, Rev. B or equivalent specification.
- The tubes are surrounded by aluminum fins, they don't need painting or galvanized. The painting is preferred for all bundle frames, headers and structures with C.S. material because of low cost and high time efficiency. (The hot dip-galvanized will be preferred by third-party.)
- The support structure and the headers could be painted as per BCA specification for applicable area or as per the applicable project painting specification.

6.3 Packing & Assembly

- Protection of fins during transport is important and shall be specified in purchase order
- Prior to shipment the cooler shall be nitrogen blanket. (0.3. bar g)
- Normal road worthy packing for delivery to BCA – Winterthur is sufficient.

In order to avoid having the air cooler delivered in single pieces and therefore spend too much time for the installation on site, the air cooler shall be delivered assembled as much as possible but at least as follow:

- Assembled tube bundle including hail mesh guard on top
- Fan housing has to be delivered completely assembled. Motor, fan blades, housing, protection mesh, vibration transmitter, V-Belt (if any) have all to be assembled at supplier location. Lifting arrangements have to be provided for proper lifting and installation on site.
- Steel frame shall be assembled as much as possible at supplier location.

- It is possible for smaller air cooler (usually for cooler in coolant system) to have them completely assembled. This means that the air cooler has only to be positioned on site without any assembly activity. Normally the supplier advises this option by his experience nevertheless it is recommended to contact BCAG shipping department to check the possibility as well.

6.4 Inspection & Documentation

- According to the project specific BCA inspection and test plan.
- Arrangement drawing, bill of material and cooler data sheets, Instruction and maintenance manual shall be provided.
- Final documentation according to VSB_1029800 is requested.

7 Applicable standards and codes

- API 661 (if required)
- ASME section VIII, div.1
- DIN EN 13445 for Europe Supply.
- PED EC Pressure Equipment Directive to be considered for installation in Europe
- ATEX or IEC

8 API vs Non API aircooler

Parameter	API	Non API
CA expect Tube	Corrosion allowance for CS material - min 3 mm	As per calculations.
Mini Thickness	Header components as per API 661 table 7.1.6.1.6	As per calculations.
Tube OD	Mini 25.4 mm	Less than 25mm or as req
Air Face Velocity	Max 3.6 m/s _ forced Draft Max 4 m/s – Induced draft	Till 5 m/s acceptable
Fan coverage	Min 40% coverage	As per optimized design.
Fan Tip Speed	60 m/s	As per calculations.
Axial Fan Installation	For axial fan add 20% extra to airside heat transfer rate due to uneven air distribution	As per calculations.

9 References

API 661 -

- Typical specifications for coolant air coolers are:
  - TSP 2012461 (2000659), TSP 2006527 (2000437), TSP_2019360 (2000892), TSP_2043415 (2001575), TSP_2049048 (2001743), TSP_2053029 (2001893)

- Typical specifications for gas air coolers are
  - TSP_2027186 (2001110) with datasheet TSP_2027187 (2001110)
  - TSP_2043195 (2001575) with datasheet TSP_2043203 (2001575)
  - TSP_2047337 (2001743) with datasheet TSP_2047338 (2001743)
  - TSP_2052925 (2001893) with datasheet TSP_2052926 (2001893)

- Recommended suppliers:
  - Bronswerk / Netherlands
  - Grenco / UK
  - GEA/ Germany
  - ALZ / Germany
  - Boldrocchi / Italy
  - ALFA LAVAL /USA
  - Kelvion/Germany

See also

- Tubular Heat Exchanger TDO 2011219
- Cooling Water Systems TDO 2012870

10 Revision

Revision	Prepared By	Date	Details
00	Daniel Manto	10.1.2017	First release
01	Komal Bhande	01.07.2025	Refined chapter 3, 4,5. Added Chapter 8
05	Komal Bhande	30.03.2026	Refined chapters 5.1, 5.5, 6.1