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PROCESS DESIGN OF AIR COOLED HEAT EXCHANGERS (AIR COOLERS)

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standards and Specifications covers the minimum process design requirements, field of application, selection of types and design consideration for air coolers.

REFERENCES

Throughout this Standard dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

DEFINITIONS AND TERMINOLOGY

Bank - One or more sections including one or more units arranged in a continuous structure.

Bare Tube Surface - 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.

Unit - The air-cooled heat exchange equipment covered by one equipment number, comprising one or more sections, the bundles to perform one specific duty.

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
A/V	Autovariable
DN	Diameter Nominal, mm
MAP	Manual Adjustable Pitch
NPS	Nominal Pipe Size, inch
P	Air-side static pressure drop, mbar (0.1 kPa)
Uo	Overall Heat Transfer Coefficient, W/m2. K (W/m2. °C)

UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

GENERAL

1. Air cooled exchangers are usually composed of rectangular bundles containing several rows of tubes on a triangular pitch. Heat transfer is generally countercurrent, the hot fluid entering the top of the bundle and air flowing vertically upward through the bundle.

   Air cooled units have been successfully and economically used in liquid cooling for compressor engine and jacket water and other recirculating systems, petroleum fractions, oils, etc. and also in condensing service for steam, high boiling organic vapors, petroleum still vapors, gasoline, ammonia, etc.

2. Since air is a universal coolant, there are numerous applications where economic and operating advantages are favorable to air-cooled heat transfer equipment. However, applications are limited to cases where the ambient air dry bulb temperature is below the desired cooling or condensing temperature.

3. Where expensive or insufficient water supplies are encountered or where cooling water pumping or treating costs are excessive, it is often found that air-cooled units are desirable for several services. The adverse conditions of high relative humidity or excessive space requirements occasionally create high costs or installation difficulties for cooling towers. In some of those cases, air-cooled heat transfer equipment offers a satisfactory solution.
4. Full consideration should be given to adequate winter protection of air-cooled units installed in cold climates. It is essential that all possibilities of freeze-up be eliminated and external recirculation of hot air is necessary for severe winter conditions when the unit is subject to freezing and heating coils provided for protection against freeze-up shall be in a separate bundle and not part of the process tube bundle.
5. If the fluid being handled is subject to wide variations in viscosity over the range of atmospheric temperatures encountered, provisions must be made to control the extent of cooling at the lower ambient air temperatures.
6. Bundles may be fabricated in widths to 3.65 m (12 ft) and depths to 8 rows. Usually the maximum dimensions are dictated by shipping requirements. Although standard bundles are available in lengths of 2.44 m (8 ft), 3.05 m (10 ft), 4.57 m (15 ft), 6.07 m (20 ft), 7.31 m (24 ft), 10.36 m (34 ft), and 12.2 m (40 ft). Bundles may be stacked, placed in parallel, or in series, for a given service. Also, several small services may be combined in one bay.

   In general, the longer the tubes and the greater the number of tube rows, the less expensive the surface on a square meter basis.
7. In moderate climates air cooling will usually be the best choice for minimum process temperatures above 65°C, and water cooling for minimum process temperatures below 50°C. Between these temperatures a detailed economic analysis would be necessary to decide the best coolant.

HORIZONTAL TYPE

Unless otherwise specified, the horizontal type is preferred.

FANS

Number of Fans

At least two fans shall be provided for each bay. Any deviation from this requirement will need the prior approval of the Company.

Fans in Various Duties

Where, for reasons of control, an air-cooled heat exchanger has to be provided with automatic variable-pitch fans, as in the case of overhead condensers, it shall not share its fans with air-cooled heat exchangers on other duties, for example product run-down coolers.

Types

1. Two general classifications of air-cooler fans are:
   a. forced draft type where air is pushed across the tube bundle;
   b. induced draft type where air is pulled through the bundle (see Fig. 1).
2. Forced draft should be selected for all normal applications. Amongst other reasons, the accessibility of fans, actuators and drives is much better for maintenance and there is thus a strong preference for this arrangement.

   Forced draft shall be selected for critical and condensing duties where the difference between the design product outlet temperature and the design air inlet temperature is 15°C or higher.

   Forced draft shall be selected for all cooling duties where air outlet temperatures would be higher than those specified as limiting for the induced-draft arrangement.
3. For critical cooling or condensing duties where the product outlet temperature falls below a point 15°C above the design air inlet temperature (*), induced draft may be considered providing the air outlet temperature will not rise to a level higher than is acceptable for the fan, fan hub and bearings for the greasing system and for all structural components exposed to the hot air stream. The degree of acceptability is subject to the Company's approval.

   Under normal operating conditions, air outlet temperatures should not exceed:

   - 60°C with fans in operation.
   - 80° C with free convection on the air side.

   A higher outlet temperature may be considered providing it does not exceed the operating temperature limits for the fan blades, the hub, the fan blade

adjusting mechanism and the bearings when the heat exchanger is at maximum operating temperature with free convection on the air side. The temperature effect of radiation under these conditions shall also be taken into account. For the power failure case, take a maximum air outlet temperature of 15°C below the maximum product inlet temperature.

***** Unless otherwise agreed by the Company, the product outlet temperature shall not be less than 10°C above the design air temperature.

4. The advantages of forced and induced draft types are listed in Appendix D. These should be weighed carefully before deciding on the choice of unit.
5. Recommendations
   a. Induced-draft units should be used whenever hot-air recirculation is a potentially critical problem.
   b. Forced-draft units should be used whenever the design requires pour-point protection, or winterization. However, consideration of possible summer recirculation must be accounted for in sizing the fans to minimize this effect.

RUST PREVENTION

The structural parts can be galvanized or pickled and painted to prevent rusting of the steel.

CHEMICAL CLEANING CONNECTIONS

If chemical cleaning maintenance is specified, connections shall be provided per the following:

a. Connections shall be installed only in nozzles DN 100 mm (NPS 4 inch) and larger. For smaller nozzles, connections will be made in the attached piping by the purchaser.
b. The minimum size connection shall be DN 50 mm (NPS 2 inch).
c. Connections shall be installed horizontally. Orientation will be specified.
d. For bundles in series or series-parallel arrangement, only one chemical cleaning connection need be provided in the inlet nozzle and one in the outlet nozzle of each series group.

OPERATING TEMPERATURE AND PRESSURE

The maximum anticipated process operating temperature will be indicated on the Process Data Sheet. Air Coolers shall be designed for a temperature at least 28°C above the maximum anticipated temperature.

The maximum anticipated operating pressure, which shall include an allowance for variations in the normal operating pressure which can be expected to occur, will be indicated on the Air Cooler Specification Sheet.

Except for air coolers operating under a vacuum, the internal design pressure shall be 10% greater than the specified maximum operating pressure, but in no case shall the difference be less than 2 bar (200 kPa). The headers on air coolers operating under a vacuum shall be designed for a minimum external pressure of 1 bar (100 kPa) unless otherwise specified. Design pressures shall be indicated on the Process Data Sheet.

AIR-SIDE DESIGN

General Requirements

1. Such environmental factors as weather, terrain, mounting, and the presence of adjacent buildings and equipment influence the air-side performance of an air-cooled heat exchanger.

   The purchaser shall supply the Vendor with all environmental factors pertinent to the design of the exchanger as per the Table 1. These factors shall be taken into account in the air-side design.

2. Air Coolers shall be designed for summer and winter conditions. The summer and winter design air temperatures and humidities shall be specified in the job specifications.
3. For winter design conditions the minimum tube wall temperature shall be at least 22°C higher than pour point temperature for both normal and minimum design throughput.
4. Proper fouling resistance shall be applied to the inside surface of the tube.

5. All heat transfer surfaces and coefficients shall be based on total effective outside tube and fin surface.
6. When calculating heat transfer coefficients, the inside fouling and inside fluid film resistance shall be multiplied by the ratio of the total effective outside surface to the total effective inside surface.
7. The effective tube wall and fin metal resistance shall be included in calculating heat transfer coefficients.
8. Pressure drops shall not exceed the maximum allowed values specified. These indicate the total pressure drops across nozzles, headers and tubes.
9. Fouling factor on air side of exchangers shall be 0.35m2. K/kW (0.002 h.ft2.°F/Btu).
10. The need for air flow control shall be as defined by the purchaser on the basis of specific process operation requirements, including the effect of weather. Various methods of controlling air flow are available.

    The type ultimately selected is dependent on the degree of control required, the type of driver and transmission, equipment arrangement, and economics. As a guide, the various methods include, but are not limited to, simple on-off control, on-off step control (in the case of multiple-driver units), two-speed motor control, variable-speed drivers, controllable fan pitch, manual or automatic louvers, and air recycling.
11. Fan selection at design conditions shall be such that at constant speed the fan is capable of providing, by an increase in blade angle, a 10 percent increase in air flow with a corresponding pressure increase.
12. In the inquiry the maximum and minimum design ambient temperatures under which fans and drivers will operate, as well as any specific requirements relating to the sizing of drivers and transmissions shall be stated.
13. For mechanical components located above the tube bundle design temperature shall be equal to maximum process inlet temperature unless otherwise specified.

DESIGN CONSIDERATIONS

1. Design maximum ambient air temperature should be selected so that it will not be exceeded more than 1-2 percent of the total annual hourly readings based on at least 5 consecutive years. Lower figures mean a smaller

exchanger but they also indicate a question on performance during the hottest weather. Daily temperature charts as well as curves showing the number of hours and time of year any given temperature is exceeded are valuable and often necessary in establishing an economical design air temperature. See Table A.1 in Appendix A as a typical study.

2. Units should preferably be placed in the open and at least 23-30 m from any large building or obstruction to normal wind flow. If closer, the recirculation from downdrafts may require raising the effective inlet air temperature 1-2°C or more above the ambient selected for unobstructed locations.

   If wind velocities are high around congested areas, the allowance for recirculation should be raised above 2°C.

3. Units should not be located near heat sources. Experience cautions that units near exhaust gases from engines can raise inlet air 8°C or more above the expected ambient.

4. Hot Air Recirculation

   Problems associated with hot air recirculation are the direct effect of poor exchanger design and location. Minimum allowable distances between air coolers and other process equipment should be considered. These, however, are based on safety requirements and should be accordingly increased if recirculation poses a potential problem. Other recommendations for combating hot air recirculation include:

   - Using induced draft fans which force the air away from the bundle.
   - Baffles and/or a stack on top of the bundle for a forced draft unit (or fan on an induced draft unit) will also direct the air away from the bundle.
   - Humidification sections or air washers: If the geographic location is such that the relative humidity is low most of the year, a humidification section could be installed below the unit. This, in effect, moisturizes the inlet air down to its wet bulb temperature which could be 5°C to 11°C cooler than ambient. However, care should be taken to insure that air entering the tube bundle is dry.
   - A-Frame, V-Frame and vertical bundle arrangements should not be used if recirculation is a potential problem.
   - Water spraying is not recommended for alleviating existing hot air recirculation problems except as a temporary solution. If the bundle is sprayed directly, tube-to-fin bonding, fouling, and corrosion problems