ENGINEERING STANDARD

FOR

PROCESS DESIGN OF AIR COOLED HEAT EXCHANGERS

(AIR COOLERS)

ORIGINAL EDITION

JAN. 1996

This standard specification is reviewed and updated by the relevant technical committee on Sep. 2001(1) and Sep. 2011(2). The approved modifications are included in the present issue of IPS.

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS are based on internationally acceptable standards and include selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein.

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS

Throughout this Standard the following definitions shall apply.

COMPANY :

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER :

Means the “Company" where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract document.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR :

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR :

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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0. INTRODUCTION

"Process Design of Non-combustion Type Heat Exchanging Equipment", are broad and contain variable subjects of paramount importance. Therefore, a group of process engineering standard design practices are prepared to cover the subject.

This group includes the following standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-771	"Process Requirements of Heat Exchanging Equipment"
IPS-E-PR-775	"Process Design of Double Pipe Heat Exchangers"
IPS-E-PR-785	"Process Design of Air Cooled Heat Exchangers (Air Coolers)"
IPS-E-PR-790	"Process Design of Cooling Towers"

This Standard Specification covers:

"PROCESS DESIGN OF AIR COOLED HEAT EXCHANGERS

(AIR COOLERS)"

Non-combustion type heat exchange equipment are contained from various types from which the above mentioned have the most application in Oil, Gas, and Petrochemical (OGP) industries and each item will be discussed separately.

1. SCOPE

This Standard Specification covers the minimum process design requirements, field of application, selection of types and design consideration for air coolers.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Sep. 2001. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 167 on Sep. 2001. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on Sep. 2011. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No. 315 on Sep. 2011. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following 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.

API (AMERICAN PETROLEUM INSTITUTE)

API 661 "Air-Cooled Heat Exchangers for General Refinery Service"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100 "Engineering Standard for Units"

IPS-G-ME-245, "Engineering and material Standard for Air Cooled Heat Exchangers"

3. DEFINITIONS AND TERMINOLOGY

For the purposes of this document, the following terms and definitions apply.

3.1 bank

one or more items arranged in a continuous structure

3.2 bare tube surface

total area of the outside surfaces of the tubes, based on the length measured between the outside faces of the header tube sheets

3.3 bay

one or more tube bundles, serviced by two or more fans, including the structure, plenum and other attendant equipment

Note : Figure 1 shows typical bay arrangements.

3.4 finned surface

total area of the outside surface exposed to air

3.5 forced-draught exchanger

exchanger designed with the tube bundles located on the discharge side of the fan

3.6 induced-draught exchanger

exchanger designed with the tube bundles located on the suction side of the fan

3.7 item

one or more tube bundles for an individual service

3.8 item number

purchaser's identification number for an item

3.9 pressure design code

recognized pressure vessel standard specified or agreed by the purchaser EXAMPLE ASME Section VIII.

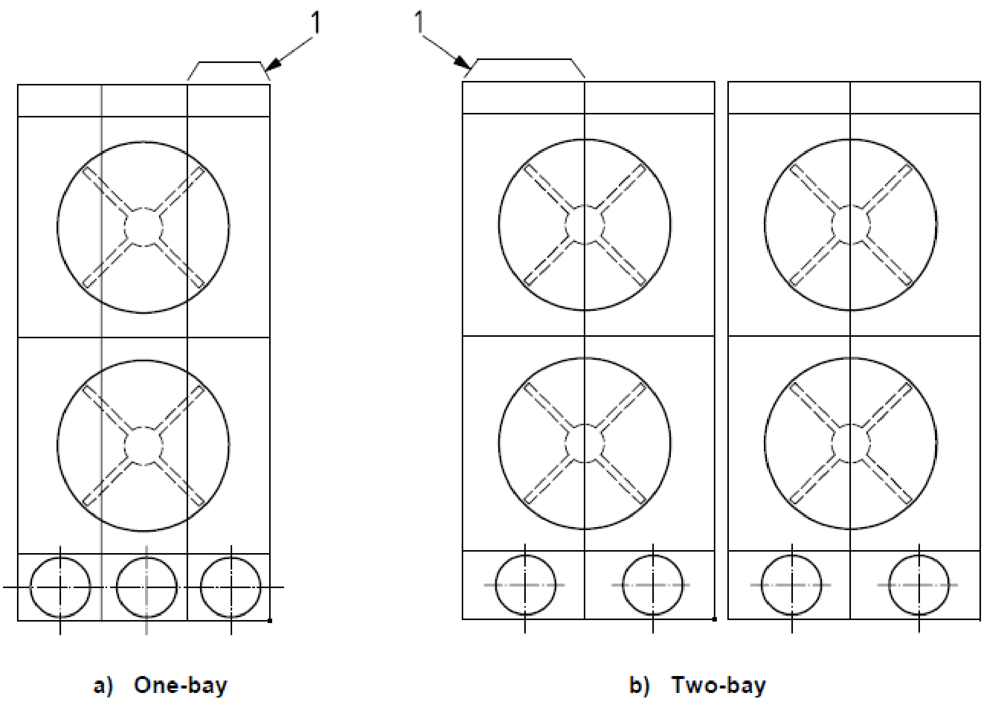
3.10 structural code

recognized structural standard specified or agreed by the purchaser

EXAMPLES AISC M011 and AISC S302.

3.11 tube bundle

assembly of headers, tubes and frames



Key

1 tube bundle

Fig. 1- Typical bay arrangements

4. SYMBOLS & ABBREVIATIONS

A/V = Auto variable

DN = Diameter Nominal, mm

MAP = Manual Adjustable Pitch

NPS = Nominal Pipe Size, inch

P = Air-side static pressure drop, mbar (0.1 kPa)

U_o = Overall Heat Transfer Coefficient, $W/m^2.K$ ($W/m^2.°C$)

5. UNITS

This Standard is based on International System of Units (SI), as per IPS-E-GN-100 except where otherwise specified.

6. GENERAL

6.1 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.

6.2 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.

6.3 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.

6.4 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.

6.5 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.

6.6 Bundles may be fabricated in widths to 3.65 m (12 ft) and depths to 8 rows. 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).Usually the maximum dimensions are dictated by shipping requirements. 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 greater the number of tube rows, the less expensive the surface on a square meter basis.

6.7 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. It is recommended vendors consider installation of air fan coolers on pipe racks.

7. HORIZONTAL TYPE

Unless otherwise specified, the horizontal type is preferred.

8. FANS

8.1 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.

8.2 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.

8.3 Types

8.3.1 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).

8.3.2 Forced draft should be selected for all normal applications. Amongst other reasons, the accessibility of fans, actuators and drivers 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.

8.3.3 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.**

8.3.4 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.

8.3.5 Recommendations

1) Induced-draft units should be used whenever hot-air recirculation is a potentially critical problem.

2) 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.

9. RUST PREVENTION

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

10. 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 needs to be provided in the inlet nozzle and one in the outlet nozzle of each series group.

11. OPERATING TEMPERATURE AND PRESSURE

11.1 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.

11.2 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.

12. AIR-SIDE DESIGN

12.1 General Requirements

12.1.1 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.

12.1.2 Air Coolers shall be designed for summer and winter conditions. The summer and winter design air temperatures and humidity shall be specified in the job specifications.

12.1.3 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.

12.1.4 Proper fouling resistance shall be applied to the outside surface of the tube.

12.1.5 All heat transfer surfaces and coefficients shall be based on total effective outside tube and fin surface.

12.1.6 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.

12.1.7 The effective tube wall and fin metal resistance shall be included in calculating heat transfer coefficients.

12.1.8 Pressure drops shall not exceed the maximum allowed values specified. These indicate the total pressure drops across nozzles, headers and tubes.

12.1.9 Fouling factor on air side of exchangers shall be $0.35 m^2.K/kW$ ($0.002 h.ft^2.°F/Btu$) as a minimum.

12.1.10 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.

12.1.11 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 not govern the driver rating.

12.1.12 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.

12.1.13 For mechanical components located above the tube bundle, design temperature shall be equal to maximum process inlet temperature unless otherwise specified.

13. DESIGN CONSIDERATIONS

13.1 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.

13.2 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.

13.3 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.

13.4 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 could be severe. The severity will depend on the operating conditions, the length of time the sprays are used, and the quality of water used.

13.5 Fouling on the outside of finned surface is usually rather small, but must be recognized.

13.6 Table B.1 in Appendix B shows the heat transfer coefficients for air-cooled heat exchangers. Appendix C shows the standard specification sheet which shall be used for air cooled heat exchanger design.

13.7 The same tube side velocity limitation which apply to shell and tube exchangers, apply for air coolers.

13.8 As per Fig. 2 embedded fins are permitted up to a Design Temperature of 400°C, extruded fins to 260°C, footed tension wound fins to 150°C, and edge wound fins up to 120°C, but are prohibited in steam condensing service. The necessity for extended surface (fin height and density) will depend upon the specific service. Some general rules are:

1) If the overall heat transfer coefficient (referred to bare tube area) is greater than 113 W/m^2. K, or if the fluid viscosity is less than 10 cP*, the higher fins (15.9 mm) are used.

2) If the overall coefficient is between 85 and 113 W/m^2. K, or if the fluid viscosity is in the range of 10 to 25 cP, intermediate size fins (7.9 mm) are used.

3) If the overall coefficient is below 85 W/m^2. K, or if the fluid viscosity is greater than 25 cP, no fins are used.

***1cP=1mPas**

13.9 Thermal Expansion of Tubes

Provision shall be made to accommodate thermal expansion of tubes.

13.10 Type of Blades

Aluminum blades are used up to 150°C while plastic is limited to about 70-80 °C air stream temperature.

14. TUBE-SIDE FLUID TEMPERATURE CONTROL

The tube-side fluid responds quickly to changes in inlet air temperature. In many applications this is of no great consequence as long as the unit has been designed to take the maximum. For condensing or other critical service, a sudden drop in air temperature can create pressure surges in distillation or other process equipment, and even cause flooding due to changes in vapor loading. Vacuum units must have a pressure control which can bleed air or other inert into the ejector or vacuum pump to maintain near constant conditions on the process equipment. For some units the resultant liquid sub cooling is not of great concern.

15. COLD CLIMATE CONSIDERATION

15.1 High Viscosity-High Pour-Point Services

The basic problem in this type of service is to prevent the fluid from "setting up" in the tubes at low flow rates and/or low ambient air temperatures. For such a service (i.e., pipestill bottoms), the following recommendations should be considered in the design:

15.1.1 Normally, the air-cooled exchanger should be designed with bare tubes rather than finned tubes to provide a higher wall temperature for a given inside heat transfer coefficient. However, sometimes it may be necessary to use low fin tubes to obtain a flow arrangement that provides a sufficient pressure drop.

15.1.2 The pressure drop through the tubes should be maximized. This results in a higher process heat transfer coefficient and therefore a higher wall temperature. Also, it will permit a series type bundle arrangement and thereby tend to eliminate flow distribution problems associated with a parallel type arrangement.

15.1.3 Steam coils should be provided under the unit to heat the incoming air during startup and shutdown operations. Also, depending on the severity of the pour-point temperature, steam might be necessary for either intermittent or continuous winter operation.

15.1.4 Air flow control should be supplied by means of louvers and/or variable pitch fans. The type of air flow control would be dictated by the individual problem.

15.1.5 Provisions should be made to take bundles out of service during low flow rate operation by installing a bypass and flushing connections to the bundle.

15.1.6 The unit can be designed with concurrent flow or for conversion from countercurrent flow to concurrent flow.The latter could be achieved either with a convertible piping arrangement or with variable pitch fans by operation at a negative angle.

15.2 Winterization

15.2.1 All air-cooled exchangers for which winterization may be required should be forced draft units with top louvers. However, since forced draft units are more susceptible to summer recirculation problems, simultaneous consideration must be given to this when determining a summer design max. air inlet temperature.

One possibility is to add 5°C to the max. design temperature to account for the possible recirculation.

15.2.2 For cases where there is a possibility that a freeze-up problem can exist on winter startup or shutdown, the exchanger should be designed from the outset to accept a steam coil. This involves leaving room in the plenum and allowing for the increased pressure drop in the fan design.

15.2.3 Process outlet temperatures should be controlled by at least one autovariable pitch fan per bay. In the case of single bays with only one A/V fan, the manual adjustable pitch (MAP) fan should be driven by a two-speed motor. The basis for this is: on reduction of heat duty when the A/V actuator first reaches its lower limit, stopping a single speed MAP fan is too big a step change. In such a case, the A/V fan control will be hunting between the conditions of full pitch with the MAP fan off and minimum pitch with the MAP fan on. In multibay units the number of MAP fans divides the incremental steps so that the A/V fans should not cycle.

15.2.4 External recirculation schemes should be side recirculation oriented if possible. This affords a better recirculation temperature distribution in the plenum than an end recirculation scheme.

15.2.5 Recirculation louvers on external schemes should be horizontally oriented. This affords better mixing of the recirculated air with fresh inlet air than if the louvers are vertical.

15.2.6 All exposed headers should be steam traced and/or insulated.

15.2.7 To account for plenum air maldistribution, the design plenum chamber temperature should be set to insure 0°C at the coldest spot. This is a function of plenum size, location of the bay, and the minimum design air temperature.

15.2.8 Sloping may be considered to facilitate complete drainage of the tube fluid during the shutdown period.

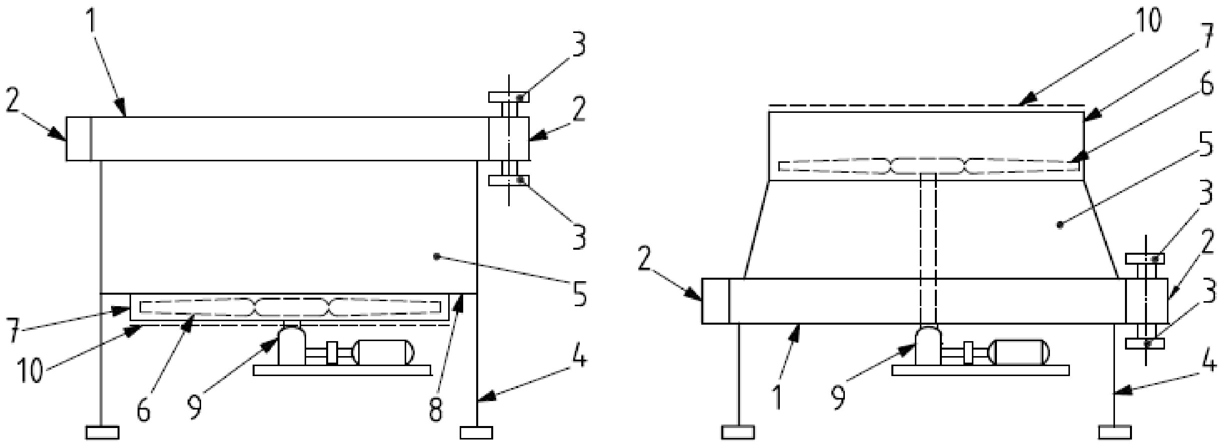
TABLE 1 - WEATHER DATA

1 Temperature Exposure:		
Winter		
Minimum ambient and average duration (1)	-------	°C
	-------	days/year
Mean daily minimum (2)	-------	°C
Mean daily maximum (2)	-------	°C
Summer		
Mean daily minimum (2)	-------	°C
Mean daily maximum (2)	-------	°C
2 Rain/ snow/hail exposure:		
Maximum rainfall or snowfall (1)	-------	mm/24 h
Maximum rainfall or snowfall storm intensity (1)	------- -------	mm/h
Average snowstorm and/or hailstorm occurrence (1)	------- -------	days/year
3 Wind exposure:		
Predominant Wind Direction		
- Summer	-------	compass heading
- Winter	-------	compass heading
Wind intensity (predominant winds)		
- 1.5 - 16 km/h	-------	% time
- 18 - 32 km/h	-------	% time
- over 32 km/h	-------	% time

Notes:

1) Specified when critical to process.

2) specified when automatically controllable louvers or fan hubs furnished for process control.



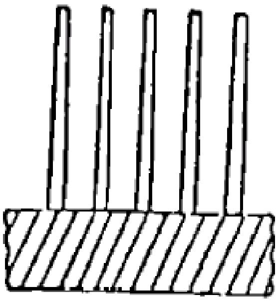
a) Forced draught **b) Induced draught**

Key

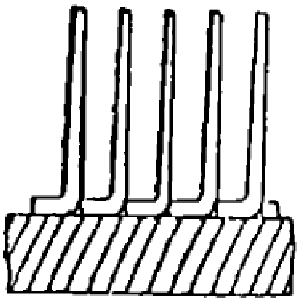
1 tube bundle
2 header
3 nozzle
4 supporting column
5 plenum
6 fan
7 fan ring
8 fan deck
9 drive assembly
10 fan guard

TYPICAL AIR-COOLED HEAT EXCHANGER CONFIGURATIONS

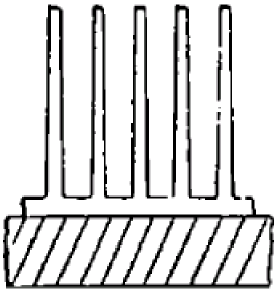
Fig. 1



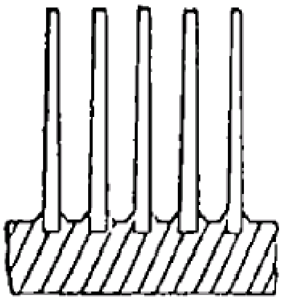
Edge Wound
(Design Temp. = 120°C (250°F) max.)



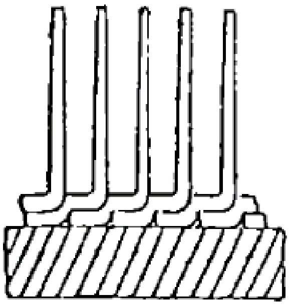
Footed Tension
(Design Temp. = 150°C (300°F) max.)



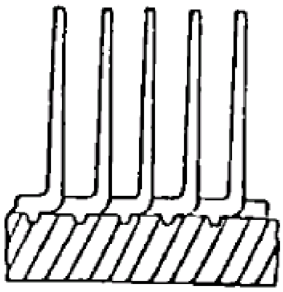
Extruded
(Design Temp. = 260°C (500°F) max.)



Embedded
(Design Temp. = 400°C (750°F) max.)



Double Footed Tension
(Design Temp. = 150°C (300°F) max.)



Footed Grooved Tension
(Design Temp. = 260°C (500°F) max.)

TYPES OF FINNED TUBES USED IN AIR-COOLED HEAT EXCHANGERS

Fig. 2

APPENDICES

APPENDIX A

TABLE A.1 - TYPICAL TEMPERATURE STUDY FOR DESIGN AIR TEMPERATURE DETERMINATION

Fin bonding type	Maximum process temperature
Embedded fins	400 °C (750 °F)
Externally bonded (Hot-dip galvanized steel fins)	360 °C (680 °F)
Extruded fins	300 °C (570 °F)
Footed fins (single L) and overlap footed fins (double L)	130 °C (270 °F)
Knurled footed fin, either single L or double L	200 °C (390 °F)
Externally Bonded (-welded or brazed fins)	> 400 °C (750 °F) (maximum should be agreed by purchaser)
Except where stated otherwise, the above limits are based on a carbon steel core tube and aluminium fins; different materials for the core tube and/or the fins may result in a different temperature limit and the manufacturer shall be consulted.	

Note:

1% = 88 Hours; 2% = 175 hours; 3% = 263 hours.

APPENDIX B

TABLE B.1 - TYPICAL HEAT TRANSFER COEFFICIENTS FOR AIR-COOLED HEAT EXCHANGERS

	Overall Finned Tube Coefficient U W/m^2. K (Btu/hr.sq.ft.°F) Referred to	
	Bare Surface	**Finned Surface**
CONDENSING SERVICE		
Amine reactivator	511-568 (90-100)	30-33 (5.3-5.9)
Ammonia	568-681 (100-120)	33-40 (5.9-7.0)
Freon 12	340-454 (60-80)	19.8-26.6 (3.5-4.7)
Heavy naphtha	340-397 (60-70)	19.8-23.2 (3.5-4.1)
Light gasoline	426-511 (75-90)	23.8-29.5 (4.2-5.2)
Light hydrocarbons	454-540 (80-95)	22.7-31.7 (4.0-5.6)
Light naphtha	397-454 (70-80)	23.2-26.6 (4.1-4.7)
Reactor effluent-Power formers Hydrofiners, Hydro formers	340-454 (60-80)	19.8-26.6 (3.5-4.7)
Steam	738-795 (130-140)	39.7-46.5 (7.0-8.2)
Fractionator overhead-light naphthas, steam and non condensable gas	340-397 (60-70)	15.3-23.2 (2.7-4.1)
GAS COOLING SERVICE		
Air or flue gas at 3.45 bar (g), (ΔP = 68.7 mbar = 6.87 kPa)	56 (10)	~ 3.4 (~ 0.6)
Air or flue gas at 6.9 bar (g), (ΔP = 137.4 mbar)	113 (20)	~ 6.8 (~ 1.2)
Air or flue gas at 6.9 bar (g), (ΔP = 345 mbar)	170-284 (30-50)	9.6-14.1(1.7-2.5)
Ammonia reactor stream	454-511 (80-90)	26.6-30 (4.7-5.3)
Hydrocarbon gases at 1.034-3.45 bar(g), (ΔP = 68.7 mbar)	170-227 (30-40)	5.6-13 (1.0-2.3)
Hydrocarbon gases at 3.45-17.23 bar(g), (ΔP = 206.1 mbar)	284-340 (50-60)	11.3-19.8 (2.0-3.5)
Hydrocarbon gases at 17.23-103.4 bar (g), (ΔP = 345 mbar)	397-511 (70-90)	19.8-30 (3.5-5.3)

(to be continued)

APPENDIX B

TABLE B.1- (continued)

	Bare Surface	Finned Surface
LIQUID COOLING SERVICE		
Engine jacket water	681-738 (120-130)	33-43.1 (5.9-7.6)
Fuel oil	113-170 (20-30)	6.8-10.2 (1.2-1.8)
Hydro former and Power former liquids	397-483 (70-85)	19.8-25.5 (3.5-4.5)
Light gas oil	340-397 (60-70)	17-23.2 (3.0-4.1)
Light hydrocarbons	426-540 (75-95)	22.7-31.7 (4.0-5.6)
Light naphtha	397-483 (70-85)	19.8-25.5 (3.5-4.5)
Process water	596-681 (105-120)	34.6-39.7(6.1-7.0)
Residuum	56-113 (10-20)	3.4-5.6 (0.6-1.0)
Tar	28-56 (5-10)	1.7-3.4 (0.3-0.6)
Heavy gas oil	284-426 (50-75)	14.1-17 (2.5-3.0)
Lube oil	113-284 (20-50)	5.6-11.2 (1.0-2.0)

APPENDIX C

AIR-COOLED HEAT EXCHANGER SPECIFICATION SHEET (SI UNITS)

AIR-COOLED HEAT EXCHANGER DATA SHEET (SI UNITS)

Job No.	________	Item No.	______
Page	1 of 2	By	______
Date	________	Revision	______
Proposal No.	________	Contract No.	______
Inquiry No.	________	Order No.	______

Manufacturer ________	Heat exchanged, kW ________
Model No. ________	Surface/item-finned tube, m^2 ________
Customer ________	Bare tube, m^2 ________
Plant location ________	MTD, eff., °C ________
Service ________	Transfer rate-finned, $W/m^2 \cdot K$ ________
Type draught ○ Induced ○ Forced	Bare tube, service, $W/m^2 \cdot K$ ________
Bay size (W × L), m ________ No. of bay/items ______	Clean, W/m^2 ________

Basic design data

Pressure design code ________	Structural code ________
Tube bundle code stamped ○ Yes ○ No	Flammable service ○ Yes ○ No
Heating coil code stamped ○ Yes ○ No	Lethal/toxic service ○ Yes ○ No

Performance data — Tube side

		In	Out
Fluid name	Temperature, °C	____	____
Total fluid entering, kg/h	Total flow rate (liq./vap.), kg/h	__/__	__/__
Dew/bubble point, °C ________/________	Water/steam, kg/h	__/__	__/__
○ Pour point ○ Freeze point, °C	Noncondensable, kg/h	__/__	__/__
Latent heat, kJ/kg	Relative Molecular mass. (vap./non-cond.)	__/__	__/__
Inlet pressure ○ kPa (ga) ○ kPa (abs)	Density (liq./vap.), kg/m^3	__/__	__/__
Pressure drop (allow./calc.), kPa ________/	Specific heat (liq./vap.), kJ/kg·K	__/__	__/__
Velocity (allow./calc.), m/s ________/	Thermal conductivity (liq/vap.), W/m·K	__/__	__/__
Inside foul res., $m^2 \cdot K/W$	Viscosity (liq./vap.), mPa·s	__/__	__/__

Performance data — Air side

Air inlet temperature (design dry bulb), °C ________	Face velocity, m/s
Air flow rate/item, (kg/h) (m^3/h) ________	Min. design ambient temp., °C ________
Mass velocity (net free area), $kg/s \cdot m^2$ ________ Air	Altitude, m
outlet temperature, °C ________ Air	Static pressure, kPa
flowrate/fan, m^3/h	

Design, materials and construction

Design pressure, kPa (ga) ________	Heating coil
Test pressure, kPa (ga) ________	No. of tubes ________ O.D., mm ________
Design temperature, °C ________	Tube material ________
Min. design metal temperature, °C	Fin material and type ________
	Thickness, mm ________
Tube bundle	Pressure design code ________
Size (W × L), m ________	Stamp? ○ Yes ○ No
No./bay ________ No. of tube rows ________	Heating fluid ________ Flow, kg/s ________
Bundles in parallel ________ In series ________	Temperature (in/out), °C ________/________
Structure mounting ○ Grade ○ Pipe rack ○ Other	Inlet pressure, kPa (ga) ________
Pipe-rack beams (distance C-C) ________	Pressure drop (allow./calc.), kPa ________/________
Ladders, walkways, platforms ○ Yes ○ No	Design temp., °C, des. press., kPa (ga) ________/________
Structure surf. prep./coating ________	Inlet/outlet nozzle, DN ________/________
Header surf. prep./coating ________	Header
Louvre	Type ________
Material ________	Material ________
Action control: ○ Auto ○ Manual	Corr. allow., mm ________
Action type: ○ Opposed ○ Parallel	No. of passes* ________

* Give tube count of each pass if irregular.

AIR-COOLED HEAT EXCHANGER DATA SHEET (SI UNITS)	Job No.	____	Item No.	____
	Page	2 of 2	By	____
	Date	____	Revision	____
	Proposal No.	____	Contract No.	____

Header (continued)

Slope, mm/m ____

Plug material

Gasket material

Nozzle	No.	Size, DN	Rating and facing
Inlet			
Outlet			
Vent			
Drain			

Misc. conn's: TI ____ PI

Chemical cleaning

Min. wall thickness, mm

Tube

Material

O.D., mm. ____ Min. wall thickness, mm.

No./bundle ____ Length, m ____

Pitch, mm ____

Layout ____

Fin

Type ____

Material ____

Stock thickness, mm ____

Selection temperature, °C ____

O.D., mm. ____ No./m ____

Customer specification ____

Mechanical equipment

Fan

Manufacturer & model ____

No./bay ____ Speed, r/min ____

Diameter, m ____ No. of blades ____

Angle ____

Pitch adjustment: ○ Manual ○ Auto

Blade material ____ Hub material

kW/fan.@des.temp. ____ @min.amb.

Max. allow./calc.tip speed, m/s ____/

Driver

Type

Manufacturer & model ____

No./bay ____ Driver kW ____

Speed, r/min ____ Service factor ____

Enclosure ____

Volt ____ Phase ____ Cycle ____

Fan noise level (allow./calc.), dB(A), @m ____/____

Speed reducer

Type ____

Manufacturer & model ____

No./bay ____

Service factor ____ Speed ratio ____/1

Support: ○ Structure ○ Pedestal

Vib. switch: ○ Yes ○ No

Enclosure ____

Controls air-side

Air recirculation: ○ None ○ Internal ○ External

Over: ○ Side ○ End

Degree control of outlet process temp.

(max. cooling), +/– °C ____/____

Action on control signal failure

Fan pitch: ○ Minimum ○ Maximum ○ Lockup

Louvres: ○ Open ○ Close ○ Lockup

Actuator air supply ____

Fan: ○ None ○ Positioner ○ Bias relay

Louvres: ○ Inlet ○ Outlet ○ Bypass

Positioner: ○ Yes ○ No

Signal air pressure, kPa (ga)

From ____ To ……………………

____ From ____ To

……………………… ____ Supply air

pressure, kPa (ga)

Max. ____ Min. ____

Max. ____ Min. ____

Shipping

Plot area (W × L), m ____

Bundle mass, kg ____

Bay ____

Total ____

Shipping, kg ____

APPENDIX D

ADVENTAGES OF FORCED AND INDUCED DRAFT FANS

Forced Draft

1) Generally requires less power for air temperature rise greater than 10°C. Horsepower varies inversely with the absolute temperature.

2) Adaptable for winterization, pour-point recirculation schemes.

3) Mechanical equipment more readily accessible for maintenance.

4) Less structural support required.

5) No mechanical equipment-exposed-to hot exhaust air. Whereas induced draft is subjected to much higher temperature.

6) Isolated supports for mechanical equipment.

7) Exchangers are easier to remove for repairs.

8) Offers better accessibility to the fan for on-stream maintenance and fan-blade adjustment.

9) Structural costs are less and mechanical life is longer.

10) Simplifies future plant expansion by providing direct access to bundle for replacement.

Induced Draft

1) Generally requires less power for an air temperature rise less than 10°C.

2) Less hot air recirculation as exhaust air velocity is about 2½ times that of forced draft.

3) Offers bundle protection from adverse weather (rain, hail, snow, etc.). Also, shields the bundle from solar heating and rain quenching.

4) Better suited for cases with close approach temperatures between inlet air and outlet fluid.

5) Will transfer more heat by natural convection with fans off because of the stack effect.

6) Air distribution over exchanger is better.

7) Sections are closer to ground and easier to maintain, provided driver mounted below cooler.

8) Few walkways needed, mounting easier overhead.

9) Connecting piping usually less.

10) permits the installation of air-cooled equipment above other mechanical equipment such as pipe racks or shell &tube exchangers

11) Better process control and stability, because the plenum covers 60% of the bundle face area, reducing the effect of sun, rain and hail.