# ENGINEERING STANDARD

# FOR

# PROCESS DESIGN OF AIR COOLED HEAT EXCHANGERS

# (AIR COOLERS)

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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, design consideration for air coolers.

## 2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant.

### IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-ME-245, "Air Cooled Heat Exchangers"

## 3. DEFINITIONS AND TERMINOLOGY

Terms used in this Specification are defined as follows:

### a) Bank

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

### b) Bare Tube Surface

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

### c) Bay

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

### d) 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.

### e) Forced Draft Type

Designed with tube bundles located on the discharge side of the fan.

### f) Induced Draft Type

Designed with tube bundles located on the suction side of the fan.

### g) Section

Assembly of two headers, finned tubes and side channels.

### h) Tube Bundle

Assembly of headers, tubes and frames.

### i) Unit

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

## 4. SYMBOLS & ABBREVIATIONS

| | | |
|---|---|---|
| **A/V** | = | Autovariable |
| **DN** | = | Diameter Nominal, mm |
| **MAP** | = | Manual Adjustable Pitch |
| **NPS** | = | Nominal Pipe Size, inch |
| **ΔP** | = | 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) 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.

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.

**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. 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.

**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. Air-cooled exchangers are used for cooling and condensing.

## 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 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.

**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.

**8.3.4** The advantages of forced and induced draft types are listed below. These should be weighed carefully before deciding on the choice of unit.

### Forced Draft

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

**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.

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

### 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.

### 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 need 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 14°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 humidities shall be specified in the job specifications.

**12.1.3** For winter design conditions the minimum tube wall temperature shall be at least 10°C higher than pour point temperature for both normal and minimum design throughput.

**12.1.4** Proper fouling resistance shall be applied to the inside 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 $0.35 m^2 . K/kW$ ($0.002 h.ft^2 .°F/Btu$).

**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 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.

**12.1.12** 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 nearconstant conditions on the process equipment. For some units the resultant liquid subcooling 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.

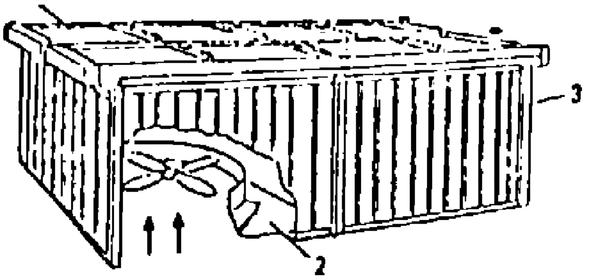
**TABLE 1 - WEATHER DATA**

| | |
|---|---|
| 1 Temperature Exposure: | |
| Winter<br>Minimum ambient and average duration (1) | ______ °C<br>______ days/year |
| Mean daily minimum (2) | ______ °C |
| Mean daily maximum (2) | ______ °C |
| Summer<br>Mean daily minimum (2) | ______ °C |
| Mean daily maximum (2) | ______ °C |
| 2 Rain/ snow/hail exposure:<br>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:<br>Predominant Wind Direction<br>- Summer | ______ compass heading |
| - Winter | ______ compass heading |
| Wind intensity (predominant winds)<br>- 1.5 - 16 km/h | ______ % time |
| - 18 - 32 km/h | ______ % time |
| - over 32 km/h | ______ % time |

**Notes:**

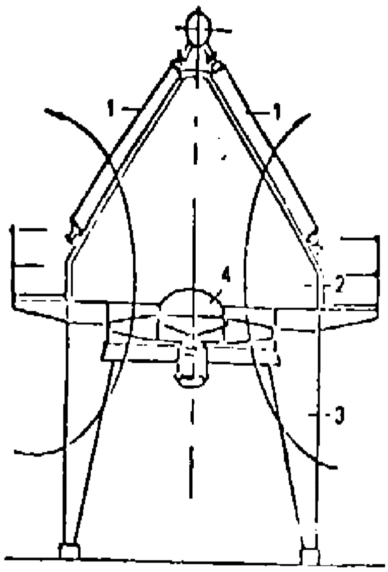
**1) Specified when critical to process.**

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

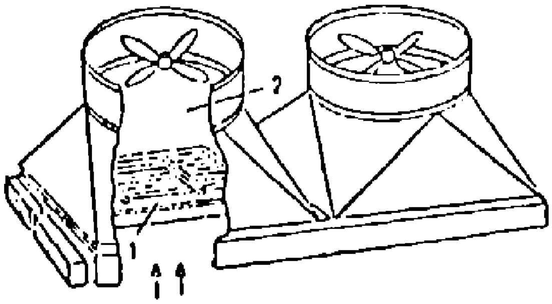



**COMPONENTS**

1 Bundle
2 Plenum
3 Supports
4 Fan and Driver



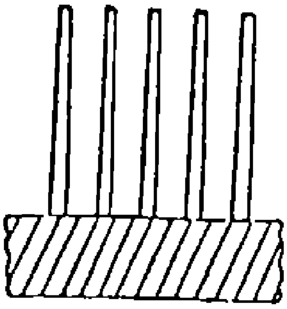

A Frame



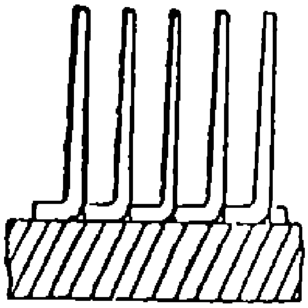

Induced Draft

**TYPICAL AIR-COOLED HEAT EXCHANGER CONFIGURATIONS**

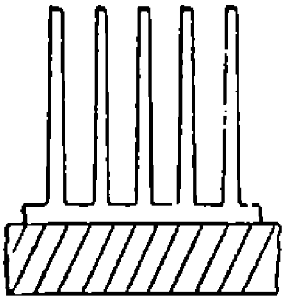
**Fig. 1**



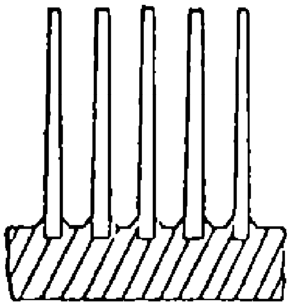
Edge Wound
(Design Temp. = 120°C (250°F) max.)



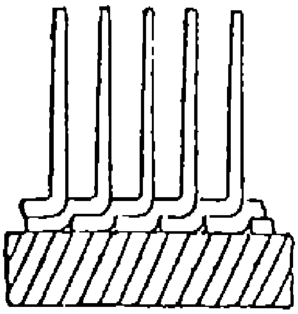
Footed Tension
(Design Temp. = 150°C (300°F) max.)



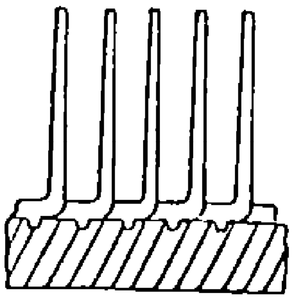
Extruded
(Design Temp. = 260°C (500°F) max.)



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

| Location | Maximum Dry Bulb Temp. °C (°F) | Dry Bulb Temp. °C (°F) % of Annual Hours Stated Temp. is Exceeded | | | Annual Average Dry Bulb Temp. °C (°F) | Suggested Design Temp. °C (°F) |
|---|---|---|---|---|---|---|
| | | 1% | 2% | 3% | | |
| Beaumont, Texas | 39 (102) | 34 (93) | 33 (91) | 32 (90) | 21 (69) | 33 (91) |
| Victoria, Texas | 43 (110) | 32 (89) | 36 (96) | 35 (95) | 22 (71) | 36 (96) |
| Parkersburg, W. Va. | 41 (106) | 32 (90) | 31 (87) | 30 (86) | 13 (55) | 31 (87) |
| New Orleans, La. | 39 (102) | 33 (92) | 33 (91) | 32 (89) | 21 (70) | 33 (91) |
| Wilmington, Del. | 41 (106) | 31 (88) | 29 (85) | 29 (84) | 13 (55) | 29 (85) |
| Grand Rapids, Mich. | 37 ( 99) | 28 (83) | 27 (80) | 26 (78) | 8 (47) | 27 (80) |

**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 $U_o$, 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-Powerformers Hydrofiners, Hydroformers | 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 @ 3.45 bar (ga), (ΔP = 68.7 mbar = 6.87 kPa) | 56 (10) | ~ 3.4 (~ 0.6) |
| Air or flue gas @ 6.9 bar (ga), (ΔP = 137.4 mbar) | 113 (20) | ~ 6.8 (~ 1.2) |
| Air or flue gas @ 6.9 bar (ga), (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 @ 1.034-3.45 bar(ga), (ΔP = 68.7 mbar) | 170-227 (30-40) | 5.6-13 (1.0-2.3) |
| Hydrocarbon gases @ 3.45-17.23 bar(ga), (ΔP = 206.1 mbar) | 284-340 (50-60) | 11.3-19.8 (2.0-3.5) |
| Hydrocarbon gases @ 17.23-103.4 bar (ga), (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) |
| Hydroformer and Powerformer 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)

| Revision | No. | Date | By |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

Manufacturer

Sheet No. ____________________

Proposal No. ____________________

Contract No. ____________________

Date ____________________ By ________

| | | |
|---|---|---|
| 1 | Customer | Item No. |
| 2 | Plant Location | Purch. Inq. No. |
| 3 | Service | Purch. Ord. No. |
| 4 | Size & Type | (Induced)(Forced) Draft No. of Bays |
| 5 | Surface per Unit-Finned Tube m$^2$ | Bare Tube m$^2$ |
| 6 | Heat Exchanged MW | MTD, Eff. °C |
| 7 | Transfer Rate - Finned Tube , Bare Tube, Service | Clean W/m$^2$·°C |
| 8 | **PERFORMANCE DATA - TUBE SIDE** | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | Fluid Name | | | Lethal Service (Yes)(No) | IN | OUT |
| 10 | Total Fluid Entering kg/s | | | Density, Liquid kg/m$^3$ | | |
| 11 | | IN | OUT | Specific Heat Capacity kJ/kg·°C | | |
| 12 | Temperature °C | | | Cond. (Liq.)(Vap.) W/m·°C | | |
| 13 | Liquid kg/s | | | (Pour)(Freeze) Point °C | | |
| 14 | Vapor kg/s, mol.wt. | | | Bubble Point °C | | |
| 15 | Noncond. kg/s, mol wt. | | | Latent Heat kJ/kg | | |
| 16 | Steam kg/s | | | Inlet Pressure kPa | | |
| 17 | Water kg/s | | | Pressure Drop, Allow./Calc. kPa | / | |
| 18 | Viscosity (Liq)(Vap) mPa·s | | | Fouling Resist., Inside m$^2$·°C/W | | |
| 19 | **PERFORMANCE DATA - AIR SIDE** | | | | | |

| | | | |
|---|---|---|---|
| 20 | Air Quantity, Total (kg/s)(std. m$^3$/s) | Altitude above Sea Level m | |
| 21 | Air Quantity/Fan act. m$^3$/s | Temperature In (Design Dry Bulb) °C | |
| 22 | Actual Static Pressure kPa | Temperature Out °C | |
| 23 | Face Velocity std m/s | Mass Velocity (Net Free Area) kg/s·m$^2$ | Minimum Design Ambient °C |
| 24 | **DESIGN - MATERIALS - CONSTRUCTION** | | |

| | | | |
|---|---|---|---|
| 25 | Design Pressure kPa | Test Pressure kPa | Design Temperature °C |
| 26 | TUBE BUNDLE | HEADER, Type | TUBE, Material |
| 27 | Size | Material | (Seamless) (Welded) |
| 28 | No./Bay No. Tube Rows | No. Passes* Slope mm/m | OD mm Min. Thick mm |
| 29 | Arrangement | Plug Material | No./Bundle Length m |
| 30 | Bundles In Parallel In Series | Gasket Material | Pitch mm |
| 31 | Bays In Parallel In Series | Corrosion Allowances mm | FIN, Type |
| 32 | Bundle Frame | No., Size Inlet Nozzle mm | Material |
| 33 | MISCELLANEOUS | No., Size Outlet Nozzle mm | OD mm Stock Thick. mm |
| 34 | Struct. Mount. (Grade)(Piperack) c/c | Special Nozzles mm | No./mm Fin Design Temp. °C |
| 35 | Surface Preparation | Rating & Facing | Code-ASME VIII, Div. 1 Stamp (Yes)(No) |
| 36 | Louvers Auto Manual | TI PI | SPECS |
| 37 | Vibration Switches | Chem. Cleaning | |
| 38 | **MECHANICAL EQUIPMENT** | | |

| | | | | |
|---|---|---|---|---|
| 39 | FAN, Mfr. & Model | | DRIVER, Type | SPEED REDUCER, Type |
| 40 | No./Bay | rev/min | Mfr. | Mfr. & Model |
| 41 | Dia. m | No. Blades | No./Bay kW/Driver | No./Bay |
| 42 | Pitch Adj. Auto | Angle | rev/min | AGMA Rating kW Ratio :1 |
| 43 | Material, Blade | Hub | Enclosure | Support (Structure)/(Pedestal) |
| 44 | kW/Fan, Des. | Minimum Amb. | Volt, Phase, Cycle | |
| 45 | Control Action on Air Failure-Fan Pitch (Minimum) (Maximum) (Lockup), Louvers (Open) (Close) (Lockup) | | | |
| 46 | Degree Control of Outlet Process Temperature (Maximum Cooling) (± °C) | | | |
| 47 | Recirculation (None) (Internal) (External Over Side) (External Over End) Steam Coil (Yes) (No) | | | |
| 48 | NOTES * Give tube count of each pass when irregular. | | | |
| 49 | | | | |
| 50 | | | | |
| 51 | | | | |
| 52 | | | | |
| 53 | | | | |
| 54 | | | | |
| 55 | | | | |
| 56 | | | | |
| 57 | Plot Area m$^2$ Proposal Drawing No. | mass Bundle kg, Shipping kg | | |