

DEP SPECIFICATION

AIR-COOLED HEAT EXCHANGERS; SELECTION AND APPLICATION

DEP 31.21.70.10-Gen.

February 2011
(DEP Circular 98/11 has been incorporated)
ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



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PART I INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the selection and specification of air-cooled heat exchangers in the refining, chemical, petro-chemical, and natural gas processing industry, for which DEP 31.21.70.31-Gen., Air-Cooled Heat Exchangers (Amendments/Supplements to ISO 13706) is to be applied.

This DEP is not intended to be applied to “A” frame, “V” frame, “roof” type air coolers, or for air coolers provided as part of a packaged gas compressor system, where inclined bundles and a single electric or engine driven fan is often used.

This DEP was created to specify the thermal design, mechanical design, and structural design considerations for air-cooled heat exchangers, and correspondingly assist the design team/designer of either the Principal or the Contractor. Specifications are provided to direct selection/design of cost effective heat exchangers consistent with the service conditions, intended design life, and criticality of the application.

In this DEP it is premised that the user has familiarity with DEP 31.21.70.31-Gen. and ISO 13706, which are primarily intended for use by the Manufacturer/Supplier.

This DEP covers the general specification requirements of the air-cooled heat exchanger data sheet with design notes and the general information typically required for a bid requisition. It is, therefore, not normally intended for air-cooled heat exchanger manufacturers.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (Part V).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://swwww.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

**Amended per
Circular 98/11**

Dual units have been incorporated throughout this DEP.

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II DESIGN

1. INTRODUCTION

- 1.1 The basic expectation is that the Contractor will provide the process and mechanical definition for the application, with the Manufacturer providing the complete thermal design and guarantee. In some cases, the initial thermal design may be completed by the Contractor.
- 1.2 Items listed in the Air-Cooled Heat Exchangers Checklist (see Annex B, ISO 13706) are covered in DEP 31.21.70.31-Gen., except for drawing requirements. The Contractor shall specify the number of copies of drawings, data, etc., required for the project.
- 1.3 When providing specifications for air-cooled heat exchangers and filling in data sheets, the items in ISO 13706 marked with a bullet (●), shall be provided by the Contractor; Standard Form DEP 31.21.70.81-Gen. should be utilized for this purpose.
- 1.4 The "design synopsis checklist" is provided in Appendix B of this Standard. It is provided as a guide for the designer(s) in understanding and specifying overall design requirements. It covers equipment integrity, process service, arrangement and process control considerations. This is considered a "living" document which will be completed and reviewed as the design develops. The design synopsis checklist shall be appended to the data sheet through the design/ specification stage of the project. It shall be retained by the Contractor and included with the equipment records/data book for the project. This document is not intended for the Manufacturer.
- 1.5 Decisions related to the design class performance categories for air-cooled heat exchangers are intended to be made by the Principal in the project "Define" phase and detailed in project scope defining documentation e.g. equipment BDEP (Basic Design Engineering Package), air-cooled heat exchanger data sheet, air-cooled heat exchanger checklist, project specific specifications, etc. This DEP is generally written for Design Class 2 / 3 facilities, with options identified basis design class where appropriate. When projects opt not to implement the design class practice, options set forth within this DEP based on design class shall default to Design Class 3 selection unless otherwise directed by the Principal.

2. PROCESS SPECIFICATION AND GENERAL DESIGN

- 2.1 Stream physical properties and data must be provided as specified in the following paragraphs to allow design and analysis using Shell's preferred methods. Transport properties for well-known components such as air or water do not need to be specified.
- 2.2 For single phase cooling, transport properties (viscosity, density, thermal conductivity, specific heat) shall be provided at the inlet and exit conditions. For liquid streams with a viscosity > 10 cP, a viscosity curve with intermediate temperatures shall be provided from the inlet temperature down to a temperature equal to the minimum ambient air temperature for units without warm air recirculation. For units with warm air-recirculation, the viscosity curve shall extend to the minimum specified plenum temperature.
- 2.3 For condensing streams, transport properties shall be provided for each phase at the inlet, outlet, and several intermediate temperature points, such that purely-interpolation-based errors do not exceed 5%. The transport properties shall be based on the total composition of each phase including water, air and/or steam when these components are part of a homogeneous phase. Liquid properties at the dew point and vapour properties at the bubble point should be included when such points occur within the air cooler. If water is present, the water dewpoint at the operating pressure shall also be specified for condensing services. Additionally, plots of heat release (or total stream enthalpy), weight fraction vapour, percent (by weight) of the second liquid phase (if present) and vapour molecular weight vs. temperature at inlet pressure and the inlet pressure minus the allowable pressure drop shall be provided. The above information shall be calculated under the assumption of thermodynamic equilibrium.
- 2.4 If condensate has immiscible components, liquid properties are to be specified separately and completely for each liquid phase.
- 2.5 If liquid disengages from vapour in an amount sufficient to alter vapour-liquid equilibrium implicit in (2.3) above, differential condensation plots of percent (weight) vapour and vapour molecular weight should be provided when requested by the heat exchanger design engineer, and considered in the thermal and hydraulic performance design.
- 2.6 The nature, size (e.g. microns) and quantity (in wt% or ppm) of solids in the stream such as silt, sand, fines, catalyst fines, etc., shall be defined on the equipment datasheet when applicable. This is particularly important for design of pressure equipment in upstream environments (e.g., tailings, slurry services in mining, froth treatment facilities) to prevent plugging and/or erosion. Where the size distribution and shape of the solids are known this information shall also be provided on the datasheet.
- 2.7 The quantity of free water (wt% or ppm) shall be defined on the equipment datasheet as well as any other compounds (e.g., ammonia, H₂S, chlorides, etc.) which when combined with water may form a corrosive environment. The Contractor SHALL [PS] indicate if the service is in sour or wet H₂S service and shall clearly identify the sulphide stress cracking (SSC), hydrogen blistering, hydrogen induced cracking (HIC), stress-oriented hydrogen induced cracking (SOHIC), or carbonate cracking severity ratings on the equipment datasheet, as determined in accordance with DEP 30.10.02.15-Gen. or DEP 30.10.02.17-Gen., as may be applicable.
- Definition of the water content is also critical to ensure that air-cooled heat exchangers are designed adequately for freeze protection and that this consideration is taken into account for design of piping systems/valves against freezing.
- 2.8 The freezing point, the pour point, the wax point, the dew point (if condensation may result in increased corrosion), the hydrate formation point, or any other temperature which can create operating difficulties for an air-cooled heat exchanger SHALL [PS] be indicated on the process data sheet if any of these critical process temperatures are greater than the minimum ambient temperature for the location in which the air cooler will be installed. All that apply shall be specified.
- 2.9 The Contractor shall indicate any exchangers subject to hydrogen service on the exchanger data sheet along with the hydrogen partial pressure. Hydrogen service is defined as any

- service in which the hydrogen partial pressure is greater than 700 kPa absolute (100 psia) at any temperature.
- 2.10 The Contractor SHALL [PS] indicate any exchangers subject to very toxic service on the exchanger data sheet. Very toxic substances are those which are considered as very hazardous for the environment or human health, as specified in DEP 01.00.01.30-Gen.
- 2.11 Data sheets and curve-specified data must represent the actual design conditions. The heat duty specified should be consistent with the flows and temperatures specified. If excess flow or heat duty is required, the resulting temperatures and flows shall also be specified.
- 2.12 All expected operating scenarios/conditions shall constitute separate alternative design cases and be identified by separate data sheets. Predictable upset conditions and full range of flows (turn-down) shall also be indicated.
- 2.13 Alternate modes of operation such as low process flow at low ambient air temperature, upsets with high process inlet temperatures ($\geq 150\text{ }^{\circ}\text{C}$ [$\geq 300\text{ }^{\circ}\text{F}$]), steam-out, loss of fans due to power failure, temperature bake-out, etc. SHALL [PS] also be defined on the data sheet. This information shall be provided on separate process datasheets along with physical properties, condensing curves, etc., in addition to the defined normal operating cases. This information is needed to ensure an adequate mechanical design.
- 2.14 Abnormal flows and/or temperature conditions that are expected to impose either additional duty requirements or require additional heat transfer surface area or air flow shall be specified. An alternate operating case shall not be dismissed from analytical review simply because it is a lower heat duty case.
- 2.15 Tube-side fouling resistances or design margins should be specified based on DEP 20.21.00.31-Gen., Fouling Margins in Tubular Heat Exchanger Design, plant experience for a specific service, project specific information, or licensor requirements. When no other data or experience is available, TEMA recommended values for the most similar fluid may be used. Through the course of detailed design, if the effective resistance for fouling is found to be greater than 30% of the overall heat transfer resistance, the thermal design engineer shall consult with the Principal's heat transfer specialist to determine if the fouling factor or margin may be reduced accordingly to optimize the design.
- 2.16 External fouling factors should not be applied. Fouling of the external surface usually affects the resistance to air flow with little effect on heat transfer coefficient. The performance of the cooler suffers due primarily to reduced air flow and resulting temperature difference so imposition of a thermal resistance (fouling factor) is not realistic. A sufficient allowance on air side static pressure loss shall be applied for the selection of the fan and motor, in addition to any other air flow margins, to adequately address the needs of a particularly dirty environment (dust, pollen, seeds, cooling tower drift, etc.) in lieu of the use of an external fouling factor. Refer to (Part III 6.7) for further information.
- 2.17 Locations which may be susceptible to environmental fouling shall consider the inclusion of lint/bug screens to minimize air-side fouling.
- 2.18 The design air dry bulb temperature shall account for both the specific geographical location and localized plant influences.
- 2.19 Air-cooled exchangers in non-critical process services shall base their inlet design air temperature on the ambient dry bulb temperature that is equalled or exceeded two percent of the time per annum; approximately 175 hours per year. The allowance required for surroundings and installation factors shall be added to this base. For minimum service design (Design Class 1 Capacity) facilities, no allowance should be added. For general service design (Design Class 2 Capacity) facilities, this allowance should be 2°C (4°F). For robust service design (Design Class 3 Capacity) facilities the allowance should be 3°C (6°F).
- 2.20 Exchangers in critical process services such as LNG process services, refrigeration condensers, column overhead condensers (when not followed by a water-cooled trim condenser), and other services as defined in (2.23), shall base the inlet design air

- temperature on the ambient dry bulb temperature that is equalled or exceeded one percent of the time per annum; approximately 90 hours per year, plus a 3°C (6°F) allowance, regardless of Design Class, to assure proper operation.
- 2.21 Exchangers in rundown service, and other services which may take advantage of the normal diurnal temperature variation, may use the ambient dry bulb air temperature determined by (2.19) less 3°C (6°F).
- 2.22 Where water trim cooling is used downstream of air coolers, consideration may be given to a reduction in the summer ambient air design temperature by 3°C (6°F). It is not recommended to reduce the air design temperature for Type 3 winterized air coolers defined as being in a "critical process service" in this same situation as they are more prone to hot air recirculation in summer, because of larger air approach velocities and potential leakage of hot air through the recirculation louvers.
- 2.23 Critical process services are defined as those services which would constitute a problem with respect to safeguarding, technical integrity of downstream equipment, tanks, etc., production capacity, or product quality, if the air cooler design outlet temperature was exceeded during normal operation. The process datasheet and design synopsis checklist shall clearly indicate if a service is considered "critical" from this perspective. Some typical examples of critical process services are as follows:
- Air-coolers in cooling-sensitive services, whose performance can directly affect the facility capacity or throughput;
 - Air coolers used to regulate column pressure;
 - Air coolers used for light hydrocarbon streams such as C5/C6 or light straight run naphtha/depropanizer bottoms streams which must be rundown a safe margin below tank vapour pressure limits; typically 5°C (9°F);
 - Air coolers used for jet fuel or other low conductivity products which must be rundown at a safe margin below flash point.
- 2.24 The design minimum ambient air temperature SHALL [PS] be provided and properly addressed in the selection of the temperature control method to avoid freeze point or dew point (if corrosive) and in mechanical design and fabrication. The latter shall be assessed if duty is allowed to vary with ambient temperature. In such cases, the process temperature range can become large and the need for split header construction, to allow the thermal expansion differential between passes, shall be analyzed with consideration of the increased cooling capacity during low ambient temperatures. In addition, the pressure drop and heat transfer of highly viscous services may be significantly impacted and shall be properly assessed and accounted for in the design.
- 2.25 Air-cooled heat exchangers are generally attractive for services with larger duties, services at elevated temperatures which would cause excessive scaling if water cooled exchangers were used, and where water use for cooling is restricted.
- 2.26 The entire service cooling duty should be achieved in one type of equipment, e.g., air-cooled or water-cooled exchanger, rather than dividing the duty between air and water cooled units when the cold end approach to the ambient air temperature is 11°C (20°F) or more. The option of applying a downstream water-cooled exchanger to handle at least part of the duty shall be evaluated when the cold end approach drops below 11°C (20°F). For such an arrangement, the following break temperatures should normally be considered:
- 25°C (45°F) above the ambient air temperature for liquid or vapour cooling services;
 - 40°C (70°F) above the ambient air temperature for condensing services.
- 2.27 When water-trim cooling is specified in combination with cooling by air, the temperature control point, when required, should be located in the product line downstream of the water-trim cooler outlet while the process control modulation for such services should be applied to the air cooler. Where cooling water systems are such that significantly cooler water temperatures may be experienced during winter operation (e.g. once-through cooling water systems), the Principal should be consulted to ensure proper operation and control.

- 2.28 During the loss of air cooler fans, DEP 80.45.10.11-Gen. dictates that for the purposes of relief valve design the natural draught duty of an air-cooled heat exchanger shall be assumed to be 5 % of design. However, a natural draught duty of greater than 5 % can be assumed if supported by analysis. The manufacturer may be required to predict the natural draught performance with design ambient air temperature when necessary to support this analysis, provided the air cooler is not equipped with fail closed louvers and/or that the air cooler is not a column overhead condenser which would flood during such an upset due to a loss of reflux.
- 2.29 For projects incorporating energy efficiency targets, manufacturers shall optimise their design relative to equipment costs and power consumption. The power cost factors and formula to be used for the design optimization and evaluation shall be provided by the Contractor.

3. THERMAL DESIGN

- 3.1 The thermal design for air-cooled exchangers is normally performed by the Manufacturer. During the evaluation of the Manufacturer's bids the Contractor shall check rate the Manufacturer's thermal designs. The Manufacturer's design shall be adjusted to meet the calculation requirements. The thermal and hydraulic design of air-cooled heat exchangers shall be based on design methods which have been proven in practice. In this respect, the design procedures and computer programs published by Heat Transfer Research Inc. (HTRI) or Aspen+ (the former Heat Transfer and Fluid Flow Services (HTFS) software), or UNISIM shall be used. Discrepancies in the performance prediction results between different design methods shall be referred to the Principal's heat transfer specialist for resolution. The heat exchanger rating files shall be turned over to the Principal at the conclusion of the project.
- 3.2 In the case of a proprietary design, the Manufacturer shall contact the Principal to agree on the calculation method and the degree of responsibility.
- 3.3 The tube side pressure drop shall be calculated using the commercial pipe friction factor for carbon and low alloy steel tubes. For high alloy and non-ferrous tubing, a smooth tube friction factor shall be used.
- 3.4 Where a tube is specified or purchased to a minimum wall specification, the tube thickness used for thermal and hydraulic purposes shall be 1.1 times the minimum wall thickness. This is to simulate the actual supplied tube thickness.
- 3.5 The minimum in-tube velocities for single phase (non-erosive) liquid streams shall be as specified in Table 1. For erosive streams, the Principal's heat transfer specialist shall be consulted.

Table 1: Minimum In-Tube Velocities

Fouling Characterization	FOULING FACTOR		Velocity (m/s)	Velocity (ft/s)
	m ² -K/W	°F h ft ² /Btu		
Very Low	≤ 0.00009	≤ 0. 0005	1.0	3.0
Low	≤ 0.00026	≤ 0. 0015	1.0	3.0
Medium	≤ 0.00052	≤ 0. 003	1.5	5.0
High	≤ 0.0012	≤ 0. 0068	2.0	6.5
Severe	> 0.0012	> 0. 0068	2.2	7.2

- 3.6 The allowable pressure drop specified by the process engineer on the exchanger data sheet shall be taken as the maximum that may be consumed in the exchanger's "fouled" condition. For vapour and condensing streams, the allowable pressure drop shall be determined by the process engineer based on process and pressure profile requirements. For pumped liquid streams, adequate thermal performance design dictates that the allowable pressure drop be sufficient to achieve target design velocities in Table 1 to ensure optimum exchanger design, sizing and fouling minimization. Allowable pressure drops for pumped liquids should be in accordance with Table 2. The heat exchanger designer shall communicate to the Principal any opportunity to reduce the size or cost of a design by >10% with more allowable pressure drop than specified in Table 2, as the specifics for certain cases may extend beyond the assumption premises of the table.

Table 2: Allowable Pressure Drop^{1, 2}

Fouling Characterization	Fouling Factor		Liquid Viscosity at the Process Outlet Temperature ¹					
	m ² -K/W	°F h ft ² /Btu	≤ 1 cP		≤ 2 cP		≤ 5 cP ³	
			kPa	psi	kPa	psi	kPa	psi
Very Low	≤ 0.00009	≤ 0.0005	75	11.0	110	16.0	165	24.0
Low	≤ 0.00026	≤ 0.0015	75	11.0	110	16.0	165	24.0
Medium	≤ 0.00052	≤ 0.003	120	17.5	150	22.0	210	30.5
High	≤ 0.0012	≤ 0.0068	200	30.0	225	32.5	300	43.5
Severe	> 0.0012	> 0.0068	275	40.0	315	45.0	350	50.0

- NOTES: 1. Values are estimated to allow the required minimum in-tube velocities specified in Table 1 to be achieved and to provide an optimized heat exchanger design. When the allowed pressure drops are insufficient to achieve the target velocities of Table 1, the Principal's heat transfer specialist shall be consulted.
2. The appropriate allowable value from the table above shall be included on the process datasheet for heat exchanger thermal design. Values shall be specified as the allowable pressure drop.
3. For tube side fluids with liquid viscosity > 5 cP, consult the Principal's heat transfer specialist for further review. In such instance, the pressure drop will be as required to achieve the minimum velocity, and to avoid laminar and/or transitional flow where possible.

- 3.7 Pressure drop in the "fouled" condition must be estimated for use in hydraulic system calculations, including pump sizing. Since the thickness and surface roughness of fouling deposits are not usually known, it is necessary to estimate the increase in pressure drop above a "clean" condition due to fouling, as it cannot be accurately calculated by simulation.

The pressure drop for the fouled condition shall be estimated by multiplying the calculated pressure drop for the clean condition by the appropriate factor from Table 3. Both the "clean" and "fouled" pressure drops shall be shown on the exchanger data sheet.

The "fouled" pressure drop shall be less than the allowable pressure drop. The "fouled" pressure drop may be used in the final hydraulic system calculations.

Table 3: Hydraulic Multipliers for Fouling

Fouling Characterization	Fouling Factor		Pressure Drop Multiplier
	m ² -K/W	°F h ft ² /Btu	
Very Low	≤ 0.00009	≤ 0.0005	1.1
Low	≤ 0.00026	≤ 0.0015	1.1
Medium	≤ 0.00052	≤ 0.003	1.2
High	≤ 0.0012	≤ 0.0068	1.3
Severe	> 0.0012	> 0.0068	1.4

- 3.8 Air-cooled exchanger design total air side static pressure drop, including any air-side multiplier applied, shall not exceed 0.2 kPa (0.029 psi) (20 mm [0.8 in] H₂O) without the approval of the Principal. In no case shall the air side static pressure drop exceed 0.25 kPa (0.036 psi) (25 mm [1 in] H₂O).
- 3.9 Air-cooled exchanger designs shall not be less than three (3) tube rows deep and nominal air face velocities shall not be less than 2.0 m/s (400 ft/min).
- 3.10 Single-pass (non-A frame) air-cooled steam condensers SHALL [PS] not be used, to avoid

- the potential for back-flow of steam from the outlet end of the upper rows into the outlet end of the lower tube rows as this can result in inert blanketing and increased corrosion.
- 3.11 The design of combination exchangers that serve two or more bundles in different process services shall require specific approval from the Principal, and shall not be used when more than one service requires active and close process outlet temperature control ($\pm 3^{\circ}\text{C}$ [5.0°F]).
- 3.12 Air-cooled heat exchangers handling a two-phase mixture at the inlet of the heat exchanger shall be designed for optimal flow distribution over the tubes and passes. At least one inlet nozzle shall be installed for every 2 m (6.5 ft) of bundle width. The use of one tube row per pass is preferred for multi-component condensing services. Where one phase is specified to be corrosive, see (9.0).
- 3.13 Tube bundles for partial or full condensing services shall have full width (not partial width) tube passes so that temperature differences and performance are readily predictable, unless the design analysis is shown to properly account for the unequal air temperatures leaving any row. The number of tube rows in the bottom pass shall be minimized. For total condensers, a single row for the last pass shall be used. The size and/or number of outlet nozzles shall be sufficient to prevent flooding of the bottom row of tubes.
- 3.14 Air-cooled heat exchanger designs in multi-component condensing services should prevent gross liquid-vapour separation. If the air cooler design is such that liquid may disengage from vapour in an amount sufficient to alter vapour-liquid equilibrium, see (2.5), the affects of differential condensation should be considered in the thermal and hydraulic performance design.
- 3.15 Tube bundle designs with partial rows per pass at the inlet (hot) end of the process fluid flow path shall apply split headers or other methods of restraint relief as necessary to prevent bowed tubes, roll leaks, and air flow restriction due to unequal thermal expansion of tube rows. The analytical review shall be included with the mechanical design calculation documentation.
- 3.16 Tube inserts, such as twisted tape turbulators, static mixers or similar devices, shall only be used with the approval of the Principal. When applied, consideration shall be given to the use of a removable cover plate header design in these services within the design pressure and temperature limits of such header boxes.
- 3.17 If plain/bare tubes are used, the exterior of the tubes shall be coated in accordance with the project specification. The coating shall extend over the full length of the exposed section of the tube plus 3 mm (1/8 in) inside each tubesheet, and shall have its thermal resistance considered in the heat transfer performance design.
- 3.18 Any special requirements assumed for the thermal design, e.g. irregular pass layouts or tube inserts, shall be recorded appropriately on the data sheets and/or equipment sketches.

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- 3.19 Consideration shall be given to the need for special provisions and/or devices to prevent erosion of the tube ends for saturated vapours and two-phase fluids if the velocity head (ρV^2) in the tubes exceeds $8,930 \text{ kg/m}\cdot\text{s}^2$ ($6,000 \text{ lb/ft}\cdot\text{s}^2$). For non-erosive liquids, the velocity head shall be calculated using the equivalent maximum water velocities as specified in DEP 20.21.00.31-Gen. for the different tube materials. For dry non-erosive gasses, no specific tube velocity limits apply.

NOTE: In the above calculation of velocity head, V is the linear velocity in m/s (ft/s) and ρ is the fluid density in kg/m^3 (lb/ft^3). For two-phase fluids, the homogeneous velocity should be used.

4. AIR-SIDE DESIGN

- 4.1 The contractor shall specify the type of air-side design (Type 1, 2, or 3) as well as the process control mode (Mode A, B, or C) for the application. These selections are based on an understanding of critical temperature of the process fluid and the process temperature control requirements as described in this section. The Principal shall approve all selections.
- 4.2 Critical process temperatures include the freezing point, pour point, wax point, dew point (if condensation causes corrosion), hydrate formation point, or any other temperature which may create operating difficulties. The Contractor SHALL [PS] include all that apply on the data sheet. For further discussion on critical temperatures refer to ISO 13706, Annex C, Winterization of Air-cooled Heat Exchangers.
- 4.3 Process temperature control requirements generally refers to the expected tolerance between temperature set point and actual bulk outlet temperature. Additional considerations include the degree of winterization required.
- 4.4 Winter performance of air-cooled heat exchangers shall be investigated in detail when:
- the critical process temperature is above the winter design ambient air temperature;
 - total or partial steam condensers;
 - condensing process fluids containing water with or without non-condensables.

Operation for both normal and process turndown conditions shall be considered.

Such an evaluation requires some knowledge of the sizing to allow proper check rating of the design. Sizing of the air-cooled heat exchanger during the front end of the process design stage is therefore required.

- 4.5 The three basic types of air-side designs are as follows:

Type 1	This is a non-winterised design where the calculated minimum inside wall temperature is greater than 10°C (18°F) above the critical process temperature for any operating condition. No air control louvers are required. Designs may be forced or induced draught arrangements.
Type 2	This is the same as Type 1, except that the calculated minimum inside wall temperature is less than 10°C (18°F) above the critical process temperature under start-up, shut-down or upset process conditions with the winter design ambient temperature. This air-side design SHALL [PS] include a supplementary heating coil or other device located below each process bundle with adjustable louvers above the bundle to allow for bundle heat-up without fans in operation. Where variable speed drives are used, louvers shall be pneumatically actuated and manually controlled from a manual load station (location to be defined by the Contractor). If louvers are used as the sole or as a supplementary means of process temperature control, the louvers shall be automatically controlled. Designs may be forced or induced draught arrangements.
Type 3	This is a winterised design where, without the special air recirculation described below, the calculated minimum inside wall temperature would be less than 10°C (18°F) above the critical process temperature with winter design ambient temperature for any defined operating case, including turndown.

The following also apply to Type 3 air-side designs:

- a) The air-side design SHALL [PS] have a full air recirculation system operated on plenum air temperature for each bay.

- b) The design SHALL [PS] include a supplementary heating coil or other device located below each process bundle.
- c) Basic arrangements SHALL [PS] include top plenum mounted exhaust air louvers, full-length side mounted recirculation air louvers (air over the side) located at the fan deck height, and fresh air inlet louvers.
- d) For units arranged adjacent to other units in multi-bank bays, the fresh air louvers SHALL [PS] be located at both ends of each bay.
- e) For stand-alone units, the fresh air louvers may be located around the entire periphery of the bay.
- f) Air exhaust and inlet louvers SHALL [PS] cover the entire width of the bundle with a solid wall provided for the full height of the recirculation air plenum including lower air mixing plenum.
- g) Designs SHALL [PS] be forced draught arrangement.
- h) Plenum temperature measurement SHALL [PS] be provided using a temperature averaging RTD located above each fan with the lowest measured value per bay being used for plenum air temperature control.
- i) Automatic control louvers SHALL [PS] be provided for exhaust air, recirculation air, and air inlets.
- j) For services subject to sub-freezing ambient air temperatures (less than 0°C [32°F]), separate actuators shall be provided for each set of louvers while other services may utilize a mechanically linked system for the exhaust and recirculation louvers.
- k) Half of the air inlet louvers on each end of the bay shall have manual controls and be located closer to the bundle. The other half shall be located closer to grade or the floor, and shall include automatic control louvers.
- l) Air inlet louvers shall include a manual lockable lever arm control for each louver inside the inlet air plenum.
- m) Pipe rack mounted units SHALL [PS] be provided with a checker-plate floor, but may require the addition of a supplementary manually louvered air inlet section built into the floor as necessary to comply with maximum air approach velocity requirements.
- n) When supplemental louvers are provided, the top of the grating covering the floor louvers shall be set at the same elevation as the top of the checker-plate on the adjacent floor sections.
- o) Type 3 air side designs SHALL [PS] utilize process control Mode C only.

Refer to Appendix 2 of DEP 31.21.70.31-Gen. for typical schematics of Type 3 winterization units.

- 4.6 Winterization schemes other than Type 2 or Type 3 may be utilized when approved by the Principal's heat transfer specialist for services which are not subject to freeze rupture, hydrate formation, formation of very corrosive condensate, or viscous flow/pour point concerns.
- 4.7 Use of Variable Frequency Drives (VFDs) control for 100% of the fans may permit some services to be specified with a Type 2 rather than Type 3 air-side design. This change can provide a significant cost reduction, and requires the review and approval of the Principal, since it may result in higher potential for operability problems. In no case SHALL [PS] this be implemented for services subject to hydrate formation and/or freezing.
- 4.8 The louvers for a fully winterized (Type 3) air-side design SHALL [PS] be controlled based on air plenum temperature which is completely independent of process temperature control. Split range control may also be considered to avoid overcooling of the process at minimum fan speed. Plenum temperature shall be measured using multi-point averaging Resistance Temperature Devices (RTDs) per bay each which run diagonally across the face of process bundle - one per fan plenum. The lower of the two plenum temperature measurements

- controls the louvers for that particular bay.
- 4.9 Except for sour gas operations, the plenum temperature set point in Type 3 air-side designs shall be such as to ensure the calculated minimum inside wall temperature is at least 10°C (18°F) above the product critical temperature. Nominally in early design, the temperature of the tempered air in the air plenum should be set at approximately 14°C (25°F) above the process critical temperature. This set point temperature shall be re-established as part of a detailed winter performance evaluation.
- 4.10 For sour gas operations, the minimum plenum temperature set point in Type 3 air-side designs SHALL [PS] be established such that the calculated minimum wall temperature is at least 5°C (9°F) above the hydrate formation temperature, for all defined modes of operation, considering a clean tube bundle condition. The two-phase flow velocity in the last pass shall be maximized and the flow regime SHALL [PS] be maintained in full shear, as high shear rates are known to help mitigate hydrate formation. This criterion is satisfied by conditions above or to the right of the heavy dashed line on the flow regime chart in Appendix A. The Principal's material's specialist shall be consulted for a maximum 2-phase velocity that may apply considering the tube material and service.
- 4.11 The required plenum temperature in Type 3 air-side designs SHALL [PS] be added to the datasheet for all defined modes of operation.
- 4.12 Applications in arctic climates which, in the absence of any process critical temperature limits, utilizing ambient air at sub-zero Celsius temperatures may require special design considerations to prevent frost and ice formation and assure the proper selection and specification of mechanical components. The Principal shall be consulted for all such applications.