

# DEP SPECIFICATION

## AIR-COOLED HEAT EXCHANGERS – SELECTION AND APPLICATION

DEP 31.21.70.10-Gen.

February 2017

ECCN EAR99

### DESIGN AND ENGINEERING PRACTICE

## DEM1



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## 1. INTRODUCTION

### 1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and application of air-cooled heat exchangers for refining, chemical, petro-chemical, and natural gas processing industries.

This DEP is not intended to be applied to “A” frame, “V” frame, or “roof” type air-cooled heat exchangers, or to air-cooled heat exchangers 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 specifies the requirements for thermal, mechanical, and structural design for air-cooled heat exchangers. The design, manufacture and supply requirements of air-cooled heat exchangers is covered in DEP 31.21.70.31-Gen and ISO 13706, on which this DEP is based.

This DEP provides information required for a bid requisition and is not 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.

This is a revision of the DEP of the same number dated February 2014; see (1.5) regarding the changes.

### 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 shall 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.

The word **may** indicates a permitted option.

### 1.3.2 Specific definitions

| Term                                | Definition                                                                                                                                                                                                                                                                                                         |
|-------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Critical process service</b>     | Services which would constitute a problem with respect to safeguarding, technical integrity of downstream equipment, production capacity, or product quality, if the air-cooled heat exchanger design outlet temperature is exceeded during normal operation.                                                      |
| <b>Critical process temperature</b> | Temperatures related to important physical properties of a process stream at which operating difficulties can occur (e.g. the freezing point, the pour point, the wax point, the dew point when condensation may result in corrosion, the hydrate formation point).                                                |
| <b>Hydrogen Service</b>             | Any service in which the hydrogen partial pressure is greater than 700 kPa absolute (100 psia) at any temperature                                                                                                                                                                                                  |
| <b>Velocity Head</b>                | Momentum energy term for fluid flow, calculated as $\rho V^2$ , where V is the linear velocity in m/s (ft/s) and $\rho$ is the fluid density in kg/m <sup>3</sup> (lb/ft <sup>3</sup> ).                                                                                                                           |
| <b>Very toxic (substances)</b>      | Substances that are very hazardous for the environment or human health. For this DEP the term "very toxic" includes Very toxic – acute, chronic, and environment categories unless otherwise specified.<br><br>Refer to DEP 01.00.01.30 Gen. Part III for further information regarding toxic fluid classification |

### 1.3.3 Abbreviations

| Term         | Definition                                  |
|--------------|---------------------------------------------|
| <b>AVP</b>   | Automatically Variable Pitch                |
| <b>HIC</b>   | Hydrogen Induced Cracking                   |
| <b>PWHT</b>  | Post Weld Heat Treatment                    |
| <b>RTD</b>   | Resistance Temperature Device               |
| <b>SOHIC</b> | Stress-Oriented Hydrogen-Induced Cracking   |
| <b>SSC</b>   | Sulphide Stress Cracking                    |
| <b>TEMA</b>  | Tubular Exchanger Manufacturers Association |

### 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 (5).

## 1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2014. The following are the main, non-editorial changes.

| Section/Clause | Change                                                                                                       |
|----------------|--------------------------------------------------------------------------------------------------------------|
| All            | Restructured and clarified requirements, enforced shall/should.                                              |
| 2.2.2, item 8  | Formerly 2.2.2, item 11. Expanded details of DEM1 statement.                                                 |
| 2.2.2, item 9  | Formerly 2.2.2, item 13. Simplified DEM1 statement, used blanket definition of critical process temperature. |
| 2.2.3, item 1  | Upgraded shall statement to SHALL [PS] for consistency with other DEPs and simplified.                       |
| 2.2.3, item 2  | Simplified DEM1 statement.                                                                                   |
| 2.2.4, item 1  | Simplified DEM1 statement.                                                                                   |
| 2.2.6, item 5  | SHALL [PS] statement downgraded to shall.                                                                    |
| 2.4.3, item 2  | Duplicate SHALL [PS] statement removed.                                                                      |
| 2.4.3, item 6  | Editorial changes to DEM1 statement.                                                                         |
| 2.4.3, item 7  | Editorial changes to DEM1 statement.                                                                         |
| 2.6.2, item 7  | Formerly 2.6.3, item 5. Downgraded SHALL [PS] statement to shall.                                            |
| 3.4.2, item 2  | SHALL [PS] statement removed.                                                                                |
| 3.7.1          | Formerly 3.7.1, item 1. SHALL [PS] statement removed to avoid duplication with other DEPs.                   |
| 3.7.1, Item 2  | Formerly 3.7.1, Item 3. Editorial changes to DEM1 statement.                                                 |

## 1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

|                                                                      |                                                                                                                                                                                                                                                                   |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Shell DEPs Online</b><br>(Users with access to Shell DEPs Online) | Enter the Shell DEPs Online system at <a href="https://www.shelldeps.com">https://www.shelldeps.com</a><br>Select a DEP and then go to the details screen for that DEP.<br>Click on the "Give feedback" link, fill in the online form and submit.                 |
| <b>DEP Feedback System</b><br>(Users with access to Shell Wide Web)  | Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal <a href="http://swwww.shell.com/standards">http://swwww.shell.com/standards</a> .<br>Select "Submit DEP Feedback", fill in the online form and submit. |
| <b>DEP Standard Form</b><br>(other users)                            | Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at <a href="mailto:standards@shell.com">standards@shell.com</a> .                                                                                               |

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

## 1.7 DUAL UNITS

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.

## 1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

*Non-normative text is normally indented slightly to the right of the relevant DEP clause.*

## 2. DESIGN

### 2.1 INTRODUCTION

1. The Contractor should provide the process and mechanical definition for the application
2. The Manufacturer should provide the complete thermal design and guarantee.
  - a. The initial thermal design may be provided by the Contractor.
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.
  - a. Standard checklist form in DEP 31.21.70.81-Gen. should be used as guidance for providing the bulleted data
  - b. The Contractor should use DEP 31.21.70.82-Gen (Std. Form) "Design Synopsis Checklist" as guidance in developing the overall design requirements.

*The design Synopsis Checklist is considered a "living" document which will be completed and reviewed as the design develops.*

- c. The Contractor shall include the design synopsis checklist with the equipment records/data book for the project.

*The design synopsis checklist is not intended for the Manufacturer.*

### 2.2 PROCESS SPECIFICATION AND GENERAL DESIGN

#### 2.2.1 General

1. Data sheets and process design data shall represent the exchanger design conditions.
  - a. The heat duty specified shall be consistent with the flows and temperatures.
  - b. If excess flow or heat duty is required, the resulting temperatures and flows shall be specified.
    - i. Heat exchangers should not be specified to have or require "excess surface" for a process margin.
2. All expected operating scenarios/conditions, including turndown, predictable upset conditions, or alternate modes of operation (e.g., steam-out) shall be identified on the data or requisition sheets when they are expected to lead to any of the following:
  - a. impose additional heat duty requirements on the exchanger design;
  - b. require additional heat transfer surface area be provided;
  - c. result in a higher stream pressure drop;
  - d. result in mechanical design conditions (e.g., header box temperature differential) which may determine the need for a split header box.
    - i. An alternate operating case should not be dismissed from analytical review simply because it is a lower heat duty case.

*Indicating all modes of operation is needed to ensure an adequate mechanical design.*

3. For exchangers where the heat duty is allowed to vary with ambient temperature, operation under low ambient temperature conditions shall be taken into account in the design.

*For highly viscous streams, the pressure drop can be much more than anticipated at lower operating temperatures.*

4. When the cold end approach to the inlet air temperature is 11 °C (20 °F) or more, the entire service cooling duty should be achieved in one type of equipment, e.g., air-cooled heat exchanger or water-cooled exchanger, rather than dividing the duty between air and water cooled exchangers.
5. The option of applying a downstream water-cooled exchanger to handle at least part of the duty should be evaluated when the cold end approach is less than 11 °C (20 °F).
  - a. For an arrangement of air-cooled and water-cooled exchangers in series, the following break temperatures should be considered:
    - i. 25 °C (45 °F) above the inlet air temperature for liquid or vapour cooling services;
    - ii. 40 °C (70 °F) above the inlet air temperature for condensing services.a

*Refer to Table 5 in DEP 20.21.00.31-Gen. for skin temperature limits for using water-cooled exchangers when choosing the break temperature.*
6. Air-cooled heat exchangers shall not be used for services where the required cold end approach to the inlet air temperature is less than 6 °C (10 °F).
  - a. For critical process services, air-cooled heat exchangers should not be used where the required cold end approach to the inlet air temperature is less than 11 °C (20 °F).

### 2.2.2 Stream property considerations

1. Stream physical properties and data should be provided to allow for the thermal and hydraulic design of the exchanger to be completed.
2. For single phase cooling, transport properties (viscosity, density, thermal conductivity, specific heat) should be provided at the inlet and exit conditions.

*Transport properties for well-known components such as air or water; do not need to be specified.*
3. For liquid streams with a viscosity greater than 10 cP.
  - a. For units without warm air recirculation, a viscosity curve with viscosity values at intermediate temperatures (from the inlet temperature down to a temperature equal to the minimum ambient air temperature) should be provided.
    - i. For units with warm air-recirculation, a viscosity curve extending from the inlet temperature to the minimum specified plenum temperature should be provided.

4. For condensing streams, the following data shall be provided.
  - a. transport properties and heat release data based on the total composition of each phase (assuming thermodynamic equilibrium) for each phase at the inlet, outlet, and several intermediate temperature points based on equal enthalpy intervals;
  - b. liquid properties at the dew point and vapour properties at the bubble point when such points occur within the heat exchanger;
  - c. if water is present, then the water dew point at the operating pressure;
  - d. heat release from inlet (or total stream enthalpy);
  - e. the weight fraction vapour, along with the percent (by weight) of any second liquid phase (if present);
  - f. the vapour molecular weight;
  - g. surface tension of the liquid phase;
  - h. the mole fraction of non-condensable components at the exchanger's inlet conditions when these are present in an amount greater to or equal to 5%.

*When the heat exchanger design is such that the liquid and vapour may separate, the heat exchanger designer may require differential condensation plots of percent (weight) vapour and vapour molecular weight. Differential condensation curves consider that the liquid and vapour phases separate as they are formed and do not remain in thermodynamic equilibrium.*

5. If the liquid formed during condensation has immiscible components, then liquid properties should be specified completely for each individual liquid phase and for the combined 'mixed phase' liquid.
6. Where multiple liquid phases exist which may form an emulsion, the heat exchanger designer and the process engineering specialist shall agree on the property data to be provided.

*The apparent or emulsion viscosity to be used in the design of the heat exchanger can have a significant effect on the equipment sizing.*

7. The data sheet should include the following:
  - a. the nature, size (e.g., microns) and quantity (in wt% or ppm) of solids in the stream such as silt, sand, fines, catalyst fines;  
*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.*
  - b. the quantity of free water (wt% or ppm) in the stream;  
*Specifying the water content in the stream is 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.*
  - c. any other compounds in the stream (e.g., ammonia, H<sub>2</sub>S, chlorides, etc.) which might form a corrosive environment when combined with water.
8. The Contractor SHALL [PS] indicate if the service is in sour or wet H<sub>2</sub>S service and 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 data/requisition sheet.
  - a. Refer to DEP 30.10.02.17-Gen. or DEP 39.01.10.12-Gen., as applicable for information on sour or wet H<sub>2</sub>S service designations.

9. All critical process temperatures SHALL [PS] be specified when they are greater than the minimum ambient temperature for the location.

### 2.2.3 Hydrogen and toxic service considerations

1. The Contractor SHALL [PS] specify if the exchanger is subject to hydrogen service along with the hydrogen partial pressure.
2. The Contractor SHALL [PS] specify if the exchanger is subject to very toxic (1.3.2) service.

### 2.2.4 Alternate operating mode considerations for mechanical design

1. Alternate operating modes which could impact the mechanical design of the exchanger (e.g., 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) SHALL [PS] be specified on the data sheet.

*This information is needed to ensure an adequate mechanical design. In cases of low ambient temperature operation where the heat duty is allowed to vary with ambient temperature, the process temperature range can become large and the need for split header construction, to allow the thermal expansion differential between passes, may be required.*

### 2.2.5 Fouling considerations

1. The fouling resistances or design margins to be applied shall be approved by the Principal and determined from one of the following:
  - a. DEP 20.21.00.31-Gen.;
  - b. facility experience for a specific service;
  - c. project specific information;
  - d. licensor requirements.

*When no other data or experience is available, TEMA recommended values for the most similar fluid may be considered.*
2. If the effective resistance for fouling is found to be greater than 30% of the overall heat transfer resistance, the thermal designer should consult the Principal to determine if the fouling factor or margin may be reduced.
3. An allowance on the 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 address the needs of a dirty environment (dust, pollen, seeds, cooling tower drift,) in lieu of the use of an external fouling factor.

*Refer to (2.4.2 Item 2) for further information.*

*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 primarily due to reduced air flow and resulting temperature difference so imposition of a thermal resistance (fouling factor) is not realistic.*

4. For locations susceptible to environmental fouling, the need for inclusion of lint or bug screens to minimize air-side fouling shall be agreed with the Principal.

### 2.2.6 Ambient condition considerations

1. The design base ambient air dry bulb temperature shall account for both the specific geographical location and localized plant influences.
2. The base ambient design air temperature in non-critical process services shall be no lower than the ambient dry bulb temperature that is only exceeded 2% of the time.
3. Heat exchangers in rundown service, and other services that can take advantage of the normal diurnal temperature variation, may reduce the base ambient design air temperature by 3 °C (6 °F).
4. The base ambient air design temperature shall not be reduced for Type 3 winterized air-cooled heat exchangers defined as being in a critical process service.  
*Such exchangers are prone to hot air recirculation in summer, because of larger air approach velocities and potential leakage of hot air through the recirculation louvers.*
5. The inlet air temperature shall be equal to the base ambient air dry bulb temperature plus the following minimum allowances to the base ambient design temperature.
  - a. For minimum service design (Design Class 1 Capacity) facilities, no allowance.
  - b. For general service design (Design Class 2 Capacity) facilities, 2 °C (4 °F).
  - c. For robust service design (Design Class 3 Capacity) facilities 3 °C (6 °F).*The base ambient temperature needs to be adjusted to determine inlet air temperature to account for surroundings and installation within a process unit.*
6. The inlet air temperature in critical process services shall be no lower than the ambient dry bulb temperature that is only exceeded 1% of the time plus a 3 °C (6 °F) allowance regardless of Design Class.
7. The design minimum ambient air temperature shall be provided.  
*The minimum ambient air temperature is used in the selection of the temperature control method and fan and motor selection.*

### 2.2.7 Critical process service considerations

1. The design synopsis checklist shall indicate if a service is considered critical.  
*Some typical examples of critical process services are as follows:*
  - Air-cooled heat exchangers in cooling-sensitive services, when not followed by a water-cooled trim cooler, whose performance can directly affect the facility capacity, throughput, technical integrity or product quality;
  - Air-cooled heat exchangers 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-cooled heat exchangers used for jet fuel or other low conductivity products which must be rundown at a safe margin below flash point.

### 2.2.8 Natural draught duty considerations

1. Refer to Section 3.2.4 of DEP 80.45.10.11-Gen. for the requirements related to natural draught duty.
2. Contractor shall request natural draught duty calculations from the Manufacturer when required by DEP 80.45.10.11-Gen.

**2.2.9 Energy efficiency considerations**

1. For projects incorporating energy efficiency targets, the Manufacturer should optimise their design relative to equipment costs and power consumption.
  - a. The power cost factors and formula to be used for the design optimization and evaluation should be provided by the Contractor.
2. The Manufacturer may consider the use of velocity recovery stacks to optimize energy efficiency.
3. When used, velocity recovery stacks should not be credited with pressure recovery greater than 67% of the theoretical recovery.

**2.3 THERMAL DESIGN****2.3.1 General**

1. The Contractor shall verify the thermal designs prior to purchasing equipment.
2. The validation of thermal and hydraulic design should be based on the design procedures and computer programs published by Heat Transfer Research Inc. (HTRI) or Aspen+ software.
3. Alternate calculation methods shall be subject to the approval of the Principal.
4. Discrepancies in the performance prediction results between different design methods shall be referred to the Principal for resolution.
5. The applicable versions of computer programs used for thermal design shall be subject to the approval of the Principal.
6. The air-cooled heat exchanger rating files (including the native electronic input files) should be turned over to the Principal at the conclusion of the project.

**2.3.2 Exchanger configuration**

1. Exchangers shall not have less than three (3) tube rows.
2. Exchangers shall not have nominal air face velocities less than 2.0 m/s (400 ft/min).
3. Unless otherwise specified in this DEP or by the Principal, the exchanger type shall be forced draught to facilitate re-tubing and for ease of access to fans and fan bearings, as well as to minimize the exposure of the rotating parts to high temperature.
4. Forced draught arrangements shall be used when the maximum process inlet temperatures equals or exceeds 150 °C (300 °F).
5. Air-side design Type 1 or 2 coolers with process inlet temperatures less than 150 °C (300 °F) where rain on the cooler could upset the process system control should be specified as induced draught.
  - a. For other services, the installation of a 'false plenum' above forced draught coolers may be considered to limit the impact of rainfall on the tube bundle.
6. If the outlet air temperature exceeds the limits for fan, bearings, grease, and appurtenances under any planned operating case including turndown, forced draught coolers shall be applied.
7. Induced draught coolers should be specified for services that require a cold end or hot end temperature approach of 11 °C (20 °F) or less (15 °C (27 °F) in critical process services) and have process inlet temperatures less than 150 °C (300 °F).