TECHNICAL SPECIFICATION

AIR-COOLED HEAT EXCHANGE EQUIPMENT
(AMENDMENTS/SUPPLEMENTS TO API STANDARD 661)

DEP 31.21.70.31-Gen.

December 1993

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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TABLE OF CONTENTS

APPENDICES

PART I INTRODUCTION

1.1 SCOPE

This DEP, which is a revision of an earlier DEP with the same title and number dated October 1982, gives amendments and supplements to API Standard 661, 'Air-Cooled Heat Exchangers for General Refinery Service', Third Edition, April 1992.

Ambiguities or contradictions stemming from the publication of later revisions and/or amendments to API Standard 661 shall be referred to the Principal.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F" as defined in DEP 00.00.05.05-Gen.).

It is intended that API Standard 661 together with this DEP shall be used for horizontal air-cooled heat exchange equipment in oil refineries, chemical plants, gas plants, and exploration and production facilities.

If national and/or local regulations exist in which some of the requirements may 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 as regards 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 Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

For the purpose of this DEP, the following definitions shall hold:

The **Contractor** is the party which 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 which manufactures or supplies air-cooled heat exchange equipment and services to perform the duties specified by the Contractor.

The terms Supplier and Manufacturer as used in this DEP are synonymous with the term **Vendor** (as used in API Standard 661) depending on the context in which the term is used.

The **Principal** is the party which initiates the project work and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a 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 standards/publications referred to in this DEP are listed in Part V.

PART II GENERAL INFORMATION

2.1 DESIGN RULES

The design, materials, fabrication, inspection, testing and preparation for shipment of air-cooled heat exchangers shall be based on API Standard 661, Third Edition, April 1992 as amended/supplemented by this DEP.

For clarity and ease of reference, the section and clause numbering of API Standard 661 has been followed throughout Part IV of this DEP. The sections/clauses in the API Standard 661 not amended by this DEP remain valid as written.

Deviations from this DEP are not permitted without the prior written approval of the Principal. Such approval shall be valid only for a specific case, and shall not be construed as having general validity for wider application.

In case of conflict between documents relating to an order, the following hierarchy shall apply:

1. The purchase order
2. This DEP

In case of conflict, the Principal shall be consulted in writing.

When specifying an air-cooled heat exchanger, the applicable data/requisition sheets listed in Appendix 1 of this DEP shall be used, completed in accordance with Appendix 2 of this DEP.

The Manufacturer/Supplier who performs the thermal design or rating of an air-cooled heat exchanger shall be responsible for the thermal design or rating. In case of a proprietary design, the Manufacturer/Supplier shall contact the Principal to agree on the calculation method and the degree of responsibility.

Air-cooled heat exchangers shall be considered to be pressure vessels. The main mechanical design code shall be ASME Boiler and Pressure Vessel Code Section VIII, Division 1 or 2, as amended/supplemented by DEP 31.22.20.31-Gen. Only requirements additional to those in the ASME code and DEP 31.22.20.31-Gen. are stated in this DEP.

In all cases the Principal shall specify the mechanical design code on the data/requisition sheet and, where applicable, in the Project Specification or BDEP ("Basis of Design Package").

2.2 UNITS OF MEASUREMENT

The SI unit system has been applied in this DEP and, where considered necessary, the metric sizes are followed by their imperial equivalents in brackets.

The use of SI units on the data/requisition sheets shall be in accordance with DEP 00.00.20.10-Gen.

Care shall always be taken to indicate whether absolute pressure or gauge pressure is intended. If bar is used as unit of pressure, this shall be qualified as bar (abs) or bar (ga), as applicable.

2.3 EQUIPMENT NUMBERING

Heat transfer equipment shall be identified by a specific equipment number in accordance with DEP 31.10.03.10-Gen.

Equipment consisting of one or more tube bundles connected in series or parallel and performing a common duty is termed an item. In such cases, the item as a whole is identified by the specific equipment number, and each bundle within the item is separately identified by the addition of a capital letter in alphabetical progression, e.g. E-101A, E-101B, E-101C, etc. Each unique motor/fan combination shall have an equipment number which may differ from the bundle number. Identical motor/fan combinations in a bank shall be numbered in alphabetical progression, e.g. EM-110A, EM-110B, EM-110C, etc.

PART III GENERAL REQUIREMENTS

3.1 SELECTION OF TYPES

3.1.1 Air-cooled heat exchanger type

For refinery services the horizontal air-cooled heat exchanger shall be applied, either forced draught or induced draught, so that several air-cooled heat exchangers can be grouped into one bank.

Vertical, "V" frame and "A" frame or "roof" type air-cooled heat exchangers are not covered by the API Standard 661 or this DEP. The selection of one of these types of air-cooled heat exchangers requires prior agreement of the Principal.

Where, for reasons of control, an air-cooled heat exchanger has to be provided with variable speed fans ("speed frequency control", SFC) or automatic variable-pitch fans (AVP), it shall not share its fans with air-cooled heat exchangers on other duties.

For items consisting of parallel bays, where it is specified that less than 100% of the fans shall have variable speed fans or automatic variable-pitch fans, the following shall be taken into account:

- the parallel bays shall be identical
- the fan arrangement shall be symmetrical
- in the case of 2 fans per bay, the controlled fan shall be at the hottest end of the bundle
- in the case of 2 or more controlled fans per item, the control shall be equal and simultaneous for all controlled fans.

Where air-cooled heat exchangers share fans in compliance with the above requirements, their respective tube bundles shall have an equal number of tube rows, the tubes shall be of equal size with identical finning characteristics, and the pitch of the tubes shall be identical.

3.1.2 Forced draught versus induced draught

Forced draught shall be selected for all non critical applications.

Forced draught shall also be selected for critical applications (for which the air design temperature is exceeded for 40 hours a year) if the difference between the design product outlet temperature and the design air inlet temperature is 15 °C or higher.

However, in case of stringent noise limitations, e.g. sound pressure level requirements of maximum 80 dB(A), the use of an induced draught air-cooled heat exchanger may be considered.

For critical applications, if the product outlet temperature is less than 15 °C above the design air inlet temperature, induced draught shall be used providing none of the limits of API Standard 661, clauses 4.2.3.15, 4.2.3.16 and 4.2.4.6 will be exceeded; this is to avoid the use of special materials or constructions. The temperature effect of radiation shall be taken into account.

3.1.3 Header type selection

Removable cover plate headers shall be applied for design pressures up to 30 bar (ga) and where mechanical cleaning will be required, except for hydrogen service.

Plug headers shall be applied for design pressures above 30 bar (ga) and hydrogen service.

Instead of a rear end header, U-bends (elbow 180°) may be used where suitable and where mechanical cleaning is not required.

Fluids with hydrogen at a partial pressure below 6.9 bar (abs) (100 psi (abs)) may be considered as non-hydrogen service.

Fluid streams with a fouling resistance equal to or greater than 0.00034 (m^2.K/W) or whose fouling can not be removed by chemical cleaning shall have a tube bundle construction suitable for mechanical cleaning.

In cases where heavy fouling or corrosion is anticipated and which will require frequent

mechanical cleaning or repairs, a removable cover plate header should be considered regardless of the above selection criteria. However, the header construction and the gasket selection/seal construction require prior agreement of the Principal.

Manifold and billet type headers are not covered by the API Standard 661 or this DEP. The selection of one of these types of headers requires prior agreement of the Principal.

Flanged multi-purpose service connections shall be installed on the header. These may be used for flushing/washing out, steaming out, chemical cleaning, pressure testing, venting and draining. Generally, each header shall have a top and bottom connection adjacent to each end, thus four in total per header. For hydrogen and very toxic service, multi-purpose service connections shall not be used unless specifically agreed with the Principal.

3.1.4 Fin type selection

Tubes with embedded aluminium fins or hot-dip galvanised steel fins, applicable up to a maximum operating temperature of 360 °C, should be used. Hot-dip galvanised steel fins shall not be used on austenitic steel tubing.

For integral (bi-metallic or extruded) tubes with extruded fins, the mechanical bond between the outer tube and the inner tube or liner shall be completely effective up to the maximum operating temperature specified (generally limited to 230 °C, depending on the tube/fin material combination). Embedded fins shall not be used on the outer tube. Air-cooled heat exchangers in coastal areas or standing idle for long periods may be susceptible to external corrosion. Where this is anticipated, integral tubes should be considered.

Tubes with laser welded fins may be considered if tubes with the above-mentioned fin types cannot be applied. However, an economic evaluation between tubes with laser welded fins versus bare tubes shall be made.

Tubes with overlapped footed and with footed fin constructions are limited to a maximum operating temperature of 120 °C and may be used only with prior approval of the Principal.

Discontinuous (segmented) fin surfaces shall not be applied.

3.1.5 Variable speed fans versus automatic variable pitch fans

For process control or for energy conservation, variable speed fans (SFC) or automatic variable pitch fans (AVP) may be used. The selection between variable speed fan and automatic variable pitch fan shall be based on economics (including maintenance costs). The power saving by reduced airflow will be higher for the variable speed fans when assuming all fans are running instead of switching off some fans.

The noise generated by reduced airflow will decrease much faster if variable speed fans are installed instead of automatic variable pitch fans. In case of stringent noise limitations during night time and when due to a lower air inlet temperature at night time the air flow rate can be reduced, variable speed fans are favoured regardless of cost.

3.2 THERMAL DESIGN OR RATING

The thermal design and rating of an air-cooled heat exchanger shall be based on design methods which have been proven in practice. In this respect, the design procedures and computer programs published by the Heat Transfer & Fluid Flow Service (HTFS) and Heat Transfer Research Institute (HTRI) are considered proven design methods.

In the event of inadequate performance, the HTFS calculation procedure shall be used as the basis for re-assessing the thermal performance rating, using the M-ACOL, cross-flow heat exchanger simulation program. The applicable version shall be stated by the Principal.

The print-out of the computer runs shall correspond to the input data. Changes or deviations shall not be made between submitting the program and printing the results.

Special requirements assumed for the thermal design, e.g. irregular pass lay-out or calculation of noise levels (e.g. fan inlet bell type), shall be recorded appropriately and/or shown on drawings (sketches).

The physical properties of the fluid and the mechanical requirements/limitations shall be

specified on data/requisition sheet DEP 31.21.70.93-Gen., sheets 1, 2 and 3. In the event that the data provided is considered by the designer or the Manufacturer to be insufficient for design purposes, it is his responsibility to request further information from the Principal.

In case of non-critical process conditions, the air design temperature shall be the higher of the following:

- the highest air temperature which is exceeded for 400 hours per year
- 4 °C lower than the highest air temperature which is exceeded for 40 hours per year.

In case of critical process conditions, the air design temperature shall be the highest air temperature which is exceeded for 40 hours per year.

Typical fouling resistances shall be taken from DEP 20.21.00.31-Gen. To cater for increasing pressure drop on the tube side due to fouling, the pressure drop for the fouled condition shall be derived from the pressure drop calculated for the clean condition multiplied by the following factor:

Fouling resistance	0.00009 - 0.00033	(m^2.K/W), multiplication factor	1.1
	0.00034 - and above	(m^2.K/W), " "	1.2

Consideration shall be given to the need for special devices to prevent erosion of the tube ends for gases and vapours when the ρV^2 in the tubes exceeds 7000 kg/(m.s^2). For liquids the ρV^2 calculated with the maximum water velocities as specified in DEP 20.21.00.31-Gen. for the different tube materials will be the maximum. For two-phase flow, the ρV^2 in the tubes shall be checked carefully against the danger of erosion of the tube ends. In such case, the velocity and density shall be based on a homogeneous gas/liquid mixture.

In exchangers with a condensing duty, the passes for the condensing phase shall extend over the full width of the bundle. In exchangers with total condensation, the size of the outlet nozzles shall be such that flooding of the bottom row of tubes cannot occur.

The Principal shall be consulted in case of the application of turbulators, inserts and/or static mixers.

3.3 REQUIREMENTS AND SCOPE OF SUPPLY

Unless otherwise specified, the scope of supply shall be as specified on data/requisition sheets DEP 31.21.70.93-Gen.

The Vendor shall include all special features which are necessary for reliable and safe operation. These should include, where applicable, adequate means of control to cope with the specified variations in operating conditions.

With regard to safety and reliability, unspecified but self-evident conditions will occur during start-up, shutdown, power failure and interruption of the process flow. These shall duly be taken into account and may require one or more of the following features:

- heating coils combined with louvers in order to keep high-pour-point fluids at an adequate temperature level under no-flow conditions.
- variable speed fans (drives) or automatic variable-pitch fans.
- hand-controlled or motor-operated louvers for improvement of the air-side control range; if, without this additional feature, direct air-side control during turn down case, winter conditions, etc., would otherwise become unattainable due to wind, rain or free convective air-flow effects.
- ducting and louvers for controlled air recirculation to enable handling of products which would otherwise cause pour-point and hydrate formation problems.

Excluded from the scope of supply are foundations, erection of supporting structure and fireproofing of structural steel.

PART IV AMENDMENTS/SUPPLEMENTS to API STANDARD 661

SECTION 1 GENERAL

1.3 Referenced publications

Delete from this list:

RP 631M, *Measurement of Noise from Air-Cooled Heat Exchangers (Metric Only)*

Delete from this list:

SSPC, *Steel Structures Painting Manual*

SECTION 2 PROPOSALS

2.1 purchaser's responsibilities

2.1.1 Delete first sentence and replace by:

The purchaser's inquiry shall contain pertinent standard forms, requisition and data/requisition sheets as specified in Appendix 1 of this DEP.

2.1.2 This clause to read:

The inquiry shall specify the number of copies of outline drawings, construction drawings, data/requisition sheets, data reports and final records to be supplied by the Vendor all in accordance with the requirements of requisition sheet DEP 40.10.01.93-Gen.

2.2 Vendor's Responsibilities

2.2.1 This clause to read:

Vendor's proposal shall include submission of a set of the completed requisition and data/requisition sheets as required by Appendices 1 and 2 of this DEP.

SECTION 3 DOCUMENTATION

3.1 Approval Information

3.1.1 Add to this clause:

o. Nameplate and its position.
p. Tube-to-tube-sheet joint and details of joint preparation.

SECTION 4 DESIGN

4.1 Tube Bundle Design

4.1.1 GENERAL

4.1.1.1 Add to this clause:

The width of the tube bundle shall be chosen with due regard to transport and handling aspects, and should not exceed 3 metres.

4.1.1.4 Add to this clause:

Tubes shall be adequately supported by tube support boxes, support rings or collar zinc supports. Collar zinc supports shall not be used in combination with austenitic stainless steel or high nickel alloy tubes; in these cases aluminium supports shall be used.

4.1.1.13 Add new clause:

Tube-to-tube-sheet joints shall be strong enough to contain the stresses caused by differential thermal expansion in the case of fouled or blocked tubes.

4.1.5 CORROSION ALLOWANCE

4.1.5.5 Add new clause:

If corrosion-resistant lining or cladding is required it shall apply for all exposed (wetted) surfaces, including the surface of the partition plates and the side and bottom of gasket grooves, but excluding tubes.

All nozzles including multi-purpose service connections applied on lined or clad equipment shall be in accordance with Standard Drawing S 10.103.

4.1.6 HEADERS

4.1.6.1.4 Add to this clause:

Air coolers handling a two-phase mixture at the inlet side shall be designed for optimal flow distribution over the tubes and passes; there should be only one tube row per pass. At least one inlet nozzle shall be installed per metre of bundle width.

Reducing the header depth can be achieved by installing more inlet and outlet nozzles in parallel. Flattened-off nozzles or oval nozzles shall not be used.

4.1.6.1.6 Add to this clause:

However, in case of a rolled tube-to-tube-sheet joint, where at least two grooves are required, the minimum tube-sheet thickness shall be 25 mm for carbon steel or low alloy steel and 22 mm for high alloy steel or other materials.

4.1.6.1.7 Add to this clause:

Drain holes shall not be provided in pass partition plates except in case of a very toxic fluid or a fluid harmful to the environment, in which cases a drain hole shall be provided in the pass partition plate.

4.1.6.2.2 This clause to read:

The removable bonnet-type header shall not be used.

4.1.6.2.3 This clause to read:

Bolted joints (stud construction or flanged construction) shall be designed with confined gaskets in accordance with Figure 4 (B). The tongue and groove joint construction and the unconfined joint construction (full-faced gasket) should not be used.

4.1.6.2.7 Add to this clause:

For stud bolting, the hole size in the cover plate shall be not less than the nominal bolt diameter plus 3 mm. Provision (e.g. sliding pins) should be made to prevent damage to studs during handling of the cover plate.

4.1.7 TUBE ACCESS PLUGS

4.1.7.8 This clause to read

Threads of plugs with nominal diameter of 40 mm (1 1/2 inch) or less shall be 12 UNF.

4.1.7.10 Add new clause:

Two part plugs should be considered for design pressures above 200 bar (ga). The plug construction should be as shown in Appendix 3 of this DEP, or a proven Manufacturer's design for which the prior approval of the Principal is required. Material of the gasket compressor part of the two part plug shall be equivalent to the material of the header box.

NOTE: For ease of removal, the gasket compressor should be provided with a blind 12 mm threaded hole at least 15 mm deep.

For hydrogen service, the gasket compressor and plug shall be provided with a vent hole of at least 3 mm diameter.

4.1.8 GASKETS

4.1.8.4 This clause to read:

The tongue and groove joint construction type A and the unconfined joint construction type C of Figure 4 should not be used.

The type of gasket used for confined joint type B of Figure 4, cover plate header flanges, shall be selected from those listed in table 1 below.

TABLE 1 TYPE OF GASKETS

Type	Description	Minimum Width (mm)	Minimum Thickness (mm)
1	CAF, oil or acid resistant	9.53	1.6 1)
2	Flat metal-jacketed soft iron, asbestos-filled	12.7	3.2 1)
3	Flat metal-jacketed AISI 304/316, asbestos-filled	12.7	3.2 1)
4	Metal reinforced expanded graphite	9.53	1.6

NOTE: 1. Gaskets contain asbestos. These types of gaskets may be restricted or prohibited by local regulations.

The arithmetic average roughness, Ra, which determines the flange face surface finish required for each type of gasket is listed in table 2 below.

TABLE 2 GASKET CONTACT SURFACE FINISH

Gasket type	Ra value µm
1 and 4	3.2 - 6.3
2 and 3	0.8 - 1.6

The selection of gaskets depends on the design temperature and pressure, and the corrosive conditions of the service to which the flange and gasket are exposed.

The service condition to which air-cooled heat exchangers are exposed are described in table 3 below.

TABLE 3 SERVICE CONDITIONS

Condition	Description
I	Non-corrosive and mildly corrosive.
II	Hydrocarbon streams containing sulphur compounds and naphthenic acids with an acid value exceeding 0.3 mg KOH/g, and for maximum operating temperatures above 230 °C.
III	Hydrocarbon streams containing sulphur compounds and naphthenic acids with an acid value to 0.3 mg KOH/g incl. and for maximum operating temperatures above 330 °C.
IV	Hydrocarbons containing hydrogen.
V	Non-corrosive cooling water below 50 °C.

VI	Mildly-corrosive cooling water below 50 °C.
VII	Corrosive cooling water below 50 °C.
VIII	Any other corrosive environment.
IX	Frequent changes in temperature and pressure, (e.g. hot washing, dewaxing, chilling) and frequent cleaning (i.e. more than twice a year under all conditions I to VIII).

The type of gasket used, considering design pressure, design temperature and service condition, shall be selected in accordance with design criteria as listed in table 4.

TABLE 4 SELECTION OF TYPE OF GASKET

Service condition	Design Temperature [°C]	Design Pressure [bar (ga)]	Preferred Type	Alternative Type
I	0 - 240 0 - 240 240 - 450 -200 - 0	20.5 max. 20.5 - 31.0 31.0 max. 31.0 max.	1 4 4 4	4 2 2 3
II	230 - 240 230 - 240 240 - 450	20.5 max. 20.5 - 31.0 31.0 max.	1 4 4	4 2 3
III	330 - 450	31.0 max.	4	3
IV	0 - 450	31.0 max.	4	-
V VI VII	0 - 50		1 3.2 mm (1/8 ") thick	4
VIII	-	-	Note 1	-
IX	0 - 450	31.0 max.	4	-

NOTE: 1. See the data/requisition sheet or as agreed between Purchaser and Manufacturer.

4.1.8.5 This clause to read:

The selection of type and size of the gasket shall be in accordance with (4.1.8.4).

4.1.8.6 This clause to read:

The minimum width of removable-cover-plate gasket shall be in accordance with (4.1.8.4, table 1).

4.1.9 NOZZLES AND OTHER CONNECTIONS

4.1.9.1 Add to this clause:

The minimum nozzle size shall be DN 40 (1½ in.).

4.1.9.6 Add to this clause:

The selection of gaskets shall be in accordance with the appropriate MF Piping Classes or EP Piping Classes (see DEP 31.38.01.12-Gen. or DEP 31.38.01.15-Gen., respectively) applied for the connecting lines.

4.1.9.8 This clause to read:

The selection of type of flanged carbon steel nozzles and connections shall be in accordance with DEP 31.22.20.31-Gen. The construction of flanged carbon steel nozzles and connections shall be in accordance with Standard Drawing S 10.101.

4.1.9.11 This clause to read:

Threaded connections shall not be used.

4.1.9.12 This clause to read:

Threaded connections shall not be used.

4.1.9.13 This clause to read:

When a thermowell connection is specified, the connection shall be located on the connecting line or on the header adjacent to the nozzle.

4.1.9.14 This clause to read:

When a pressure gauge connection is specified, the connection shall be located on the connecting line or on the header adjacent to the nozzle.

4.1.9.15 This clause to read:

Threaded connections shall not be used.

4.1.9.17 This clause to read:

When instrument connections are specified, at least one connection on inlet and one on outlet side of each bundle will be required. For the location of the instrument connection see clauses 4.1.9.13 and 4.1.9.14.

4.1.9.18 This clause to read:

Threaded connections shall not be used.

4.1.9.21 This clause to read:

Threaded connections shall not be used.

4.1.11 TUBES

4.1.11.1 Add to this clause:

Tubes shall be cylindrical. Elliptical tubes shall not be used.

4.1.11.7 Add to this clause:

The maximum number of fins per tube length shall be 394 per metre (10 fins/inch). In order to prevent fouling, segmented tubes shall not be used.

4.1.11.10 Replace the equation by the following equation, and add to this clause:

$$tb = t / [1 + (OD / (4 \times Rm))]$$

Bends with radius Rm < 1.5 times nominal tube OD shall not be applied.

4.1.11.12 This clause to read:

Carbon steel and low-alloy steel U-tube bends having a mean radius smaller than 5 times the nominal tube OD shall be stress-relieved by heat treatment.

U-tubes shall be totally heat-treated when the application of local heat treatment to the bent portion only would possibly induce embrittlement or susceptibility to stress corrosion in the transition zones between the straight legs of the U-tube and the U-bend.

If cold working induces susceptibility to stress corrosion in some materials or environments then heat treatment should be considered

4.1.11.13 Add new clause:

The tolerance of the centre-to-centre distance between the parallel legs of the U-tubes should be within the following:

- ± 1.0 mm; if the distance is less than or equal to five times the nominal tube OD
- ± 1.5 mm; if the distance is more than five times the nominal tube OD.

4.2 Air-Side Design

4.2.1 GENERAL

4.2.1.1 Add to this clause:

The height of the underside of the fan inlet bell (for forced draft units) or of the underside of the bundle (for induced draft units) shall be at least 2 m or one fan diameter (whichever is the greater) above the ground level, elevated floor or pipe bridge.

4.2.1.5 Add new clause:

Fans, actuators, transmissions and drives shall be designed for at least 3 years continuous operation (for electric motors, see DEP 33.66.05.31-Gen.).

4.2.2 NOISE CONTROL

4.2.2.1 Replace last sentence by:

The Contractor shall comply with DEP 31.10.00.31-Gen. and thereby communicate to the Vendor the specified equipment noise limitations, in terms of sound pressure level and sound power level, by using data/requisition sheet DEP 31.10.00.94-Gen., which forms part of the requisition. The Vendor shall be responsible for assuring that these equipment noise limitations have been specified.

Vendor shall submit guaranteed sound power levels and sound pressure levels of the equipment, together with any other relevant information, e.g. inlet shape (type and dimensions) and other obstacles which are taken into account for assessing the noise levels.

4.2.2.3 This clause to read:

The procedure for determining noise levels shall be in accordance with EEMUA publication No. 140.

4.2.2.4 Add new clause:

The sound pressure level shall be measured at the centreline of the fan shaft and 1m below the underside of the fan inlet bell for forced draft fans, or 1m below the underside of the bundle for induced draft fans.

4.2.3 FANS AND FAN HUBS

4.2.3.7 Add to this clause:

One of the blades of each fan should be selected as the master blade of this fan and shall be marked as such. As an alternative, if there is an even number of blades, pairwise moment-balancing may be used.

4.2.3.11.3 Add to this clause:

The stroking time, from minimum to maximum pitch or reverse, shall be 10 seconds maximum with the fan rotating. Hysteresis should not exceed 1% of full stroke.

Exposed rotating parts of actuators shall be protected by a wire mesh screen.

4.2.4 FAN SHAFTS AND BEARINGS

4.2.4.3 Add to this clause:

The bearings shall be selected as specified by the Principal.

4.2.5 LUBRICATION FACILITIES

4.2.5 Add to this clause:

To prevent overgreasing, a grease release shall be provided for all bearings.

4.2.6 FAN GUARDS

4.2.6.1 Add to this clause:

The materials selected for fans and fan guards shall be a non-sparking combination.

4.2.7 DRIVERS

4.2.7.2.1 to 4.2.7.2.8 These clauses to read:

Electric motors shall be of the cage-induction type and shall be in accordance with DEP 33.66.05 31-Gen. and as specified on requisition sheets DEP 33.66.05.93-Gen.

Attention shall be paid to the high moment of inertia of fans when calculating unit running-up time.

If, due to reversed rotation of the electric motor as a result of free convective air flow through the fan, the starting conditions as specified in DEP 33.66.05.31-Gen. cannot be

met, self-actuating provisions shall be included which prevent such reversed rotation of fan and motor.

4.2.7.2.9 Add new clause:

Direct motor drives shall have a minimum speed of 290 r/min and the maximum motor power shall not exceed 22 kW.

Direct motor drives may be used for fans up to and including 3.66 metres (12 feet) in diameter. However, the specified noise levels shall not be exceeded due to high tip speeds, e.g. 55.6 m/s for a motor with 290 r/min and a fan diameter of 3.66 m.

4.2.7.2.10 Add new clause:

The variable speed drive system shall be in accordance with DEP 33.66.05.33-Gen.

4.2.8 COUPLING AND POWER TRANSMISSIONS

4.2.8.2.6 This clause to read:

A multi-V-belt drive shall consist of an integral multi-V belt instead of a set of single V-belts. The number of V's in an integral multi-V belt shall not exceed 4.

4.2.8.4.2 Add to this clause:

The materials selected for mechanical transmission components and transmission guards shall be a non-sparking combination.

4.2.10 LOUVERS

4.2.10.10 Add to this clause:

If bushing-type bearings are used, they shall be attached securely in order to prevent rotation.

4.2.10.25 Add new clause:

Tube bundles of forced draft units without louvers shall be provided with a bolted-on 50 mm square by 4 mm galvanised or alloy wire mesh guard fitted above the tubes in order to protect the fins from mechanical damage during operation and maintenance.

4.3 Structural Design

4.3.1 GENERAL

4.3.1.1 This clause to read:

The supporting structure and framework shall be designed and fabricated in accordance with DEP 34.00.01.30-Gen., and with DEP 34.28.00.31-Gen. (if made of steel) or DEP 34.19.20.31-Gen. (if made of concrete).

4.3.1.2 Add to this clause:

High-strength friction grip bolts in accordance with BS 4395 - Parts 1 & 2 and BS 4604 - Parts 1 & 2 shall be used for all site connections.

4.3.2 VIBRATION TESTING

4.3.2.1 Add to this clause:

In order to contain vibration, the structural design calculations shall assume 120% of the total mass of the main equipment. This total mass is the mass of the exchanger, the mass of the rotating equipment plus the mass of its contents, but does not include the mass of the supporting structure.

4.3.2.4 Add new clause:

The effective velocity of vibration, measured on the bearings perpendicular to the shaft centre line, shall not exceed 6.3 mm/s up to 600 r/min and 3 mm/s above 600 r/min.

4.3.5 MECHANICAL ACCESS FACILITIES

4.3.5.1 Add to this clause:

Ladders or stairs shall be provided at both ends of the bank.

4.3.5.3 Add to this clause:

If the air outlet temperature at design conditions exceeds 90 °C, heat protection shielding shall be installed along the platforms of forced-draught heat exchangers.

SECTION 5 MATERIALS

5.1 General

5.1.9 Add to this clause:

The average coating thickness for structures in a tropical climate shall be 500 g/m^2, but nowhere less than 450 g/m^2. For all other climates the average coating thickness shall be 350 g/m^2, but nowhere less than 300 g/m^2.

5.1.11 Add new clause:

Galvanised materials or zinc-containing paints, etc., shall not be used on or near austenitic stainless steel and/or high nickel alloy equipment.

5.2 Headers

5.2.5 Add new clause:

If non-ferrous or alloy steel header materials are specified by the Principal, the Vendor should offer either solid or clad material after approval by the Principal.

Clad tube-sheets shall meet the following extra requirements:

- the cladding shall be integrally and continuously bonded to the base material.
- all surfaces exposed to the corrosive medium, excluding gasket seating surfaces, shall have at least a 10 mm thickness of cladding when tubes are expanded only (to allow a groove within the cladding thickness) or at least a 5 mm thickness for a strength welded connection.
- bonding the cladding to the tube-sheet with solder is not permitted.
- integrally clad tube-sheets and tube-sheets with linings applied by overlay welding shall be ultrasonically tested to check the integrity of the bonding in accordance with ASTM A578, with an acceptance level of S7.

5.4 Other Components

5.4.1 This clause to read:

Fin material shall be aluminium in accordance with ASTM B209 Alloy 1060 unless otherwise specified or approved by the Principal.

SECTION 6 FABRICATION

6.1 Welding

6.1.1.3 Add to this clause:

Typical weld details are shown in Appendix 4 of this DEP.

6.1.3.1 This clause to read:

Removable cover plate flanges on units with design temperatures of 260 °C (500 °F) or less shall be installed with full-penetration welding.

6.3 Tube-to-Tube-Sheet Joints

6.3.2.1 This clause to read:

Tube hole grooving shall be in accordance with TEMA Standards as amended and supplemented by DEP 31.21.01.30-Gen.

6.3.3.3 This clause to read:

The ends of tubes shall extend by at least 1.5 mm, but by not more than 5 mm, beyond the tube-sheet.

6.3.4.2 This clause to read:

Seal-welded joints shall not be used.

Add new subsection 6.8:

6.8 Tubes with embedded fins

6.8.1 Unless otherwise agreed between Principal and Vendor, grooving of the tubes shall be carried out by means of a rotating knife (disc) with a fixed groove depth setting, i.e. the groove depth shall be determined by the profile of the cutting knife, not by adjusting the knife position.

6.8.2 To produce a sound bond between the fin material and the tube wall, the metal that has been displaced during the grooving cycle shall be forced back simultaneously on both sides of the fin against its inserted base. The bond between tube and fin shall not be achieved by forcing back the displaced metal from only one side.

SECTION 7 INSPECTION, EXAMINATION AND TESTING

7.2 Quality Control

7.2.10 Add to this clause:

Typical weld details are given in Appendix 4.

7.2.20 Add new clause:

Inspection and test requirements for tubes with embedded fins shall be as follows:

- The tube ends shall be free from burrs, weld build-up and any other discontinuities, both inside and outside, which may adversely affect the tube installation and/or rolling.
- The fin should not be interrupted at more than 2 locations per tube, provided adjacent fin ends are connected to each other by means of stapling.
- The actual depth of the groove and the minimum wall thickness under the groove shall be regularly checked during the production of the finned tubes. To realise this checking, special tools should be available or alternatively part of the grooved tube can be machined down to the root of the groove.
- For tubes with a diameter of 25 mm and larger, the bond shall meet the following minimum requirement. A force of at least 30 N shall be required to pull a fin section out of its groove over a chord length of 12 ± 0.2 mm. To form the test section the fin shall be fully cut. If more than 80 percent of the bond tests meet this requirement the tube bond may be considered acceptable provided the minimum force required for the other 20 percent is 25 N. At least 2 mechanical bond tests shall be carried out on each selected tube and the test locations shall be at least 25 mm from the mechanically bonded fin ends and a minimum of 1 m apart.

7.5 Nameplates

7.5.3 Add to this clause:

The name plate shall be in accordance with Standard Drawing S 10.114.

SECTION 8 PREPARATION FOR SHIPMENT

8.2 Surfaces and Finishes

8.2.1 This clause to read:

Surfaces to be painted shall be degreased and cleaned in accordance with DEP 30.48.00.31-Gen.

8.2.3 This clause to read:

Unless otherwise specified, carbon steel headers shall be prepared to a near-white sand blast finish and than be coated in accordance with DEP 30.48.00.31-Gen.

8.3.4 Add to this clause:

The construction of the transport frame and location of the lifting lugs should be in accordance with Standard Drawings S 21.074 and S 21.075.

SECTION 9 SUPPLEMENTAL REQUIREMENTS

9.2 Design

9.2.3 This clause to read:

Seal-welded tube-to-tube-sheet joints shall not be used.

9.2.4 This clause to read:

Recessed type tube-to-tube-sheet welds in combination with expanded joints shall not be used.

APPENDIX DATA SHEETS

Delete first sentence and replace by:

In conjunction with this standard, the standard forms, requisition and data/requisition sheets as mentioned in Appendix 1 of this DEP are intended to provide all the data necessary for the description and the design of air-cooled heat exchangers for general refinery services.

AIR-COOLED HEAT EXCHANGER CHECKLIST

Delete second sentence of first clause and replace by:

Data/requisition sheet DEP 30.10.00.94-Gen., suitable for notes, shall be used for additional specific requirements mentioned on the air-cooled heat exchanger checklist and not allready covered by this DEP or the data/requisition sheets mentioned on Appendix 1.

AIR-COOLED HEAT EXCHANGER NOISE DATA SHEET

Air-cooled heat exchanger noise data sheet to be replaced by DEP 31.10.00.94-Gen.

AIR-COOLED HEAT EXCHANGER SPECIFICATION SHEET

Air-cooled heat exchanger specification sheets to be replaced by applicable data/requisition sheets as mentioned in Appendix 1.

PART V REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEPs and standard specifications	DEP 00.00.05.05-Gen.
Index to standard drawings	DEP 00.00.06.06-Gen.
The use of SI units	DEP 00.00.20.10-Gen.
Fouling resistances for heat transfer equipment	DEP 20.21.00.31-Gen.
Painting and coating for new construction projects	DEP 30.48.00.31-Gen.
Noise control	DEP 31.10.00.31-Gen.
Symbols and identification system - Mechanical	DEP 31.10.03.10-Gen.
Shell and tube heat exchangers (Amendments/Supplements to TEMA Standards)	DEP 31.21.01.30-Gen.
Pressure vessels (Amendments/Supplements to ASME Section VIII, Division 1 and 2)	DEP 31.22.20.31-Gen.
MF Piping classes	DEP 31.38.01.12-Gen.
EP Piping classes	DEP 31.38.01.15-Gen.
Electric motors - Cage induction and synchronous type	DEP 33.66.05.31-Gen.
Electrical variable speed drive system	DEP 33.66.05.33-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Reinforced concrete foundations and structures	DEP 34.19.20.31-Gen.
Steel structures	DEP 34.28.00.31-Gen.

STANDARD DRAWINGS

NOTE: The latest revisions of Standard Drawings are identified in DEP 00.00.06.06-Gen.

Flanged nozzles to apparatus	S 10.101
Details of bush-lined and overlay clad nozzles	S 10.103
Nameplate with bracket for vessel and heat exchange equipment	S 10.114
Transport frame for air-cooled heat exchanger (forced draught)	S 21.074
Transport frame for air-cooled heat exchanger (induced draught)	S 21.075

AMERICAN STANDARDS

Air-Cooled heat exchangers for general refinery service	API Standard 661

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington, DC 20005
USA.

ASME Boiler and Pressure Vessel Code Pressure vessels	Section VIII Division 1 and 2

Issued by:
American Society of Mechanical Engineers
345 East 47th Street, New York NY10017,
USA.

Straight-beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications	ASTM A578
Aluminium and Aluminium-Alloy Sheet and Plate	ASTM B209

Issued by:
American Society for Testing and Materials
1916 Race St., Philadelphia Pa19103,
USA.

Standards of the Tubular Exchanger Manufacturers Association	TEMA Standards Seventh Edition, 1988, and 1990 Errata

Issued by:
Tubular Exchanger Manufacturers Association Inc.
331 Madison Avenue, New York NY10017,
USA.

Air-cooled heat exchangers (computer program)	ACE

Issued by:
Heat Transfer Research Incorporated
1500 Research Parkway, Suite 100
College Station,Texas 77840,
USA

BRITISH STANDARDS

High strength friction grip bolts and associated nuts and washers for structural engineering	BS 4395 Parts 1 & 2
The use of high strength friction grip bolts in structural steelwork. Metric series	BS 4604 Parts 1 & 2

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS
United Kingdom.

Noise Procedure Specification	EEMUA Publication no. 140

Issued by:
EEMUA

14 Belgrave Square, London SW1X 8PS,
United Kingdom.

Performance of air-cooled heat exchangers (computer program) M-ACOL

Issued by:
Heat Transfer and Fluid Flow Service
Harwell Laboratory, Building 392.7,Harwell
Oxfordshire, OX11 0RA
United kingdom.

PART VI APPENDICES

Appendix

1. Standard forms, requisition and data/requisition sheets
2. Completion of data/requisition sheets
3. Detail of two-part plug with gasket compressor
4. Typical welding details

APPENDIX 1 STANDARD FORMS, REQUISITION AND DATA/REQUISITION SHEETS

The following standard forms from DEP 00.00.10.05-Gen., and requisition and data/requisition sheets from DEP 30.10.01.10-Gen., shall be used for the specification of air-cooled heat exchangers in conjunction with this DEP.

Specification of design and engineering documents	DEP 05.00.50.82-Gen.
Approval drawing specification	DEP 05.00.54.81-Gen.
Final drawing specification	DEP 05.00.54.82-Gen.

To be submitted during Detailed Engineering phase (purchasing phase):

DEP 01.00.03.84-Gen.	Heat exchanger summary
DEP 40.00.10.93-Gen. sh. 1/2	EDP supplement
DEP 30.10.00.94-Gen. sh.1	Data/requisition sheet general
DEP 31.21.70.93-Gen. sh. 4	Equipment details (one sheet for each item)
DEP 33.66.05.93-Gen. sh. 2	Electric motors (one sheet per motor type)

To be submitted during Project Specification phase (design phase):

DEP 31.21.70.93-Gen. sh. 1	Bank data (one sheet for complete bank)
DEP 31.21.70.93-Gen. sh. 2	Equipment process data (one sheet for each item)
DEP 31.21.70.93-Gen. sh. 3	Equipment mechanical data (one sheet for each item)
DEP 30.10.00.94-Gen. sh. 2	Suitable for outline drawing.
DEP 33.66.05.93-Gen. sh. 1	Electric motors (one sheet per motor type)
DEP 31.10.00.94-Gen.	Equipment noise limitation (one sheet for 10 items)
DEP 40.10.01.93-Gen.	Requisition for engineering documents

The following sheet may also be used when required:

DEP 30.10.00.94-Gen. sh. 3	Suitable for notes

NOTES: All air cooler items of an air cooler bank shall be combined into one specification, i.e. one set of sheets as Indicated above shall be submitted by the Principal. This is irrespective of the fact that one or more air-cooled heat exchanger items may belong to different processing units. Thus all equipment for one bank shall be ordered under one requisition number. The Vendor shall add to each copy of his tender a completed set of sheets as indicated above.

Even when ordering one item of equipment only, the complete set of data/requisition sheets shall be used.

APPENDIX 2 COMPLETION OF DATA/REQUISITION SHEETS

The preparation of the data/requisition sheets is a shared responsibility of the Principal and the Manufacturer.

When the data/requisition shows alternatives, those items which are not applicable shall be deleted.

Additions/insertions/changes to the sheets shall be made only under the heading 'Remarks'.

The following explains some details of the data/requisition sheets DEP 31.21.70-93-Gen.

'Bank data' sheet

Basis for optimising	:	these figures, together with the maximum allowable plot dimensions, determine the optimum solution
Max. available plot length and width	:	based on this information the Vendor will select the maximum possible tube length from which, in conjunction with the 'basis for optimising', the length of the air cooler bank will be determined. Thus the tube length is not normally specified.

'Equipment process data' sheet

This sheet is suitable for single phase cooling and for condensing.

In the case of single-phase cooling, the physical properties shall be given at inlet and outlet temperatures.

In the case of condensation, the physical properties shall be given at inlet temperature, dew point, bubble point and outlet temperature and, preferably, at three temperatures between dew point and bubble point. If none of the three intermediate conditions are specified, straight-line behaviour between dew point and bubble point shall be assumed.

If an air-cooled heat exchanger should have to satisfy more than one process condition, separate 'Equipment process data' sheets shall be used for each condition. The relevant process condition number shall be given on each sheet.

'Equipment mechanical data' sheet

Design code	:	only one code shall be specified
Inspection authority	:	only one inspection authority shall be indicated. This can be either a government agency, the Principal or an inspection authority carrying out the inspection on behalf of the local government
Approval authority	:	in general this will be the Contractor

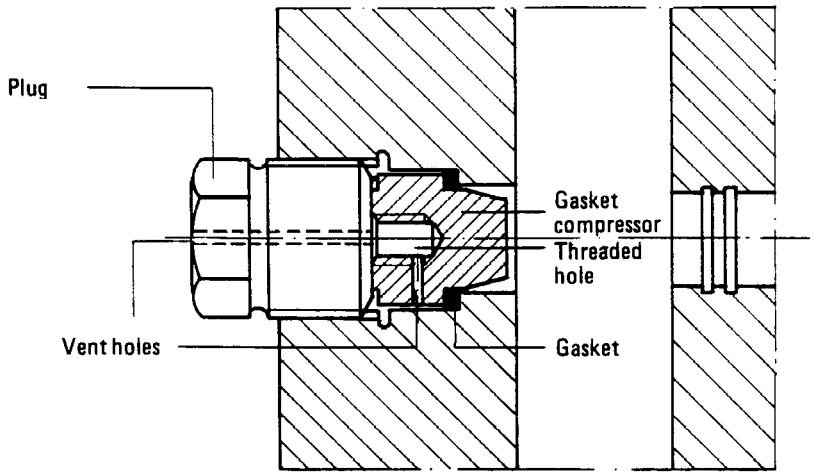
'Equipment details' sheet

This sheet to be completed by the Manufacturer.

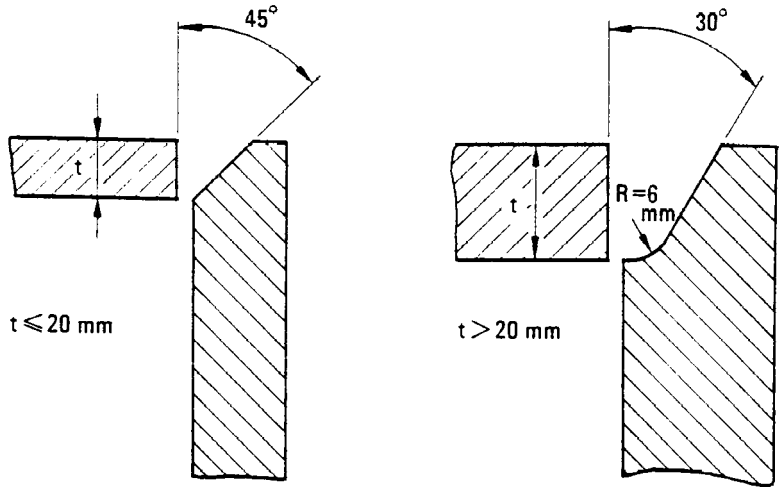
Outline drawing and notes sheets

Any additional information about supporting structure, arrangement of platforms, stairs and ladders or other special requirements, together with such detailed information as actual nozzle loading, shall be specified on these sheets.

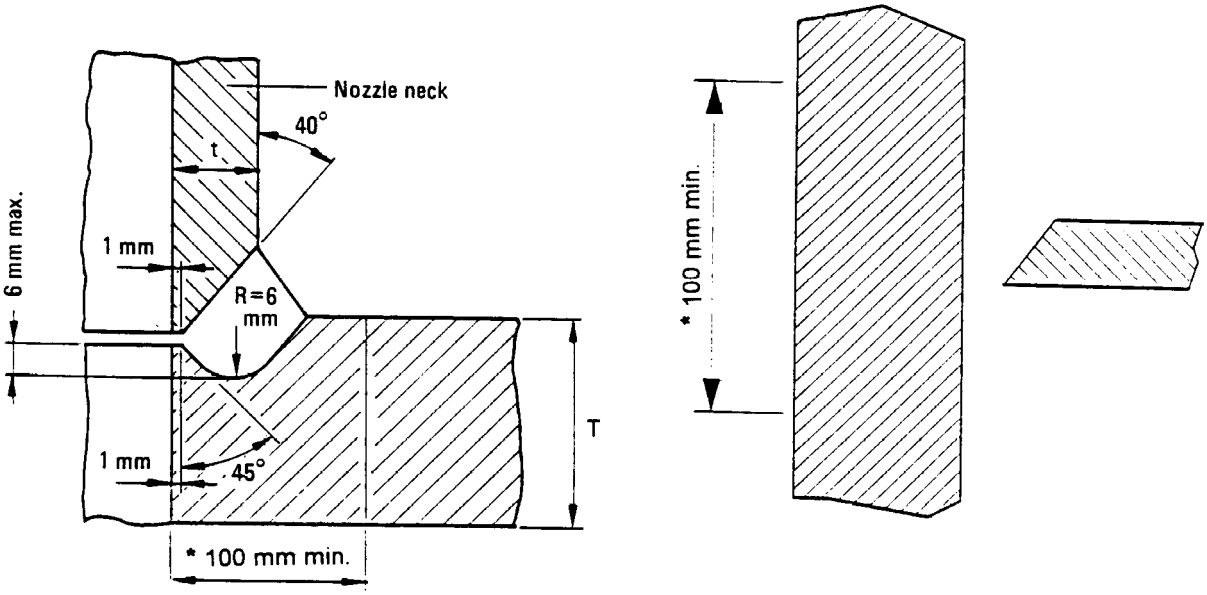
APPENDIX 3 DETAIL OF TWO-PART PLUG WITH GASKET COMPRESSOR



APPENDIX 4 TYPICAL WELDING DETAILS



CORNER WELDS



SET-ON NOZZLE

PARTITION PLATE

* The plate to which the set-on nozzle or partition plate is welded shall be in accordance with DEP 31.22.20.31-Gen., and shall meet the following requirements:

- the material shall meet ASTM A770-S3 (with a minimum reduction of area of 35%).
- 100% ultrasonic examination shall be performed on the indicated area and shall meet BS 5996 L4.