أدنـوك
ADNOC

ADNOC GROUP PROJECTS AND ENGINEERING

SHELL AND TUBE HEAT EXCHANGER SPECIFICATION

Specification

AGES-SP-06-003

ص ب 898، أبوظبي، الإمارات العربية المتحدة
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adnoc.ae

شركة بترول أبوظبي الوطنية
Abu Dhabi National Oil Company

GROUP PROJECTS & ENGINEERING / PT&CS DIRECTORATE

CUSTODIAN	Group Projects & Engineering / PT&CS
ADNOC	Specification applicable to ADNOC & ADNOC Group Companies

Group Projects & Engineering is the owner of this Specification and responsible for its custody, maintenance and periodic update.

In addition, Group Projects & Engineering is responsible for communication and distribution of any changes to this Specification and its version control.

This specification will be reviewed and updated in case of any changes affecting the activities described in this document.

INTER-RELATIONSHIPS AND STAKEHOLDERS

a) The following are inter-relationships for implementation of this Specification:

   i. ADNOC Upstream and ADNOC Downstream Directorates and

   ii. ADNOC Onshore, ADNOC Offshore, ADNOC Sour Gas, ADNOG Gas Processing. ADNOC LNG, ADNOC Refining, ADNOC Fertilisers, Borouge, Al Dhafra Petroleum, Al Yasat

b) The following are stakeholders for the purpose of this Specification:

   ADNOC PT&CS Directorate.

c) This Specification has been approved by the ADNOC PT&CS is to be implemented by each ADNOC Group company included above subject to and in accordance with their Delegation of Authority and other governance-related processes in order to ensure compliance

d) Each ADNOC Group company must establish/nominate a Technical Authority responsible for compliance with this Specification.

DEFINED TERMS / ABBREVIATIONS / REFERENCES

'ADNOC' means Abu Dhabi National Oil COMPANY.

'ADNOC Group' means ADNOC together with each COMPANY in which ADNOC, directly or indirectly, controls fifty percent (50%) or more of the share capital.

'Approving Authority' means the decision-making body or employee with the required authority to approve Policies and Procedures or any changes to it.

'Business Line Directorates' or **'BLD'** means a directorate of ADNOC which is responsible for one or more Group Companies reporting to, or operating within the same line of business as, such directorate.

'Business Support Directorates and Functions' or **'Non- BLD'** means all the ADNOC functions and the remaining directorates, which are not ADNOC Business Line Directorates.

'CEO' means chief executive officer.

'Group COMPANY' means any COMPANY within the ADNOC Group other than ADNOC.

'Standard' means normative references listed in this specification.

'COMPANY' means 'Abu Dhabi National Oil COMPANY or any of its group companies. It may also include an agent or consultant authorized to act for, and on behalf of the COMPANY'.

'CONTRACTOR' means the party which carries out the project management, design, engineering, procurement, construction, commissioning for ADNOC projects.

'SHALL' Indicates mandatory requirements "**Group COMPANY**" means any COMPANY within the ADNOC Group other than ADNOC.

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GENERAL

PART I

1. INTRODUCTION

The purpose of this specification is to provide design, fabrication, testing and preparation for shipment of Shell and tube heat exchangers. Unless specified otherwise, all Shell & Tube Heat Exchangers shall be designed in accordance with API 660, TEMA, ASME Section VIII Div.1 and 2, this specification and other project specifications referenced in the requisition. Pressure Vessels specification requirements shall be considered to be an integral part of this specification

Part-II of this Specification specifies amendments and supplements to the Standards of the TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION, Tenth Edition 2019 known as TEMA Standards. The latest edition in force at the time of contract award shall apply. Modifications to TEMA are identified as Add, Modify to Read, or Delete. Clause numbers in this Specification correspond to TEMA. Clauses in TEMA which are not mentioned in this specification shall remain valid as written.

1.1. PURPOSE

1.1.1. This Specification along with any attached drawings and/or data sheets, specified codes and standards defines minimum requirements for the thermal and hydraulic design, mechanical design, supply of materials, fabrication / construction, shop / site testing and inspection, code stamping, certification marking, quality assurance and quality control, documentation, preservation, painting, packing, preparation for shipping and supply of Shell and Tube Heat Exchangers for various projects of the COMPANY.

1.1.2. Shell and tube heat exchangers of special or proprietary design may conform to the manufacturer's standard design and construction practices but must meet the Design Code and performance requirements of this specification as a minimum subject to mutual agreement between SUPPLIER, COMPANY and CONTRACTOR.

1.1.3. The CONTRACTOR / SUPPLIER shall be responsible for ensuring that this Specification will be met in all subcontracted supplies and services. Copies of this Specification may be passed on to subcontractors for this purpose.

1.2. DEFINITIONS

COMPANY: ADNOC and its associated subsidiary companies or authorized representative

CONTRACTOR: The party(s) which carries out all or part of the design, engineering, procurement, construction, commissioning or management of the Project.

MANUFACTURER/SUPPLIER/VENDOR: The party(s) which manufactures and/or supplies equipment, technical documents/drawings and services to perform the duties specified by COMPANY AND CONTRACTOR.

SUBCONTRACTOR/SUBVENDOR/SUBSUPPLIER: The party(s) which carries out all or part of the design, procurement, installation and testing of the System(s) as specified by the CONTRACTOR/SUPPLIER.

CONSULTANT – is the party that performs specific services, which may include but are not limited to, Engineering, Technical support, preparation of Technical reports and other advisory related services specified by the party that engages them, i.e. COMPANY, CONTRACTOR or its Subcontractors.

DESIGN CERTIFYING AGENCY/ AUTHORISED INSPECTION AGENCY: Agency or agencies appointed or nominated to certify the design thereof by reference to Design Code, Standards, Specifications and procedural documents.

THIRD PARTY AGENCY: Any person or firm represents COMPANY AND CONTRACTOR to inspect the equipment/documents comply to purchase order requirements at Suppliers and sub-Suppliers shop.

SHALL and SHOULD: The word ‘Shall’ is to be understood as a mandatory and the word ‘Should’ as strongly recommended to comply with the requirements of this document.

WILL: The word “Will” is used normally in connection with an action by COMPANY and/or nominated representative, rather than by a CONTRACTOR or SUPPLIER

MAY or CAN: The word ‘May or Can’ is used where alternatives/action are equally acceptable.

CONCESSION REQUEST: A deviation requested by the CONTRACTOR or SUPPLIER, usually after receiving the contract package or purchase order. Often, it refers to an authorization to use, repair, recondition, reclaim, or release materials, components or equipment already in progress or completely manufactured by which does not meet or comply with COMPANY requirements. A CONCESSION REQUEST is subject to COMPANY approval.

AREA DESIGN MARGIN - Area design margin is the additional area included in the exchanger to account for fouling potential, uncertainties in process conditions, and correlations.

CLEAN OVERALL HEAT TRANSFER COEFFICIENT (Uclean) - Clean overall heat transfer coefficient is calculated from the predicted cold and hot streams heat transfer coefficients and is the maximum heat transfer coefficient for a given exchanger configuration and fluid conditions. Uclean can be obtained from the Heat Transfer Research Institute (HTRI).

SERVICE OVERALL HEAT TRANSFER COEFFICIENT (Uservice) - Service overall heat transfer coefficient is calculated from heat duty, temperature driving force, and exchanger area and is the minimum heat transfer coefficient required to satisfy the thermal service for a given exchanger area. Uservice can be obtained from the HTRI output.

CLEAN SERVICE - Clean services shall include services where the fouling resistance is less than or equal to 0.00041 m2hr ^{o}C/kcal (0.002 ft2 hr ^{o}F/Btu).

FOULED SERVICE - Fouling Service shall include all services not otherwise defined as “clean service,” or where mechanical cleaning is required.

QUALITY ASSURANCE - All those planned and systematic actions (QA) necessary to ensure quality i.e. to provide adequate confidence that a product or service will be fit for its intended purpose

QUALITY MANUAL - A Document setting out the general quality policies, procedures and practices of an organization

QUALITY PLAN - A document prepared by the Contractor/Supplier setting out the specific quality practices, resources and activities relevant to a particular project

1.3. ABBREVIATION

ADM Area design margin
API American Petroleum Institute
ASME American Society of Mechanical Engineers
ASTM American Society for Testing And Materials
CFD Computational fluid dynamics.
CMCL Corrugated metallic gasket with covering layers.
CP Cathodic Protection
DN Durchmesser Nach (German: nominal diameter).
EPC Engineering Procurement Construction
ePTFE Expanded polytetrafluoroethylene.
FCC Fluid catalytic cracking.
FEED Front End Engineering Design
FF Flat faced.
FM Flange moment factor.
GMCL Grooved metallic gasket with covering layers (Kammprofile).
GTAW Gas tungsten arc welding.
HB Brinell hardness.
HTRI Heat Transfer Research Institute
H_2S Hydrogen Sulphide
HSE Health, Safety and Enviroment
ID Inside diameter.
ISO International Organization for Standardization
ITP Inspection and test plan.
LTCS Low temperature Carbon steel
LWN Long weld neck
MAP Maximum allowable pressure
MAWP Maximum allowable working pressure.
MDMT Minimum Design Metal Temperature
MDR Manufacture Data Report
MSDS Materials safety data sheet.
MT Magnetic particle testing.
NACE National Association of Corrosion Engineers
NDE Non-destructive Examination
NPS Nominal pipe size.
NPT National pipe taper threads.
NTIW No tube in window.
OD Outside diameter.
PQR Procedure Qualification Record
P&ID Piping and Instrument Diagram
PT Dye penetrant testing.

PTFE	Polytetrafluoroethylene
PFP	Passive Fire Protection
PWHT	Post-weld heat treatment
QA	Quality Assurance
QAS	Quality Assurance System
QC/QP	Quality Control / Quality Plan
QMS	Quality Management System
Ra	Roughness average.
RC	Recessed face.
RF	Raised face.
RFQ	Request For Quotation
RTJ	Ring type joint.
VDRL	Vendor Data Requirements List
SPWD	Spiral wound.
SS	Stainless Steel T&G
	Tongue and groove.
TEMA	Tubular Exchanger Manufacturer Association
TPA	Third Party Agency
TSCAD	Technical Standards & Compliance Assurance Division
TSD	Technical Standard Documents
UDS	User Design Specification
UT	Ultrasonic
WFMT	Wet Fluorescent Magnetic Particle Testing
WIV	Wind Induced Vibrations
WPS	Welding Procedure Specification

1.4. EXCEPTION

1.4.1. This Specification does not apply to Double Pipe Exchangers, Plate and Frame Exchangers, Spiral Exchangers, Economisers, Brazed Aluminium Fins Type Heat Exchangers, Water Cooled Surface Condensers, Printed Circuit Exchangers, etc.

1.4.2. For other special applications and equipment, only part of this Specification may be relevant, subject to mutual agreement between SUPPLIER/MANUFACTURER, COMPANY and CONTRACTOR.

1.5. LANGUAGE

All Documents and Correspondences shall be in English language.

1.6. UNITS OF MEASUREMENT

1.6.1. The Metric (SI units) shall be regarded as the standard for design calculations, drawings and all documents; Imperial units may be included for reference in brackets.

1.6.2. Pressure, temperature, nozzle sizes and flange class, shall be based on Imperial units. Metric units may be included for reference in brackets.

SECTION A

2. CODES AND STANDARDS

The following Codes and Standards shall, to the extent specified herein, form a part of this Specification. When an edition date is not indicated for Code or Standard, the latest edition (including addenda) in force at the time of contract award shall apply.

Designation	Title
British Standards Institution (BSI)	
BS EN 10204	Metallic Products – Types of Inspection Documents
BS EN 1991-1-4	Eurocode 1 - Actions on Structures, Part 1-4: General actions - Wind actions
International Organization for Standardization (ISO)	
ISO 9001	Quality Management Systems – Requirements
ISO 9004	ISO 9004 Quality management -- Quality of an organization -- Guidance to achieve sustained success
ISO 16812	Petroleum, petrochemical and natural gas industries- Shell and tube heat exchangers
ISO 3690	Welding and Allied Processes-Determination of hydrogen content in arc weld metal
Abu Dhabi International Building Code	
ADIBC	Abu Dhabi International Building Code
American Petroleum Institute (API)	
API 510	Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration
API 521	Pressure-Relieving and De-pressuring Systems
API 660	Shell-and-tube Heat Exchangers
API RP 2A-WSD	Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design
American Society of Civil Engineers (ASCE)	
ASCE Standard 7	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
American Society for Nondestructive Testing (ASNT)	
ASNT CP-189	Standard for Qualification and Certification of Nondestructive Testing Personnel

Designation	Title
American Society of Mechanical Engineers (ASME)	
ASME Sec. VIII Div.1	Rules for Construction of Pressure Vessels
ASME Sec. VIII Div. 2	Rules for Construction of Pressure Vessels (Alternative Rules)
ASME Sec. II – Part A	Ferrous Material Specifications
ASME Sec. II – Part B	Non Ferrous Material Specifications
ASME Sec. II – Part C	Material Specification for Welding rods, Electrodes and Filler Metals
ASME Sec. II – Part D	Material Properties
ASME Sec. V	Non–Destructive Examination
ASME Sec. IX	Qualification Standard for Welding, Brazing and Fusing Procedures; Welders; Brazers; and Welding, Brazing and Fusing Operators
ASME B16.5	Pipe Flanges and Flanged Fittings; NPS ½ through NPS 24
American Society of Mechanical Engineers (ASME)	
ASME B 16.47	Large Diameter Steel Flanges; NPS 26 through NPS 60
ASME B 16.9	Factory made Wrought Butt Welding Fittings
ASME B 16.11	Forged Fittings, Socket Welding and Threaded
ASME B 16.20	Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral- Wound and Jacketed
ASME B 16.21	Non-Metallic Flat Gaskets for Pipe Flanges
ASME B 16.25	Butt Welding Ends
ASME B 30.20	Design of Below-the-Hook Lifting Devices
ASME B 31.3	Standards of Process Piping
ASME B 36.10M	Welded and Seamless Wrought Steel Pipe
ASME B 36.19M	Stainless Steel Pipe
ASME B 46.1	Surface Texture (Surface Roughness, Waviness and Lay)
ASME B1.1	Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	Pipe Threads, General Purpose (Inch)
ASME BTH-1	Design of Below-the-Hook Lifting Devices
ASME PCC-1	Guidelines for Pressure boundary bolted flange joint assembly
AWS	
AWS A2.0	Welding Symbols
AWS A2.2	Nondestructive Testing Symbols

Designation	Title
AWS A2.4	Standard Symbols for Welding, Brazing & Nondestructive Examination
AWS D1.1	Structural Welding – Steel
National Association of Corrosion Engineers (NACE)	
NACE MR0175/ISO 15156, Parts 1-3	Petroleum and Natural Gas Industries – Materials for Use in H2S-Containing Environments in Oil and Gas Production: Part 1 - General Principles for the Selection of Cracking- Resistant Materials Part 2 - Cracking-Resistant Carbon and Low Alloy Steels and the Use of Cast Irons Part 3 - Cracking-Resistant CRAs (corrosion-resistant alloys) and other alloys
NACE TM0103	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking in H2S Environments
NACE SP0198	Control of Corrosion under Thermal Insulation and Fireproofing Materials – A Systems Approach
National Association of Corrosion Engineers (NACE)	
NACE SP0472	Methods and controls to prevent in-service environmental cracking of carbon steel weldments in corrosive Petroleum Refining Environment
NACE TM0177	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments
NACE TM0284	Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking
NACE SP0387	Metallurgical and inspection requirements for Cast Galvanic Anodes for Offshore Applications
Welding Research Council (WRC)	
WRC - Bulletin 297	Local Stress in Cylindrical Shells due to External Loadings on Nozzles – Supplement to WRC Bulletin No. 107
WRC-Bulletin 368	Stresses in Interconnecting Cylinders subjected to Pressure
WRC-Bulletin 452	Recommended Practices for Local Heating of Welds in Pressure Vessels
WRC - Bulletin 537	Precision Equations and Enhanced Diagrams for Local Stresses in Spherical and Cylindrical Shells Due to External Loadings for implementation of WRC 107
Process Industry Practices (PIP)	
PIP VEFV 1100M	Vessel/S&T Heat Exchanger Standard Details
Miscellaneous	

Designation	Title
AISC – ASD	AISC Manual of Steel Construction: Allowable Stress Design
ASTM SI 10	American National Standard for Metric Practice
ASTM D6120	Standard Test Method for Electrical Resistivity of Anode and Cathode Carbon Material at Room Temperature
PD 5500	Specification for unfired fusion welded pressure vessels
TEMA	Standards of the Tubular Exchanger Manufacturers Association
Zick, L.P.	Stresses in Large Horizontal Cylindrical Pressure Vessels on Two Saddle Supports, The Welding Journal Research Supplement, September 1951
DNVGL-ST-E273	Portable Offshore Units

3. REFERENCE DOCUMENTS

3.1. ADNOC Specifications, Standard Drawings and Other References

The following reference documents, to the extent specified herein, form a part of this specification. When an edition/revision date is not indicated for a document, the latest edition/revision in force at the time of the contract shall apply.

Structural Steel Supply, Fabrication And Erection Specification	AGES-SP-01-002
Structural Design Basis – Onshore Specification	AGES-SP-01-003
Design Criteria for Static Equipment	AGES-SP-06-001
Pressure Vessel Specification	AGES-SP-06-002
Material Selection Guidelines & Specifications	AGES-SP-07-001
Specifications for Cathodic Protection	AGES-SP-07-002
Isolation, Drain and Vent Philosophy	AGES-PH-08-001
Process Design Criteria	AGES-SP-08-002
Piping Basis of Design	AGES-SP-09-001
Piping Material Specification Index	AGES-SP-09-002

3.1. ADNOC Group Companies Requirement

The following Annexures list documents provides specific Group COMPANY requirements to be followed in addition to the requirement in this specification.

ANNEXURE 1 ADNOC Gas Processing, Additional References and Requirements
ANNEXURE 2 ADNOC Refining, Additional References and Requirements
ANNEXURE 3 Borouge, Additional References and Requirements
ANNEXURE 4 ADNOC Onshore, Additional References and Requirements
ANNEXURE 5 FERTIL, Additional references and Requirements
ANNEXURE 6 ADNOC Offshore, Additional References and Requirements

4. DOCUMENT PRECEDENCE

It shall be the CONTRACTOR or VENDOR'S responsibility to be knowledgeable of the requirements of the referenced Codes and Standards.

The VENDOR shall notify the CONTRACTOR of any conflict between this Specification, the related vessel data sheets/drawings, the Codes and Standards and any other specifications noted herein.

Resolution and/or interpretation precedence shall be obtained from the COMPANY in writing before proceeding with the design/manufacture.

Unless specifically stated/agreed with COMPANY, the most stringent requirements shall apply.

In case of conflict, the order of precedence shall be:

a. UAE Federal Acts and Regulations
b. Design Data Sheets
c. Project Specification
d. COMPANY Specification and Standard Drawings
e. International Codes and Standards

5. SPECIFICATION DEVIATION/CONCESSION CONTROL

This specification is complementary to requirements of certifying authority, legislative requirement, guidance note issued by any authority & documents referenced herein. Compliance with this Specification & Standards and documents referenced therein does not relieve SUPPLIER of his responsibility to furnish units of proper design, workmanship & materials to meet the specified conditions & duties required in data sheet.

Deviations to this Specification are only acceptable where the CONTRACTOR/VENDOR has listed in his quotation the requirements he cannot comply with and the COMPANY/CONTRACTOR has accepted in writing these deviations before the order is placed.

In the absence of a list of deviations, it will be assumed that the CONTRACTOR/VENDOR complies fully with the Specification.

Post Purchase order, any technical deviations to the Purchase Order and its attachments shall be sought by the CONTRACTOR/VENDOR only through Concession Request procedure and formats. All Concession Requests require the COMPANY's review/approval, prior to the proposed technical changes being implemented.

The COMPANY decision shall be final without any cost & schedule impact to the gasket COMPANY/project.

Technical changes implemented prior to COMPANY approval are subject to rejection.

SECTION B

6. DESIGN REQUIREMENTS

6.1. DATA SHEETS

6.1.1. When specifying a heat exchanger during the FEED Stage or the detailed engineering phase, the applicable Data Sheets shall be used and filled out accordingly.

6.1.2. When specifying a heat exchanger, the mechanical design code and equipment design standard shall be stated on the Data Sheets.

6.2. DESIGN CODE AND STANDARD

6.2.1. Heat exchanger mechanical design and fabrication shall be in accordance with the ASME Code and requirement as specified in Pressure Vessel specification and Design Criteria for Static Equipment specification

6.2.2. The principal design standards shall be Tubular Exchanger Manufacturers Association (TEMA). Shell and tube heat exchanger shall conform to Part II of this specification which is written as amendment and supplement to TEMA standard. The requirements of TEMA standard which are not amended shall be considered mandatory. Recommended Good Practice section of TEMA shall also be followed where applicable.

6.2.3. Shell and tube heat exchanger design shall conform to latest edition of API STD 660 Petroleum, petrochemical and natural gas industries.

6.2.4. Supplemental requirement referred in Para 12.0 of API 660 shall be considered applicable for any of the following condition

a. For exchanger in lethal service or cyclic service
b. When vessel thickness is equal to 50mm and greater
c. For design pressure greater than 70 barg

6.3. CODE STAMP

All exchangers designed as per ASME Sec.VIII, Div.1 or Div.2 shall be code stamped and shall be registered with National Board.

6.4. CORROSION PROTECTION

When specified on Data Sheets, corrosion protection by means of sacrificial anodes/plates shall be provided. They shall be in accordance with Standard Drawings, where available. If not available, Supplier shall propose the arrangement for COMPANY's acceptance. Sacrificial anode/plate shall not obstruct tube side flow.

6.5. CRITICALITY RATING (CR)

6.5.1. A Criticality Rating (CR) shall be assigned to each shell and tube heat exchanger and shall be indicated on the Equipment Data Sheets/Drawings. The calculation method and the checking level shall be based on requirements based on respective Group COMPANY specification for “Criticality Rating System”.

6.5.2. The Criticality Rating (CR) listed on the equipment Data Sheets shall be used to determine factory inspection and testing requirements as outlined in respective Group COMPANY specification

6.6. END FLANGES

6.6.1. For the purpose of this Specification, end flanges shall include stationary head flanges, shell flanges, shell cover flange and floating head cover flange.

6.6.2. Flanges for external girth joints shall be forged welding neck type. Forged slip-on is not acceptable. Slip on flanges is not acceptable. For lethal and cyclic service, Floating head cover flange shall be as per fig 1. b of API 660.

6.6.3. External girth flange and floating head flanges shall be designed as per ASME Section VIII Div1, Appendix 2. Flange rigidity index shall not exceed 1.0.

6.6.4. Gasket pass partition rib area shall be added to the peripheral gasket area for purpose of determining the required bolt loads.

6.6.5. The use of a nubbin to decrease the gasket seating width is not permitted.

6.7. LONGITUDINAL BAFFLES

a. TEMA type F shells may be considered where the temperature profile of the process fluids requires two or more heat exchangers in series (temperature crossovers), or to increase the shell side velocity, unless there are considerable economic savings or design advantage, subject to the following restrictions and approval by the COMPANY.
b. For design of new facilities, multiple shell pass designs should be applied only in services with non-removable bundles or removable bundles that will not require frequent disassembly for mechanical cleaning; i.e., shell side fluid is clean.
c. The longitudinal baffle is welded to the shell (maximum allowable shell side pressure drop to be less than 0.7 bar)
d. For a removable bundle, (maximum allowable shell side pressure drop not to exceed 0.5 bar) the gap between the baffle and the shell is closed with a double-sided, multi-layered clip-on spring set.
e. On the shell side the difference between the inlet and outlet temperature does not exceed 110°C.

6.8. BUNDLE ROTATION

Where possible, without decreasing the thermal performance of the exchanger, the tube bundles shall be designed to allow their operation after being placed back into the exchanger, following a 180° rotation around the bundle's longitudinal axis

6.9. ELECTRIC HEATERS

The shell side of an electric heater shall be in accordance with this Specification.

6.10. SPECIAL APPLICATIONS

6.10.1. Slurry Service

a. Slurry services shall be routed through the tubeside of the exchanger.
b. Minimum tube size shall be 25.4 mm (1 in.) OD at 2.77 mm (0.109 in.) (12 BWG) minimum wall thickness.
c. Velocity limits for cycle oil containing catalyst fine shall be as listed below. The optimum velocity is 1.75 m/sec (5.74 ft/sec).

Table Part I – 6.10.1 – Velocities in Tubes

Velocity m/s (FPS)

	Maximum		Minimum	
Straight tube	2.13	(7.0)	1.14	(3.74)
U-tube	1.75	(5.74)	1.14	(3.74)

d. Straight tube construction is recommended.
e. Slurry flow shall be horizontal or downward.

6.10.2. HF Acid

To minimize potential of acid leakage into the process area, exchanger design shall provide as few joint closures as practical.

6.10.3. Sour and wet H2S and other Critical Services

For equipment in Sour and wet H2S service in addition to requirements stipulated in Design criteria for Static equipment and Pressure Vessels Specification, requirement in respective Group COMPANY specification for Material for Sour Service or Critical Services shall also be complied.

a. External bolting shall comply with sour service requirement regardless of shell and tube heat exchanger being insulated or not.

6.10.4. Lethal Service

a. Lethal Service requirement stipulated in Design criteria for Static Equipment and Pressure Vessel Specification shall be followed for Shell and Tube Heat Exchangers. Additionally, following shall be followed
b. Tube to tube-sheet joint is rolled and strength welded

c. Helium leak test will be performed after the first weld tube pass, dye penetrant test will be performed after the final tube pass weld and final tube rolling.
d. Lap joint flanges and Slip on body flanges are not allowed.
e. Rigidity Index (J) of 0.85 shall be used in the design of non-standard flange.

6.10.5. Pulsating Flow on Shell Side

a. Maximum unsupported tube length for vapor or 2-phase flow shall be 914 mm (36 inches).
b. Design shall include adequate impingement protection plate or a distributor belt so that ρV2 into a bundle shall not exceed 744 kg/(m.sec2) (500 lb/(ft.sec2)).

7. THERMAL DESIGN

7.1. TUBE SIDE / SHELL SIDE SELECTION

7.1.1. In general, tubeside/shellside selection shall be made to satisfy as many as possible of the following points, unless otherwise indicated on Data Sheets. Also refer Part-II for further requirements on the selection.

Table Part I – 7.1.1 – Selection of Type

Service	Shellside	Tubeside
Seawater		X
Cooling Water		X
Condensing Vapors (except steam)	X	
Lower Allowable ΔP	X	
Larger Flow and Similar Properties	X	
Higher Pressure Fluids		X
Corrosive Fluids / Alloy Construction		X
*High Fouling Factors		X
High Viscosity / Laminar Flow	X	

* If chemical cleaning can be utilized, the fouling fluid may be placed on the shell side after Purchaser's approval.

7.1.2. Unless specified on the Equipment Data Sheets, the selection of a type of heat exchanger shall be in accordance with this specification.

7.1.3. Heat exchangers should be of the horizontal type; however, for process requirements or where cleaning and other maintenance will be infrequent or space requirements make it more attractive, the vertical arrangement may be considered.

7.1.4. When horizontal arrangements are preferred, the stacking of exchangers should be considered to conserve space in the structure. Preferred stacking should be 2 (two) shells high. Exchanger shells shall not be stacked in combinations of more than two, unless approved by the COMPANY

7.2. TUBE SIDE VELOCITY

7.2.1. Velocity limits for liquid streams in tubes with different tube materials shall be as per table below. The minimum velocity for tube shall be 1m/s unless otherwise noted in Table below.

Table 7.2.1-Velocity limits for liquid streams with different tube materials excluding cooling water

Tube Material	Operating Velocity Limit	
	Minimum	Maximum
	m/s	
Admiralty brass	1	1.5
Aluminium or copper	1	1.5
Aluminium brass	2	2.4
Aluminium bronze	2	3
Cupro-nickel 70/30	2	3
Cupro-nickel 90/10	2	2.4
Titanium	2	4.5
Monel	2	3.7
Austenitic stainless steel	2	4.6
Ni-Fe-Cr alloys	2	4.6
Carbon steel with an organic protective lining	2	2.5
Carbon steel	2	3
Duplex stainless steel	2	4.6
Super duplex stainless steel	2	4.6

7.2.2. Minimum velocities for single phase non-erosive liquid streams, excluding cooling water should be as per Table below.

Table 7.2.2 Minimum velocities for single-phase non-erosive liquid streams excluding cooling water

Fouling Characterization	Fouling Factor; m^2-K/W(hr-ft^2-°F/Btu)	Tube Side Velocity; m/s (ft/s)	Shell Side Velocity; m/s (ft/s)
Very Low	<0.00009 (0.0005)	1.0 (3.0)	0.3 (1.0)
Low	<0.00026 (0.0015)	1.0 (3.0)	0.3 (1.0)
Medium	< 0.00052 (0.003)	1.5 (5.0)	0.5 (1.6)
High	< 0.0012 (0.0068)	2.0 (6.5)	0.6 (2.0)
Severe	> 0.0012 (0.0068)	2.2 (7.2)	0.7 (2.3)

7.2.3. Cooling water shall be placed on the tubeside and should run upwards through the tubes in order to avoid gas build-up. The tubeside velocity should be as specified in this specification. The tubeside shall be maintained at a positive pressure so that air cannot separate from or be sucked into the water.

7.2.4. Tube side velocity maximum limit as shown the table below.

Table Part I – 7.2.4a – Cooling Water (Seawater/Brackish water) Velocity

Tubeside velocity range for seawater or brackish water shall be as follows:

Tube Material	Velocity m/s (FPS)	
Titanium	2.0 – 4.6	(6.6 – 15.1)
70-30 Cu-Ni	1.5 – 3.7	(4.9 – 12.1)
90-10 Cu-Ni	1.5 – 2.7	(4.9 – 8.9)
Al Brass, Al Bronze	1.5 – 2.0	(4.9 – 6.6)
Monel	1.5 – 3.7	(4.9 – 12.1)
Incoloy 825, Carpenter 20CB3	1.5 – 3.7	(4.9 – 12.1)
Incoloy 625, Hastealloy C	1.5 – 3.7	(4.9 – 12.1)

Table Part I – 7.2.4b – Cooling Water (Treated/Fresh water) Velocity

Tubeside velocity range for treated/fresh cooling water shall be as follows:

Tube Material	Velocity m/s (FPS)	
Carbon and Low Alloy Steel	1.0 – 2.1	(3.3 – 6.9)
Austenitic Stainless Steel	2.0 – 4.5	(6.6 – 14.8)
Titanium	2.0 – 6.0	(6.6 – 19.7)
Inhibited Admiralty	1.0 – 2.7	(3.3 – 8.9)
70-30 Cu-Ni	1.5 – 7.0	(4.9 – 23.0)
90-10 Cu-Ni	1.5 – 7.0	(4.9 – 23.0)
Aluminum Brass	1.5 – 2.1	(4.9 – 6.9)
Aluminum Bronze	1.5 – 2.1	(4.9 – 6.9)
Monel	1.6 – 7.0	(5.2 – 23.0)
Incoloy 825, Carpenter 20 CB3	1.5 – 3.7	(4.9 – 12.1)

7.2.5. Maximum allowable outlet water temperature shall be limited to 50°C in case of seawater and brackish water. This limit may be 60°C for freshwater.

7.2.6. Maximum allowable hot stream temperature shall be limited to 175°C in case of water cooled heat exchangers.

7.2.7. For erosive fluids, maximum allowable tube inlet design velocity for gas streams:

a. 38 m/s (125 ft/s) for streams containing no liquid or solid particles.
b. 20 m/s (66 ft/s) for gas streams anticipated to contain particles or droplets (including condensing service).

7.2.8. For gas heat exchangers with glycol or methanol injection, dry gas velocities (with linear interpolation and extrapolation) limited to:

a. 6 m/s (20 ft/s) for gas at 69 barg (1 000 psig).
b. 8,5 m/s (28 ft/s) for gas at 6,9 barg (100 psig).

7.2.9. For gas heat exchangers with glycol or methanol injection, the glycol or methanol injection system and tube bundle sized such that the glycol or methanol wets the entire tubesheet and the entire tube wall for all potential gas flowrates.

7.3. SOFTWARE REQUIREMENTS

7.3.1. The thermal design and rating of shell and tube heat exchangers shall be based on the latest version of Heat Transfer Research Institute (HTRI) software.

7.3.2. Thermal design, hydraulic performance & vibration calculations shall be checked and the result shall be submitted to COMPANY in hard copy and native file.

7.3.3. In the event that the data thus provided is considered by the designer or the SUPPLIER/MANUFACTURER to be insufficient for design purposes, it is his responsibility to request further information from the COMPANY AND CONTRACTOR.

7.3.4. Calculated weight from computer software is treated as an estimation. Suitable contingency allowance shall be added.

7.4. TUBE VIBRATIONS

Flow induced vibration and Acoustic vibration requirements are provided in Part II of this specification to be in compliance for all exchangers.

7.5. BAFFLE-TO-SHELL CLEARANCE

Calculated heat transfer coefficient for high viscosity (above 2cP) shall be with the baffle-to-shell clearance taken as ‘large’, to allow for wear and tear. The shell side pressure drop, however, shall be calculated with the baffle-to-shell clearance taken as ‘average’.

7.6. PRESSURE DROP

7.6.1. In order to design a heat exchanger with a minimum area requirement, the allowable pressure drop of the heat transfer controlling side should be fully utilized.

7.6.2. The calculated pressure drop for clean service to be reported in the data sheet. The calculated pressure drops shall not exceed the allowable pressure drops specified on data sheets. To ensure the exchanger performance in fouled conditions, margins shall be added to the calculated clean pressure drop.

7.6.3. The allowed pressure drop is normally between heat exchanger inlet and outlet nozzles.

7.6.4. Design with pressure drops higher than the allowable pressure drop may be proposed for an enhanced design, but shall be subject to approval by COMPANY and Contractor.

7.7. TUBE LAYOUT/SHELL DIAMETER

The tubesheet layout drawing shall show at least one half of the tubesheet symmetrical to the other half). Otherwise the complete tubesheet layout shall be provided. The tubesheet layout drawing, whether in datasheets generated by Supplier, shall indicate the following, as a minimum:

a. Tube pattern,
b. Number of tubes per pass,
c. The provision (or otherwise) of impingement protection,
d. The provision (or otherwise) of sliding strips,
e. The provision (or otherwise) of sealing devices,
f. No. of baffles, baffle cut and orientation,
g. Support plates,
h. Tie rods,
i. Drain notch,
j. Nozzles,
k. Main dimensions in millimeters (including outer tube limit).

Design of shell and tube heat exchangers for the Project shall target maximum interchangeability of complete units or components.

The maximum number of tube passes shall be 16 for any given heat exchanger.

7.8. BAFFLE SPACING OF END COMPARTMENTS

Except for divided/split flow, baffles and end supports shall be spaced so that they do not obstruct the shell side nozzles.

7.9. KETTLE-TYPE REBOILERS AND EVAPORATORS

7.9.1. Kettle shell diameter depends on vapour space area above the tube bundle. Vapor velocities shall nowhere exceed the maximum vapor velocity determined by the entrainment requirements.

7.9.2. An allowance of minimum 125-mm shall be provided for frothing above the liquid level. The height of the escape area above the frothing allowance shall be at least 250 mm minimum.

7.9.3. The entrainment ratio shall be calculated and it must meet a minimum entrainment specified on the datasheet. The entrainment coefficient shall be calculated per Xist latest edition manual and used in the Xist latest edition program to size the vapor space. Other methods may be used with COMPANY approval.

7.9.4. Minimum of two (2) vapor outlet nozzles shall be used for bundles longer than 4880 mm (16 ft), but the number of nozzles should match the generated vaour flowrate, velocity and entrainment requirement.

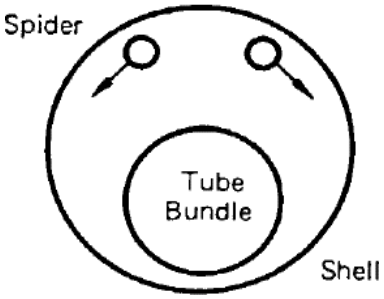
7.9.5. A distance of 50mm minimum shall be maintained between bottom of bundle and the bottom inside diameter of the shell for re-circulation purpose as indicated in the specifications.

7.9.6. The kettle type shell, Type K, should be selected for boiling where almost 100% vaporization (0 % to 5 % entrainment) is required or where phase separation is required. Adequate disengaging space and if required an entrainment eliminator in the shell shall be considered.

7.9.7. The entry for vapor/liquid mixtures shall be above the boiling pool. A deflector baffle, spider pipe or other suitable means is required for vapour/liquid mixture inlet nozzle.

7.9.8. The requirements for spider pipes are as follows:

Figure 1. SPIDER PIPES



a. Located at the position of lowest vapor generation
b. The mixed vapor/liquid stream should direct downwards against the shell wall to promote separation of the liquid and vapour
c. No holes in the direct path from the inlet nozzle
d. The velocity head in the inlet nozzle shall be 4000 kg/m/sec2 maximum
e. The velocity head in the spider header shall be 1000 kg/m/sec2 maximum
f. The velocity head in the holes shall be 4000 kg/m/sec2 maximum
g. If considered necessary, provision shall be made for cleaning the spider.

7.9.9. Weir height is at least 25mm above the top of tube, vortext breaker is required at the liquid outlet.

7.9.10. Square pitch or rotated square pitch may be used to allow a path for vapour to boil.

7.9.11. If the liquid level has to be maintained at a fixed height, a weir shall be installed between the boiling compartment and the rundown compartment to keep the bundle submerged. Weir plate shall be located behind tube bundle, and it shall be welded tightly to the shell. Weir plate shall have no drain holes. The top of the weir shall be at least 25 mm above the top of the bundle. Unless required by process considerations, drain holes are not permitted in this weir.

7.9.12. If the liquid level is to be controlled by instrumentation, a calming baffle shall be installed to prevent boiling turbulence from affecting the level instruments.

7.9.13. The liquid space shall be determined by the liquid hold-up requirements.

7.9.14. The minimum distance between weir plate and the shell head tangent line shall be 1220 mm.

7.10. THERMOSYPHON REBOILERS

7.10.1. For thermosyphon reboilers, vertical orientation is preferred to horizontal orientation. However, all aspects of design, vibration, maintainability, and performance should be evaluated when making a selection.

7.10.2. Also Refer Para 2.3 of Section 8 Part II for additional requirement for Thermosyphon Reboiler

7.11. ENHANCED HEAT TRANSFER TECHNOLOGY

7.11.1. Proprietary technology such as helical baffles, twisted tubes, tube inserts etc when proposed shall provide significant economic and technical advantage with little to no detrimental impact to operability and maintainability.

7.11.2. The use of proprietary technology of the type described shall only be used when approved by the COMPANY. In such cases, the thermal and hydraulic design and guarantee shall be included in the scope of the technology owner, not the equipment manufacturer (except where the manufacturer is licensed to carry out the design by the technology owner).

7.11.3. Whenever enhanced heat transfer solutions are proposed, the equivalent 'Base Case' solution using conventional technology (as per this specification include HTRI) shall be supplied to allow a meaningful comparison.

8. EARTHING

Each saddle/support of horizontal/vertical exchangers shall have one earthing clip as a minimum and shall be as per COMPANY standard drawing

9. INSULATION

9.1. Insulation, Insulation clips when specified, shall be in accordance with the respective Group COMPANY specification as applicable for "Hot Insulation Piping and Equipment" or "Cold Insulation for Piping & Equipment".

9.2. Insulation requirements, thickness, type and applicable specification shall be specified on the Data Sheets/Drawings.

9.3. Insulation clips are not required on horizontal heat exchangers with an outside diameter less than 2000 mm.

SECTION C

10. QUALITY ASSURANCE/QUALITY CONTROL

10.1. SUPPLIERS's Quality Management Systems shall comply with all the requirements of ISO 9001 "Quality Management Systems – Requirements" and ISO 9004 "Quality management -- Quality of an organization -- Guidance to achieve sustained success" with due regard to ISO 1901.

10.2. To ensure that all work is being performed consistently and accurately and to the requirements of the Project Specifications, CONTRACTOR shall ensure that the SUPPLIER shall have in effect, at all times, a QA program which clearly establishes the authorities and responsibilities of those responsible for the Quality System. Persons performing Quality functions shall have sufficient and well-defined authority to enforce Quality requirements that they initiate or identify and to recommend and provide solutions for Quality problems and thereafter verify the effectiveness of the corrective action.

10.3. Quality System and Quality Control requirements shall be identified and included in the CONTRACTOR's Purchase Documentation. Based on these requirements the SUPPLIER will develop a QA/QC program which shall be submitted to the CONTRACTOR for review and approval. The SUPPLIER's QA/QC program shall extend to SUB-CONTRACTORS and SUBSUPPLIERS. On request, the SUPPLIER shall provide objective evidence of QA/QC surveillance for all levels of the SUPPLIER activity.

10.4. COMPANY/ CONTRACTOR reserves the right to inspect materials and workmanship at all stages of manufacture and to witness any or all tests. The SUPPLIER, 30 days after award but prior to the pre-inspection meeting, shall provide the CONTRACTOR with a copy of its manufacturing Inspection and Test Plan and with copies of all related/ referenced procedures for review and approval. The Inspection and Test Plan will also be reviewed for inclusion of any mandatory COMPANY/ CONTRACTOR witness or hold points.

10.5. The Supplier shall make regular QA audits on all their Sub-Contractors compliance with ISO-9001. Details of these audits shall be made available to COMPANY and Contractor. The Contractor/Supplier shall maintain sufficient Inspection and Quality Assurance staff, independent of the service provider management, to ensure that the QMS is correctly implemented and that all related documentation is available.

10.6. The Criticality Rating (CR) System outlined in respective Group COMPANY Specification shall be used by CONTRACTOR or CONTRACTOR's designee to develop the design checking levels and minimum requirements for shop inspection, testing and material certification given in respective Group COMPANY Specification.

11. SUPPLIERS / SUBCONTRACTORS / SUBSUPPLIERS SCOPE OF SERVICES AND RESPONSIBILITES

11.1. Thermal and hydraulic design, vibration analysis, mechanical design, provision of materials, fabrication, inspection, testing, code stamping, certification, painting, packing, preservation, spares, special tools, preparation for shipping, quality assurance, quality control, documentation, performance and mechanical guarantee of shell and tube heat exchangers which shall be provided in conformance to this specification, HSE regulations, local codes jurisdictional and purchase order including all referenced documents.

11.2. Shell and tube heat exchangers designed in conformance to the ASME Code shall be code stamped and registered with the National Board Registration

11.3. Design of a shell and tube heat exchanger or a review of Supplier documentation or a shell and tube heat exchanger component furnished or release for shipment by COMPANY and Contractor shall not relieve the Supplier from their responsibility to conform to the requirements of this specification and other purchase order documents.

11.4. COMPANY and Contractor shall be allowed for shop access to inspect materials and activities during shell and tube heat exchanger fabrication, testing, painting and packing for conformance to this specification and purchase order documents. Work or materials not conforming shall be cause for rejection. The rejected material or items shall be clearly marked as rejected items and to be segregated in a specific designated area.

11.5. Data sheets, calculations, drawings, quality control records and other items which assist in determining the acceptability of a shell and tube heat exchanger for inspection shall be made available for COMPANY and Contractor review. All related approved deviations and concessions to be attached and provided along with engineering and other supplier's deliverables.

11.6. The nominated SUPPLIER shall be responsible for the complete Purchase Order. The SUPPLIER shall assume full responsibility for the Shell & Tube Heat Exchangers including design, materials, fabrication, inspection, testing and preparation for shipment. Moreover, Supplier shall be responsible for assuring that sub-supplier fabrication work is in conformance to this specification and purchase order documents.

11.7. The SUPPLIER shall transmit all relevant purchase order documents including specifications to his SUBSUPPLIERS and SUBCONTRACTORS. The SUPPLIER shall be responsible for assuring that subcontracted fabrication work is in conformance to this specification and purchase order documents. It is SUPPLIER'S Responsibility that engineering data including drawings from SUBSUPPLIER and SUBCONTRACTORS are meeting project quality requirements to submit to the CONTRACTOR for review and approval. Supplier shall submit experience summary list of all his Sub-Supplier.

11.8. Supplier shall be responsible for furnishing a complete Shell and Tube Heat Exchanger with maximum shop assembly consideration.

11.9. Supplier’s Scope of Services shall include the following as a minimum;

a. Exchanger sizing/thermal rating verification.
b. Thermal and hydraulic guarantees for process performance.
c. Mechanical design and engineering.

d. Mechanical Guarantees for design, material and workmanship.
e. Flow induced Vibration analysis.
f. Design of bundles, internals, attachments and supports.
g. Fabrication and assembly.
h. Post weld heat treatment as required by Code/Specifications/Datasheets.
i. Inspection of equipment.
j. All required non-destructive testing.
k. Hydrostatic testing and drying of equipment after hydrotest.
l. Material inspection testing and certification.
m. Positive Material Identification.
n. ASME Code stamping & National Board Registration
o. Surface preparation and external painting.
p. Pickling and passivation.
q. Packing, marking, preservation and protection for transportation and site storage.
r. Documentation in accordance with these requirements specified in this specification.

11.10. Supplier's Scope of Supply shall include the following as a minimum;

a. Supply of all materials.
b. Heat exchangers complete with shell, channel, shell and channel covers, all nozzles and flanges, girth flanges, blind flanges, equipment supports and appurtenances in accordance with the data sheets.
c. Tube bundle complete with tube sheet, baffles, sliding strips, tie-rods, sealing strips, impingement rods and support plates.
d. Spare tube bundle if required by the COMPANY.
e. Bundle pulling eye bolts, guide rails etc. (for removable bundles).
f. Bundle extractor/bundle lifter.
g. Nozzles complete with reinforcement and flanged connections.
h. Bolted covers including lifting lugs/davits, bolts, nuts and gaskets.
i. Supports, lifting and earthing lugs.
j. Bolts, nuts and gaskets for all exchangers' girth flanges, blind flanges, interconnecting nozzles and interconnecting pipework.
k. Warning plate with reference to PWHT of the heat exchanger.
l. Blind flanges, gasket and bolting when indicated on data sheets.
m. Bolting and shim plates (12 mm min) for interconnecting supports of stacked exchangers.
n. All external attachments welded to the exchangers including stiffeners, insulation support clips, pipe clips, ladder and platform clips, fireproofing clips per data sheets.
o. Jackscrews, eyebolts, locking studs, as required for installation/dismantling.
p. Manufacturer's and Code Stamp name plates and nameplate brackets.
q. Temporary blinds, gaskets and bolting for testing.
r. Bolt tightening device.
s. All special tools, test flange, test ring, test "dummy" shell and tackles required for testing, installation, commissioning and maintenance.
t. Temporary cover, gaskets and bolting for shipment.
u. Shipping/transportation supports.
v. Spare parts (Supplier shall quote for the spare parts separately. Spare parts shall be designed and manufactured as Original part).
w. Base anchor bolts (design only)

12. MATERIALS

12.1. GENERAL

12.1.1. Material and Corrosion requirements shall be as specified in the heat exchanger data sheet. The material shall meet quality as specified in this specification, Pressure Vessel specification, Design Criteria for Static Equipment, ASME Sec. II material specifications and requisition including all referenced documents as a minimum. All materials shall be new, unused, and free of defects.

12.1.2. All materials shall be defined with complete ASME designation

12.1.3. Material for heat exchanger component shall meet the requirement in TABLE 12.1 of this specification

12.1.4. Material requirements in Pressure Vessel Specification applicable to the service requirement (sour, caustic, amine, etc.) shall also be followed.

12.1.5. Material certification requirement shall be as per applicable COMPANY specification for Shop Inspection and Test Plan. For ADNOC Offshore, Inspection and certification requirements for material shall be in accordance to BS EN 10204 and COMPANY document A0-Q-PQ-CP-001 in addition to requirements specified in this Specification. If Insurance Inspection is specified, all documents are to be certified by the Insurance Authority and are to be countersigned by the Inspecting Engineer.

12.1.6. Nozzles shall have same corrosion allowance as specified for the shells or heads they are attached to

12.1.7. All carbon steel parts which have been cold formed over 5% shall be subjected to an appropriate normalizing treatment and, if necessary, a tempering treatment.

12.1.8. All pipe used for shell, channel, shell covers or nozzles shall be seamless. Manufacturing tolerance shall be taken into account and minimum wall shall be certified by the manufacturer.

12.1.9. Carbon steel materials SA-36 and SA-283 shall not be for pressure parts.

12.1.10. Unless otherwise specified, Stainless Steel SS 304 shall not be used.

12.1.11. Castings shall not be used.

12.1.12. Any contact between galvanized steel and stainless steel shall be avoided.

12.1.13. For direct sea water cooling tube and tube sheet shall be Monel, Titanium or Cu Ni unless otherwise stated in datasheet

12.1.14. Titanium tubes shall meet the following requirements

a. Titanium tubes may be seamless. Inspection requirements as per B338 GR2.
b. Titanium sheets shall be according to specification, and to ASME SB 265 Gr.2.

c. Low fin tubes shall confirm compliance to ASTM B-891. Seamless bare tube used for manufacturing of low fin tubes shall confirm to ASME SB338 Gr 2. 100% Tubes shall be Eddy current test before and after finning. 100% of tube shall be hydrotested after finning as per ASTM B-891. Tubes ends shall be deoxidized externally for at least 20". Fin tube manufacturer shall submit detail manufacturing and testing procedure for fin tube for COMPANY review and approval.

d. On titanium clad products, the bond shear strength shall be checked as per ASME SA265 para 7.1 and bond quality level shall be Quality Class 1

e. The Supplier of titanium semi-finished products and the manufacturer which will perform the explosion cladding shall be approved by the COMPANY

12.2. TUBES

12.2.1. Seamless tubes shall be eddy-current tested in the finished condition over their full length.

12.2.2. Integrally finned tubes shall conform to ASTM A1012 and pass an air underwater test in conformance to ASTM A450 after finning, bending and heat treatment.

12.2.3. All tubes shall be seamless.

12.2.4. Randomly selected tubes shall be inspected for conformance to mill tolerances as specified in the data sheets and Purchase Order documents including out of roundness, thickness variation, and other key parameters.

12.3. TUBESHEET

12.3.1. Naval rolled brass shall be used with admiralty tubes.

12.3.2. When 22Cr Duplex, 25Cr Duplex or 6 Mo is envisaged for tubesheet, it shall be solid metal and not clad.

12.3.3. Electrical earthing (grounding) shall not be welded to the tubesheet.

12.4. BAFFLES AND SEAL STRIPS

12.4.1. The material for baffles, seal strips, spacers and tie rods shall be compatible to tube material to avoid galvanic coupling.

12.4.2. Baffles, tie rods, spacers, and/or sealing strips shall be at least equivalent in corrosion resistance to the shell, shell cladding or shell overlay.

12.5. BOLTS

All requirements shall be in accordance with Pressure vessel specification, unless additional requirements are specified for Heat Exchangers

TABLE PART-1 12.1: TYPICAL MATERIAL OF HEAT EXCHANGER COMPONENT

MATERIAL	LTCS	CARBON STEEL	STAINLESS STEEL SS316L	TITANIUM
Vessel Component	**(Note 1,2)**	**(Note 2)**		
Channel, Channel Head, Floating head, Shell, Shell cover (Plate)	SA 516 Gr. 60/65/70	SA 516 Gr. 60/65/70	SA 240 Type 316 L	SB 265 Gr 2
Channel, Shell, Shell cover (Pipe)	SA 333 Gr 6	SA 106 Gr B	SA 312 TP 316 L	SB 861 Gr 2
Cladding/Weld Overlay of Shell/Head/Tubesheet/Nozzle, etc.	(Note 4)	(Note 4)	NA	NA
Channel flange at tubesheet, Channel flange at cover, Shell flange at tubesheet, Shell cover flange	SA 765 Gr. II / SA 350 LF 2 Cl. 1 (Note 5)	SA 266 Gr. 2 / SA 105 (Note 6)	SA 336 Gr.F316 L / SA 182 Gr. F316 L, (Note 7)	SB 381 F-2, Use of Lap type flange with CS backing ring shall be with COMPANY Approval
Tubesheet	SA 765 Gr. II / SA 350 LF 2 Cl. 1 (Note 5)	SA 266 Gr. 2 / SA 105 (Note 6)	SA 336 Gr.F316 L / SA 182 Gr. F316 L, (Note 7)	SB 381 F-2, Forged CS + SB 265 Gr 1 (for stationary tubesheet when specified)
Floating head flange	SA 765 Gr. II / SA 350 LF 2 Cl. 1 (Note 5)	SA 266 Gr. 2 / SA 105 (Note 6)	SA 336 Gr.F316 L / SA 182 Gr. F316 L, (Note 7)	SB 381 F-2,
Reinforcing Pads	SA 516 Gr. 60/65/70	SA 516 Gr. 60/65/70	SA 240 Type 316 L	SB 265 Gr 2
Tubes	SA 334 Gr 6 (seamless)	SA 179 (seamless)	SA 213 TP316L(seamless)	SB 338 Grade 2 (seamless)
Nozzles: - Pipe	SA 333 Gr. 6	SA 106 Gr. B	SA 312 TP 316 L	SB 861 Gr 2
- Plate	SA 516 Gr. 60/65 / 70	SA 516 Gr.60/65 / 70	SA 240 Type 316 L	SB 265 Gr 2
- Forgings	SA 765 Gr. II / SA 350 LF 2 Cl. 1 (Note 5)	SA 266 Gr. 2 / SA 105 (Note 6)	SA 336 Gr.F316 L / SA 182 Gr. F316 L, (Note 7)	SB 381 F-2
Nozzle Flanges (ASME)	SA 350 LF 2, Cl. 1	SA 105	SA 182 Gr. F 316 L	SB 381 F-2

MATERIAL	LTCS	CARBON STEEL	STAINLESS STEEL SS316L	TITANIUM
Vessel Component	**(Note 1,2)**	**(Note 2,)**		
Baffle and support plate	SA 516 Gr. 60/65/70	SA 516 Gr. 60/65/70	SA 240 Type 316 L	SA 240 Type 316 L (When Tube side require Titanium) else SB 265 Gr 2
Test Ring and Flange	Carbon steel	Carbon steel	Carbon steel	Carbon steel
External Welded Attachment	SA 516 Gr. 60/65/70	SA 516 Gr. 60/65/70	SA 240 Type 316 L	SB 265 Gr 2
Stud Bolts external (upto 400°C)	SA 320 Gr. L7(Note 9)	SA 193 Gr. B7 (Note 9)	SA 193 Gr. B8M Cl. 2	Compatible to flange material
Nuts external (upto 400°C)	SA 194 Gr. 7(Note 9)	SA 194 Gr. 2H (Note 9)	SA 194 Gr. 8M	Compatible to flange material
Nozzle Gaskets, External	As per ADNOC Piping Material Systems Specification			
Body Flange Gasket	As per this specification			
Saddles Wear Plate	SA 516 Gr. 60/65/70	SA 516 Gr. 60/65/70	SA 240 Type 316 L	Based on shell material
Anchor Bolts (Note 10)	Normal Temp - SA36 or SA 307 Gr B/ Cold Temp - SA 320L7	SA36 or SA 307 Gr B	Normal Temp. - SA36 or SA 307 Gr B/ Cold Temp - SA 320L7	Based on shell temperature

NOTES:

1) For Low Temperature Carbon steel, Charpy impact requirements shall meet the requirement of Pressure Vessel Specification
2) For equipment which requires PWHT, simulated coupon from raw material shall be subjected to one extra cycle of PWHT for future modification/repair by the COMPANY. Required heat treatment for plate, heads, PWHT for the equipment, repair by the vendor shall be considered extra. These simulated coupons shall be tested and shall meet all relevant material requirements. Combining of PWHT cycle are not permitted. Coupons shall be taken from plate from with highest carbon equivalent.
3) Deleted
4) Material of Cladding/Weld overlay shall be as indicated in MSD (Material selection Diagram).
5) Custom - special forgings SA 765 Gr. II, for standard forgings SA 350 Gr. LF 2 Cl. 1
6) Custom - special forgings SA 266 Gr. 2, for standard forgings SA 105
7) Custom - special forgings SA 336 Gr. F316 L, for standard forgings SA 182 Gr. F316 L
8) Deleted

9) Grade M bolts and nuts to be used in sour service and other service wherever specified (e.g. SA 320 Gr. L7M, SA 193 Gr. B7M, SA 194 Gr. 7M, SA 194 Gr. 2HM)
10) Refer COMPANY Standard Drawing Anchor bolts for more detail. Use of High Strength Anchor bolts is not recommended and shall be subject to COMPANY Approval.

13. FABRICATION

13.1. GENERAL

13.1.1. All exchangers shall be fabricated in accordance with this specification, Pressure Vessel specification, Design Criteria for Static Equipment, Requisition including all referenced Specifications, Codes and Standards.

13.1.2. Fabrication and Testing shall shall be in accordance with respective Group COMPANY specification for Welding and NDE of Pressure Vessels and Heat Exchangers (wherever available) and Group COMPANY specific ANNXEURE, as applicable.

13.1.3. For critical service application, see para. 6.10.3 of this specification.

13.1.4. Unless otherwise agreed with the COMPANY, heat treatment shall be applied to bonnet and floating head cover if there are 4 or more tubeside passes and the partition plates are in two different planes.

13.1.5. PWHT is required for cyclic service shell and tube heat exchangers with thickness exceeding 20 mm.

13.1.6. Following shall be ensured during fabrication & inspections of heat exchanger:

a. SUPPLIER shall utilize proper manufacturing technique like installing temporary stiffeners to avoid out of roundness, and especially during nozzle to shell welding in order to meet shell to baffle clearance fabrication tolerance as per TEMA Standard.

b. Shell of exchanger shall be inspected for out of roundness/ovality for inside diameter just before bundle insertion

c. After template insertion and prior to bundle insertion, the shell surface of the shell side exchanger shall be visually inspected from the inside. If grinding is observed, the thickness of ground region shall be 'verified by UT inspection.

13.1.7. For full / partial replacement of exchanger by COMPANY, material receiving inspections by Third Party Inspector (TPI) shall include shell thickness verification before accepting/installing the new exchanger. For new exchanger supply by EPC CONTRACTOR, baseline thickness shall include shell thickness measurement specific but not limited to shell around the nozzle. Further, during Warranty shutdown shell thickness verification specific but not limited to shell around the nozzle shall be ensured.

13.1.8. Tubesheet, flange, Shell, nozzle shall be cladded or weld overlayed when required. Loose liners in any form shall not be provided.

13.2. WELDING

Certified welding procedures and complete qualification test records shall be in accordance with this specification, pressure vessel specification, requisition including all referenced specifications, codes and standards.

13.3. FABRICATION REQUIREMENT OF TITANIUM PARTS

13.3.1. Fabrication of tube bundles with titanium components shall comply with the following additional requirements:

a. All contact with steel shall be minimized throughout fabrication, storage and shipping. Nylon straps shall be used for lifting. Nylon or wooden slats shall be used to avoid contact with floors. When shipped separately, bundles shall be crated for shipping. All brushes and tools shall not have had previous use on any other materials besides titanium. No steel brushes can be used and brushes shall be stainless steels or higher alloys.

b. At the completion of fabrication, the bundle surfaces shall be pickled by flushing or soaking in a 35 to 5 (or 12 to 1 volume percent) HNO3-HF solution at ambient temperature for 5 to 10 minutes. This shall be followed by flushing with potable water.

c. Nylon straps shall be a minimum of 25 cm wide and multiple lifting points shall be used.

d. U-bends shall not be stress relieved.

e. Rolling shall be done per the tube SUPPLIER'S recommendations, subject to CONTRACTOR'S review.

f. Tube-to-tube sheet strength welding, shall be done using automated GTAW processes and the welding procedure shall be submitted to CONTRACTOR for approval.

13.3.2. The tests to be carried out for welding procedure qualification shall be indicated by the SUPPLIER and approved by COMPANY, who reserves the right to witness the performance of the tests. These tests will include a dye penetrant test and Vickers hardness tests on the weld and in the heat affected zones. The hardness value thus detected shall not exceed by more than 40 HV10 than the hardness measured on the base metal.

13.3.3. Fillet welds shall be carried out with at least two passes.

13.3.4. Before welding, both the edges and the filler material shall be cleaned and degreased, preferably with ethyl alcohol (methyl alcohol shall not be used); all traces of oxide shall be removed.

13.3.5. Each weld shall be carried out taking the greatest care to ensure the necessary shielding, by argon or helium, with uniform and non-turbulent flow, over all titanium areas.

13.3.6. During the visual examination, titanium welds shall have a regular appearance and shall be free from irregularities, undercuts or surface defects. Furthermore, after completion of welding and before any cleaning, they shall be of bright silver or light straw color. Any blue color beside the weld or in small areas of the bead is acceptable provided it is removed by brushing and/or polishing.

13.3.7. In any case, COMPANY Inspector has the authority of requiring a production hardness testing on each weld seam suspected to be oxidized or contaminated. If Titanium welds metal hardness is more than 40HV10 greater than base metal hardness the weld shall be removed.

13.3.8. During the heat treatment of titanium parts, the necessary precautions shall be taken to avoid damage or deterioration in the titanium (as, for example, protection with argon). In particular, care shall be taken to avoid any iron contamination (for example by performing pickling and/or phenanthroline or ferroxyl tests).

13.3.9. Titanium tube-to-tube sheet joints shall be strength welded and expanded.

14. INSPECTION AND TESTING REQUIREMENTS

14.1. GENERAL

14.1.1. SUPPLIER shall conform to 'Inspecton and Test Plan' included in the requisition, equipment data sheet, this specification, Pressure Vessel specification, Design criteria, relevant specification, codes and standards.

14.1.2. Mock-up test for tube to tubesheet joint shall be performed if specified in the datasheet.

14.1.3. Exchangers which are to be stacked in service shall be shop assembled.

14.2. NON DESTRUCTIVE TESTING

14.2.1. NDE shall be in accordance with respective Group COMPANY specification for "Welding and NDE of Pressure Vessels and Heat Exchangers" and for Critical Services, shall be followed (wherever available) and Group COMPANY specific ANNXEURE, as applicable.

14.2.2. Where the internals are designed for design pressure on one side with full vacuum on the other side, the test pressures on the tube or shell side shall be calculated to test the internals at least to their full design pressure (including vacuum) multiplied by the Code factors.

14.2.3. A separate hydrostatic test shall be carried out for shell and tube-side. Then a hydrostatic test for the complete exchanger (both sides) shall be carried out.

14.2.4. The shell-side hydrostatic test shall be conducted with the bonnet or channel cover removed.

14.2.5. Shell side hydrotest shall be performed with the tube to tubesheet joints visible for inspection.

14.2.6. Piping bolts and gaskets used during testing shall be replaced with new sets before the equipment is packed for delivery. SUPPLIER shall ensure that tube bundle thoroughly drained and dried following the pressure test to ensure no corrosion takes place between testing and installation. Heat shall not be used in this drying process.

14.2.7. Supplier shall provide a test component consisting of a test ring and packing gland, in accordance with TEMA, Figure E-4.1,3-2 or equivalent, for each heat exchanger or group of similar heat exchangers with split ring floating heads ("S" type).

14.2.8. Each exchanger with a bonnet-type head, a removable bundle, and a tubesheet of diameter smaller than the outside diameter of the connecting shell flange shall be provided with a test flange.

14.2.9. Unless otherwise specified in the data/requisition sheet, each unit of identical heat exchangers performing a common duty shall be equipped as follows:
a. One test flange or ring, for two bundles per unit,
b. Two test flanges or rings, for three or more bundles per unit,
c. Two test flanges or rings, for stacked exchangers with direct interconnections.

14.2.10. Special tests, such as helium or submerged bundle leakage testing shall be required when stated in the requisition / datasheet.

14.3. TESTS FOR IRON CONTAMINATION ON TITANIUM SURFACE

14.3.1. Iron contamination tests shall be performed after liquid penetrant examination for all Titanium surfaces.

14.3.2. In case of execution of heat treatment, the iron contamination tests shall be performed on all accessible titanium surfaces, previously cleaned (for example with a 30% HNO3 and 3% HF solution at 86~122°C, followed by water rinsing). Otherwise, iron contamination test shall be performed only on Titanium cladded surface of tube-sheets and the relative end-tubs.

14.3.3. In any case, COMPANY Inspector has the authority of requiring the Iron contamination tests on each surface suspected to be iron-contaminated.

14.3.4. The iron contamination shall be checked with phenanthroline test or with ferroxil test: The procedure for test shall be described in detail by SUPPLIER and approved by COMPANY.

14.3.5. Where any coloration (orange-red for phenanthroline, blue for ferroxil) reveals iron contamination, this shall be removed with abrasive cleaning or suitable pickling and the iron contamination tests shall be repeated.

15. PAINTING REQUIREMENTS

15.1. Surface preparation, coating and painting for all external steel surfaces shall be performed in accordance with respective Group COMPANY specification for “Specification for Painting & Coating of New Equipment”.

15.2. External surface preparation, priming and painting shall only be carried out after hydro test and all other tests have been satisfactorily completed.

15.3. The following surfaces shall not be painted:

a. No painting for Inside surfaces of exchangers.
b. Machined surfaces and flanged faces.
c. Nameplates and identification tags.

16. PACKING, SHIPPING AND PRESERVATION REQUIREMENTS

16.1. PACKING

16.1.1. Packing of equipment shall be in accordance with respective Group COMPANY specification for “Preservation and Export Packing” and additional requirements of this Specification.

16.1.2. SUPPLIER shall be solely responsible for the adequacy of the preparation for shipment provisions with respect to materials and application, and to provide equipment at the destination in ex-works condition when handled by commercial carriers. All components shall be adequately supported / protected to prevent mechanical damage and atmospheric corrosion in transit and job site.

16.1.3. For Kettles (type “K”) a “hold” angle shall be provided, placed above the tube bundle, to keep bundle in place during shipment and handling. It is to be located directly above and close to the floating head flanges (type “T”) or the full support plate (at u-bend) when u-tube construction is used.

16.1.4. Preparation for shipment and packing will be subject to inspection and rejection by COMPANY’s/CONTRACTOR’s inspectors. All costs associated by such rejection shall be to the account of the SUPPLIER.

16.1.5. Shop assembled stacked exchangers shall be designed for single lift in fully-dressed-up condition with all necessary fixtures suitable for lifting, transportation and erection shall be designed and supplied by SUPPLIER.

16.1.6. All nozzle openings / connection points / flanges shall be provided with metal covers of 5 mm thickness and synthetic rubber gaskets. At least 4 full diameter bolts shall be used for this. Unpainted finished surfaces shall be coated with a suitable rust preventative. Threaded openings shall be protected with steel caps or solid shank steel plugs. Non-metallic plugs or caps shall not be used.

16.1.7. Post weld heat treated boxes shall be marked: “DO NOT WELD”. SUPPLIER shall provide adequate protection against sea water / salt laden air, during sea transportation, as required by applicable specifications.

16.1.8. All lifting items (spreader bars, slings, shackles) shall be certified with one of internationally reputed certifying agency.

16.1.9. Exchangers shall be thoroughly cleaned inside and outside and shall be free of grease, weld spatter, scale, slag, rust and all other foreign matter. After inspection and test, equipment shall be completely free of water and dry before start of preparation for shipment.

16.1.10. When a heat exchanger is dismantled for any cause, it shall be reassembled with new gaskets of the same type and material.

16.1.11. The COMPANY / CONTRACTOR shall carry out a final inspection prior to shipment to check and ensure a proper protection for shipment. However, SUPPLIER shall be entirely responsible for the adequacy of the packing for shipment and storage on site.

16.2. SHIPPING

The method of shipping shall be in accordance with the Purchase Order.

16.3. PRESERVATION

16.3.1. Preservation of equipment shall be in accordance with respective Group COMPANY specification for “Preservation and Export Packing” specification.

16.3.2. The Supplier shall ensure that detailed and specific instructions for the preservation and maintenance of equipment while stored at the construction site, from receipt at site to operational start-up, shall be delivered to construction site with the equipment. Such instructions shall include as a minimum the preservation and maintenance schedule, preservative materials, lubricants to be used etc.

16.3.3. Components (tube bundles) requiring storage at restricted temperatures and humidity shall be boxed separately and identified for controlled climate storage.

16.3.4. Spare parts shall be preserved from environmental corrosion, and preservation methods shall be suitable for long term storage (Humid environment).

16.4. STORAGE

16.4.1. Equipment shall be adequately protected and packaged to allow storage without any damage or negative effects of atmospheric conditions at site for the period of time specified in the Purchase Order.

16.4.2. For additional requirements refer to respective Group COMPANY specification for “Preservation and Export Packing”.

17. DOCUMENTATION

17.1. Supplier shall submit the types and quantity of drawings and documentation for CONTRACTOR'S and COMPANY'S authorization or information as listed in the individual Material Requisitions, Purchase Orders and API 660, cl. 5 & 6 and in respective Group COMPANY vendor document specifications.

17.2. Documentation required along with Technical bid / proposal are as follows;

a. Confirmation for Guarantees (Thermal performance, hydraulic design, vibration free design, Mechanical design, Materials, Workmanship, Accessories etc.).
b. Thermal performance warranty shall verify that exchangers will operate satisfactorily in clean and fouled conditions over the entire range of operating conditions including normal and abnormal operating conditions, steady state, start-up, shutdown and transient operating cases as specified in the data sheets.
c. Thermal and hydraulic performance, vibration analysis calculations shall be performed and submitted even if thermal design of the heat exchanger is carried out by the COMPANY.
d. Alternative design may be offered and specified in proposal. However, the base case shall be submitted as a main scope.
e. Input data and complete results of thermal design shall be submitted in the form of an HTRI.
f. Preliminary general arrangement drawing with all major component dimensional details, minimum thickness calculated in accordance to all applicable specifications and pressure design code, material of construction, saddle location, foundation load data, weights and maintenance space.
g. If an ASME BPVC code case is applied, Supplier to advise in the proposal which shall be subject to approval by the COMPANY and Contractor.
h. Supplier shall submit a Mechanical datasheet or complete the technical details including exchanger type, size, duty, capacity and all details in the datasheet provided.
i. Clause-wise Technical deviations and Exceptions (if any, with detailed technical reasons).
j. Supplier shall confirm to the Vendor Document Requirement List (VDRL) included in the Requisition or provide Supplier's VDRL.
k. Sub-SUPPLIER's list for all major workmanship/materials shall be provided.
l. Fabrication, inspection, and testing shall not be subcontracted without prior written approval by the COMPANY and Contractor.
m. Proposal shall clearly indicate intentions to subcontract part of the work and the name and location of sub supplier.
n. Supplier experience list with similar project.
o. Estimated man-days for supervision of Erection, Pre-commissioning, Commissioning, Start-up, Performance test at site.
p. Size and Weight (shipping and operating) considered for erection.
q. List of special tools, recommended spare parts list and accessories including for site-testing, shipping and erection.

17.3. Documentation required after award of Purchase order

17.3.1. Supplier shall submit the Vendor Document Requirement List (VDRL) directly after award of Purchase Order. This list shall contain all the documents for Supplier work scope, which is mutually agreed between Supplier and COMPANY and Contractor during Purchase order stage.

17.3.2. SUPPLIER shall submit the types and quantity of drawings and documentation for CONTRACTOR'S authorization or information as listed in Vendor Document Requirement List (VDRL) included in the individual Material Requisitions and Purchase Orders.

17.3.3. Comments made by CONTRACTOR on drawing submittal shall not relieve SUPPLIER or SUBSUPPLIERS of any responsibility in meeting the requirements of the specifications. Such comments shall not be construed as permission to deviate from requirements of the Purchase Order unless specific and mutual agreement is reached and confirmed in writing by COMPANY and Contractor.

17.3.4. SUPPLIER shall provide all engineering and design documentation required for erection/installation, commissioning, start-up and maintenance. References to any system and / or mechanical piece of equipment on any document shall be by its tag number and service.

17.3.5. SUPPLIER shall ensure that all the documents can be reproduced clearly and completely.

17.3.6. Wherever safety is involved, documents shall be approved by certifying authority prior to proceed to fabrication.

17.3.7. All documents to be prepared by the SUPPLIER shall be checked and signed by a competent representative of the SUPPLIER for compliance with codes and specifications before the documents are submitted to the COMPANY. For example, all welding-related documents must have been checked and signed by the SUPPLIER's welding engineer. Any documents, in which the checked or approved signature is missing, shall be deemed as having not been submitted.

17.3.8. Following information/data shall be submitted as a minimum:

All additional, requirements as per respective Group COMPANY specifications shall be complied.

17.3.8.1. General Arrangement / Certified Dimensional Outline Drawing shall include;

a. Reference to applicable design codes, tag number, and service
b. Process design data
c. Mechanical design data
d. ASME 'U' / 'U2' stamp requirement and other registrations (if applicable)
e. Hydrotest pressures
f. Wind and seismic codes
g. Critical category
h. Tube to tubesheet joint
i. Materials of construction and corrosion allowances
j. Insulation and fire proofing thickness
k. Special services
l. Bundle, Empty, operating and hydrotest weights
m. Capacity
n. Overall dimensions and direction of flow
o. Nozzle schedule-sizes, flange ratings, types, finishes, projection, locations and orientation
p. Nozzle loadings
q. Gasket details
r. Hydraulic bolt tensioning
s. Nameplate facsimile and location
t. Plant north, datum point and elevation
u. Lifting lug, earthing boss and locations

v. Anchor bolt locations, sizes and projections
w. Tube bundle removal and Shell/channel cover removal clearance
x. Centre of gravity of equipment load
y. Foundation loading data
z. Heat treatment and nondestructive examination requirements
aa. Surface preparation and painting requirements
bb. Reference to applicable project specification and standards
cc. Reference to all relevant detail drawings along with Supplier, Contractor and COMPANY document numbers.

17.3.8.2. Detail Drawings shall identify all component parts with cross reference to indexed bills of materials and shall include:

a. Full views and cross-sectional views with all dimensions
b. Wall thicknesses and corrosion allowances thicknesses
c. Fabrication and assembly details
d. Destructive and Non-destructive Examination requirements for each pressure retaining welds
e. Detailed notes including design, fabrication, materials, NDE, testing, painting, packing, transportation, preservation and installation.
f. Name plate facsimile provided on a separate nameplate drawing

17.3.8.3. Bill of materials may be on drawings or separate documents. Reference balloons shall be used on drawings to identify materials. If on separate documents, a reference table shall be shown on drawings. Bill of Materials shall include:

a. All components' materials of construction and quantity
b. Sizes, thicknesses, ID balloons, and reference drawings
c. ASME Standard designations
d. Manufacturer name, model number, and size of proprietary components

17.3.8.4. Welding data shall include:

a. Welding procedure specifications and procedure qualification records
b. Weld map
c. PWHT procedure
d. Welder/operator qualifications (available for inspection)

17.3.8.5. Data Sheets format and requirements are outlined in API 660, Annex C. The datasheet shall include;

a. Process data including physical properties and heat release curves, when applicable.
b. Parameters defining exchanger's thermal performance (i.e. heat transfer coefficients, calculated pressure drops, Mean temperature Difference, mean metal temperature on shell side and tube side for fixed tubehseet exchanger, etc.).
c. Definition of exchanger's type and orientation.
d. Identification of applicable specification, applicable design code and standard, code stamping requirement, any special design considerations.
e. Design condition on shell side and tube side (design pressure, design temperature, hydrotest pressure, Minimum design metal temperature, depressurization temperature and corresponding pressure, corrosion allowances (Internal/External))
f. Identification of materials for all components including cladding and weld overlay.
g. Outline drawing, defining overall dimensions, baffle spacing, internal expansion joints, required maintenance clearances, locations of vents, drains and any other non-process connections,

process nozzles size, rating, location and projection, saddles location and projections, location and sizing of the anchor bolts, and flow direction.

h. Definition of internals, like baffle spacing, or internal expansion joints.
i. Tube layout including as a minimum: number of tubes, tube diameter, outer tube limit (OTL), baffle cut, baffle orientation, sealing and sliding strips, tie rod location and size, definition of impingement protection (if required), schematic identification of the shellside nozzle size.
j. Identification of materials for all components of heat exchanger including material for gasket for girth flanges and its width.
k. Identification of special services (Sour, Lethal), HIC, extent of NDE requirements, PMI, PWHT requirement, impact test, non-destructive electric test on tube and applicable specification.
l. Identification insulation (Type, thickness, applicable specification), painting system and applicable specification
m. Identification of Criticality Rating and Material test certification.
n. Indicating all nozzles in schedule table with nozzle rating and facing and indicating nozzles which are blind flanged.
o. Indicating Weight (Bundle weight, Erection weight, Hydrotest Weight).
p. Supplier shall provide foundation loading notes for empty, operating, test loading condition for all applicable primary loads including wind, seismic, thermal loads, etc."
q. Identification of type of Tube to tubesheet joint
r. Indicating information for Tube (OD, quantity, minimum thickness, seamless.
s. Identification of requirement of test flange, test ring, hydraulic bolt tensioner etc.
t. Preliminary to the scale drawing outlining major dimensions including but not limited to Shell & Channel minimum thicknesses, girth flanges and Tube sheet dimensions including raised face thicknesses etc.
u. For fixed tubesheet exchanger, differential thermal expansion data for all designated operating and upset conditions.
v. For reboilers, thermosyphon type, inlet and outlet piping lengths (sketch) for hydraulic calculation and related Column details.
w. For Kettle type exchanger, maximum allowed entrainment.
x. Identification of any special components such as annual distributor, internal injection ring, integral heating/cooling jacket, etc.

17.3.8.6. Calculations shall include;

a. Thermal Calculation shall include complete input, output, run-time messages & vibration analysis using latest version of HTRI.
b. Pressure parts such as shells, heads, nozzle reinforcements, flanges, gaskets, Cover, tubes, pass partition, supports, lifting devices and pulling devices for design case and hydrotest case.
c. Structural design for all dead, test, operating, transport, seismic and wind loads
d. Nozzle shall be checked for the external loads for the Design Pressure and Temperature in the corroded condition. Nozzles are to be checked for the specified load across the nozzle neck, at the edge of the nozzle attachment, and at the edge of the pad attachment
e. Wind and Earthquake/ Seismic loads shall be calculated as per Structural Design Basis specification.
f. Calculations corresponding to percent expansion of tubes for tube-to-tubesheet mechanical connection.

17.3.8.7. Procedures shall include;

a. Quality plan/Quality control procedure.
b. Inspection and test plan (ITP).

c. Tube-to-tubesheet joints procedures for welding, uniform hydraulic expansion, inspection, testing and repair.
d. Mock-up test procedure of tube to tubesheet joints shall be furnished before the commencement of tube to tubesheet expansion and/or welding.
e. Non-destructive examination procedures including radiographic, magnetic-particle, liquid-penetrant, ultrasonic, etc.
f. Destructive examination procedures including Impact testing procedure
g. Positive material identification (PMI)
h. PWHT procedures.
i. Tube-to-tubesheet leak-test procedure
j. Bundle extractor procedure
k. Hardness test procedure
l. Bolt tightening procedure
m. Procedures for assembly of flanged joints, if controlled bolt-tightening procedures (such as hydraulic torque wrenches or hydraulic tensioning devices) are used. Any required lubricants shall be stated. For the application of bolt tensioning equipment, the following information shall be available for each flange of the equipment to be tightened:

    i. Required bolt stress/load, from the flange calculation, load factor and hydraulic pressure
    ii. Tool size and number of tools to be applied
    iii. The maximum work load that can be applied by the tool at maximum pressure
    iv. Provision of bolts with extra threaded lengths for attachment of the bolt tensioners.

n. Hydrotesting procedures
o. Surface Preparation and Painting Procedures
p. Procedures for the shipping, lifting, storage, preservation and erection of equipment
q. Procedures for assembly/disassembly and cleaning

17.3.8.8. Records shall include;

a. Tube wall reduction records.
b. Certified record of all impact tests performed.
c. Hydrostatic test records in the form of a chart or certification.
d. Certified mill test reports for all pressure parts, including tubes (each material test report shall be identified by a part number).
e. Temperature charts of all post-weld heat treatments.
f. Nameplate rubbing.
g. Certificates for each mechanical and / or performance test shall be furnished, including hydrostatic test certificates.
h. The SUPLLIER shall supply test documentation covering all the tests, which are to be performed during the implementation stages and the installation & commissioning Phase. The SUPPLIER shall supply all relevant test and calibration certificates applicable to the instrumentation equipment.

17.3.8.9. Shipping and Handling Data shall include;

a. Layout drawings for the testing, shipping, lifting, storage and erection of equipment
b. Lifting arrangement drawing for vertical exchangers
c. layout drawings for assembly/disassembly and extraction of tube bundles, cleaning and bolt tightening

17.3.8.10. Spare Parts and interchangeability Record (SPIR) shall include the list of all spare parts. SPIR shall be submitted with proper drawings and documentation before commissioning in order to prepare the required spare parts list with correct data and quantity on time.

17.3.8.11. Final documentation shall include;

a. Final “as-built” drawings and documents shall be supplied in accordance with the requirements of Purchase Order and shall be part of the Supplier final documentation compiled for each exchanger. The specific format and content of the Manufacture's data books shall be in accordance with the “Pressure Vessel Specification and respective Group COMPANY Specification. Number of hard copies shall be agreed in Vendor Drawings & Requirement List (VDRL).

b. Soft copy of the final As-built documentation shall be submitted in native format with agreed version as agreed in the requisition. Purchaser should be able to edit the native files submitted. The drawings and design submitted are considered the property of the Purchase and are not to be used or reproduced without his permission.

i. All drawings are in Autocad file.
ii. Datasheet and Documents in Excel/Word file.
iii. Thermal calculation in HTRI
iv. Mechanical calculation in PV Elite/Compress files.
v. Miscellaneous calculation in Excel files
vi. All other documents in editable files.

17.3.8.12. Lessons Learned shall be prepared upon completion of works related to the scope of this document, a descriptive summary of lessons learned and made available to the Supplier / Consultants / COMPANY Stakeholders and shall be forwarded to COMPANY and Contractor Lessons Learned System as appropriate.

SECTION D

Standard Drawing:

Applicable Standard Drawings indicated in group COMPANY ANNEXURE shall be followed

SECTION E

PART II AMENDMENTS AND SUPPLEMENTS TO TEMA STANDARD

Amendments and supplements to TEMA Standards tenth Edition, 2019. The paragraph numbers as listed in TEMA are maintained. Paragraphs of TEMA that are not mentioned in this specification shall apply as written. Latest edition of standard at the time of Contract shall be followed. For editions/amendments subsequent to tenth edition, CONTRACTOR/SUPPLIER shall amend this specification and obtain COMPANY approval prior to implementation. The latest available is TEMA Standards Tenth Edition, 2019 to be aligned with.

SECTION 1 HEAT EXCHANGER NOMENCLATURE

N-1.1.1 NOMINAL DIAMETER

Delete this clause and replace with:

Nominal diameters shall be listed in millimeters and shall be in accordance with paragraph RCB-3.1.1 of this Specification. For kettles, port diameter shall be stated first, followed by shell diameter

N-1.1.2 NOMINAL LENGTH

Delete first sentence of paragraph and replace with:

The nominal length of the heat exchanger shall be the tube length in millimeters.

N-1.2 TYPE

Add new clause:

N-1.2.1 Front end stationary head and Rear end head type selection

1. Type B front head shall be used for “clean service” and/or for design pressure above 30.0 kg/cm2(G). (Extended tubesheet shall be used for B type Heads). For “fouling service” and for design pressure less than or equal to 30.0 kg/cm2 (G), Type A front head shall be used.

2. For fixed tubesheet designs, Rear end head Type M should be used, however, for those heat exchangers with a Type A front end stationary head and an odd number of tube passes, Type L shall be selected.

3. Rear end head Type S should be used for floating head type heat exchangers with a nominal shell diameter of more than DN 250. Alternative construction would need to be considered for diameters up to DN 250. Rear end head Type T shall be used for a kettle type heat exchanger with floating head.

4. Types P and W are not permitted.

5. High pressure or other design requirements may justify deviation from the guidelines shown.

N-1.2.2 SHELL TYPE SELECTION

1. The single-pass shell, Type E, shall be selected for general duties, except as indicated below:

    a. Where the shellside pressure drop is a restricting factor, the divided flow shell Type J or cross-flow shell Type X or double-split flow shell Type H, should be considered. Divided flow may be considered where tube vibration is a problem.
    b. For horizontal shellside thermosyphon reboilers, Types G, H, J, or X should be selected.
    b. The kettle type shell, Type K, should be selected for boiling where almost 100% vaporization (0-5% entrainment) or where a phase separation is required. Adequate disengaging space and if required an entrainment eliminator in the shell shall be considered.
    c. The use of TEMA Type F shells with removable bundles is discouraged unless there are considerable economic savings or design advantages.

2. Floating head design is preferred for high frequency of cleaning on shellside or provision for differential thermal expansion between shell and tubes is required.

3. When F shell is used, limit shellside pressure drop to 0.49 kg/cm2 (7.0 psi) per shell and temperature differential between shell inlet and shell outlet to 110°C (200°F). For a removable bundle, the gap between the baffle and the shell is closed with a double-sided, multi-layered clip-on spring set. For non removable bundle, the longitudinal baffle is welded to the shell.

4. The use of longitudinal baffles preferred for less frequency shell side cleaning. Tube bundle longitudinal baffles shall be limited to exchangers with TEMA type F, G and H and clean service on shell side. Longitudinal baffle shall also be designed for maximum Deflection in corroded condition and VENDOR shall provide its calculations.

5. Whenever a temperature cross exists, either (1) design the heat exchanger as a true counter-current unit or (2) increase the number of shells until finite the LMTD correction factor is 0.8 or more. In the latter case, the correction factor shall be based on intermediate temperatures (the temperature between the shells) rather than temperatures from the plots for each zone.

N-1.3 TYPICAL EXAMPLES

Typical examples in TEMA N-1.3 shall not be used. Project units of measurement shall be followed.

SECTION 2 HEAT EXCHANGER FABRICATION TOLERANCES

F-3 TUBESHEETS, PARTITIONS, COVERS AND FLANGES

Add to this clause:

1. The alternate tongue and groove joint arrangement shown in Figure F-3 is not permitted. The plus tolerance on dimension R4 shall be 5 mm, see Note 1 to Figure F-3.
2. The manufacturing tolerances shall be such that nominally identical parts shall be interchangeable. For fabrication tolerances, refer pressure vessel specification, API 660, TEMA and PIPVEFV 1100. Most stringent conditions shall apply.
3. Nozzle flange shall be according to ADNOC Piping Material specification.

SECTION 3 GENERAL FABRICTION AND PERFORMANCE INFORMATION

G-3.2 PURCHASER'S NAMEPLATE

Delete this clause and replace with:

1. All exchangers shall have nameplate in accordance with the applicable COMPANY standard drawing. SUPPLIER/MANUFACTURER may choose to add their standard nameplate as a supplement, but nameplate and bracket materials shall be in accordance with the requirement.

2. Stainless steel nameplate shall be furnished by the Supplier and will be located on the shell near the channel end. Location shall be shown on Supplier's general arrangement drawing. Name plate information and bracket details shall be in accordance with the standard nameplate drawing (later by CONTRACTOR).

3. ASME nameplate shall be marked in accordance with the requirements of the Code. Project Nameplate (per standard drawing), ASME Nameplate and Manufacturer's Nameplate (if require) shall be provided by the Supplier.

4. The nameplate thickness shall be sufficient to resist distortion due to the application of the marking and to be compatible with the method of attachment.

5. The data markings shall be produced by either stamping or preferably engraving, except that the certification mark shall be stamped on the nameplate.

6. Mounting bracket for nameplates shall protrude at least 50 mm beyond the outside of the shell (non-insulated) or outside of insulation/personal protection (insulated).

7. For equipment designed for differential pressure, a suitable warning plate shall be supplied accordingly in addition to the project and ASME nameplates.

G-3.3 ASSET NUMBER PLATE (NEW CLAUSE)

1. If required by the COMPANY, an asset number plate of corrosion-resistant metallic material shall be provided, attached to the exchanger alongside the MANUFACTURERS name plate.

2. When a spare tube bundle forms part of the supply, an asset number plate shall also be provided and fixed to the tubesheet.

3. The asset number plate shall show the text 'ASSET No.' in lettering 6 mm high, followed by a space 15 mm (5/8 inch) by 65 mm (2 1/2 inch) for the asset number.

G-4.1 DRAWINGS FOR APPROVAL AND CHANGE

Add to this clause:

SUPPLIER/MANUFACTURER drawings shall be supplied in accordance with respective Group COMPANY specification for Supplier / Vendor document and deliverables list attached to the Purchase Order agreement, which shall define which drawings are for Approval and which are for Information. Mutually agreed schedule of submittals shall be included in the Purchase Order.

G-4.2 DRAWINGS FOR RECORD

Delete this clause and replace by:

Final “as-built” drawings shall be supplied in accordance with the requirements of Purchase Order and shall be part of the SUPPLIERS/MANUFACTURERS final documentation compiled for each exchanger. The specific format and content of the SUPPLIER/MANUFACTURER data books shall be in accordance with the respective Group COMPANY specification for Supplier / Vendor document and deliverables list and pressure Vessel specification.

G-5 GUARANTEE

G-5.1 GENERAL

Add to this clause:

1. SUPPLIER/MANUFACTURER is ultimately responsible and shall guarantee the thermal performance and mechanical design of the Shell and Tube Heat Exchangers in clean and fouled conditions over the entire range of operating conditions based on the information shown on the equipment Data Sheets irrespective of who perform initial thermal design or rating of the heat exchanger. Exchanger thermal design shall ensure that calculated pressure drop does not exceed the allowable pressure drop specified on the data sheets.

2. Heat exchangers shall be guaranteed by the Supplier against defective design, material and workmanship in accordance with the terms of the Purchase Order

3. The guarantee shall extend for a period of 18 months after shipping date or 12 months from date of start-up of the exchanger unless otherwise specified in Purchase order / Contract Document.

4. If the performance of heat exchanger is not satisfactory after operation, Supplier shall make necessary changes including replacement of defective parts as required, to the original equipment furnished, per COMPANY approval. COMPANY decision is final in acceptance.

5. If exchangers furnished do not meet the specified operating conditions, the Supplier shall furnish FOB (Freight On Board) to the point of use, any necessary additional equipment to meet the specified conditions, or make changes, as required, to the original equipment furnished, per COMPANY approval.

G-6.2 DRAINING

Delete last sentence.

G-6.4 THREADED CONNECTION PROTECTION

Delete this sentence (since threaded connections are not permitted).

G-7.1.1 HORIZONTAL UNITS

Add to this clause:

1. Support saddles shall be in accordance with equipment datasheet, this specification, Pressure vessel specification, and requisition along with referenced project specifications and standard drawings.

2. Each shell and tube heat exchanger shall be designed as a self-supporting unit without guys or braces. The support type shall be specified in the mechanical data sheet by the Contractor.

3. Supplier shall be responsible for verification of all thicknesses in saddle design, especially the thickness of the base plate, at the point of interface with foundation design.

4. Saddle bearing plates shall be of the same material as shell and shall be continuously welded to the shell.

5. Sliding saddles shall be designed to allow thermal expansion and contraction during start-up, shutdown and normal operating conditions including full vacuum, as specified on the data sheets. The sliding saddle support shall have slots oriented in the direction of thermal movement. Stacked exchanger design shall consider the differential expansion requirements for both shell side interconnection nozzle and tubeside interconnection nozzles.

6. The fixed saddle support shall have holes of suitable size for the anchor bolts.

7. The datasheet shall specify locations of the fixed and sliding saddles and dimension from shell and tube heat exchanger centerline to underside of saddle base plate indicated.

8. The Supplier shall be responsible for design and sizing of the anchor bolts, slots and holes considering requirements indicated in project standard drawing.

9. For stacked exchangers, the saddles shall be continuous over the shell circumference, except for the top shell.

10. Saddle supports for stacked exchangers shall be designed to carry the superimposed loads, which occur during operations and during shut down for maintenance, e.g. pulling of tube bundles, without distorting the lower shell.

11. For stacked heat exchangers where the nozzles on the shell side and channel side are directly connected, a set of shim plates of corrosion-resistant material, with a total thickness of 12 mm (7/16 inch), shall be provided for inserting between the upper and lower saddle supports. The shim plates shall not be permanently attached to the saddles.

12. For stacked heat exchangers, the combined construction shall be able to accommodate the weight and withstand the pulling force as defined in the TEMA standards otherwise the saddles shall be continuous over the shell circumference, except for the top shell.

13. Bolting of flanges of mating connections between stacked exchangers shall be removable without moving the exchangers.

14. To ensure correct alignment of stacked exchangers, a trial assembly shall be carried out at Supplier works, using the specified gaskets between the intermediate nozzle flanges.

15. Saddles shall protrude beyond the bottom process nozzles and/or drain nozzle with blind flange, by at least 50 mm (2 inch) to prevent damage to flange facings during transport, storage and maintenance.

16. Anchor bolt details with locations, schematic diagram of base plates etc. shall be provided in general arrangement drawing for foundation design.

17. The support and interconnecting saddles (stacked condition) shall also be designed to withstand bundle pulling force equal to 150% bundle weight, referenced to the top exchanger's centerline.

18. When use of PTFE replacement is practically feasible, following shall be followed.

    The saddle base plate on the sliding end shall be welded with a slide plate assembly. Slide plate size shall be larger than the saddle base plate size composed of metal backing plate (SS 316 3 mm thick) and a low friction coefficient material (PTFE or similar, 2.5 mm Thick) bonded on it. A similar slide plate assembly composed of metal backing plate thickness no less 20 mm bonded with low friction coefficient material (PTFE or similar) of the same order thickness shall be provided on the Structural Beam / deck beam (for Offshore) / concrete pedestal. The heights of fixed and sliding saddles shall be varied during manufacture to permit sliding plate assembly installations with centerline for the equipment remaining horizontal. Initially, composite thickness of both the sliding plates' assembly can be assumed to be 27 mm before detailed engineering is performed. The thickness/metallurgy/sizes of the of the low friction coefficient pad plates shall be revisited during detailed design activity when final dimensions will be computed. Necessary guiding arrangement shall be provided.

    The value of co-efficient of friction of aged-sliding surface shall be obtained from the MANUFACTURER and same values shall be used in the design. But in no case co-efficient of friction used in design shall be less than 0.1.

    Maximum bearing stress on the low friction coefficient material (PTFE or similar) shall be checked. The bearing stress on low friction coefficient material (PTFE) shall be within allowable limits for the equipment design temperature.

When PTFE replacement is not practically feasible. same arrangement of sliding plate assembly as stated above shall be provided without PTFE and co-efficient of friction used in design shall be 0.4

Alternate proposal to above when proposed by Manufacturer shall be subject to COMPANY approval

19. The base plates for saddles shall be preferably in one-piece construction without any weld joints

G-7.1.2 VERTICAL UNITS GASS

Delete this clause and replace with:

Vertical heat exchangers shall be supported with ring supports, support brackets welded on shell / tubesheet in accordance with COMPANY Standard Drawing

G-7.2 LIFTING DEVICES

Add to first paragraph:

1. Stacked exchanger shall be designed to handle a complete stack unit & all lifting accessories shall be suitably designed for the same.

2. Exchangers with stacked supply (if specified in the requisition), shall be completed in all respects (at shop) for ready to install conditions. Shop assembled stacked exchangers shall be designed for single lift in fully-dressed-up condition. All necessary fixtures suitable for lifting, transportation and erection shall be designed and supplied by SUPPLIER.

3. Eye bolts shall be provided. The required size and length of thread for the insert and for the eye bolt shall be calculated to resist the force of tube bundle removal. The threads shall be well formed and be a tight fit for maximum grip.

4. Jack bolts shall be provided in all shell and channel girth flanges.

5. Removable channel covers, channel shells, bonnets, and shell return covers shall have a permanent lifting lug(s). The actual weight of the component shall be indicated on the Supplier general arrangement drawing and also stamped in minimum 10 mm high letters on the side of the lug.

6. Channel covers of exchangers located in the area with no crane access or lifting provisions for cover removal shall be provided with a davit. CONTRACTOR shall identify such cases on the Project Data Sheets.

7. Wherever possible, the lug shall be located at the top of component, above the center of gravity; otherwise two lugs shall be provided, located approximately 45 degrees apart. The lifting lugs shall be designed for 200% of the weight of the component.

Notes:

1. Attention shall be given to the possibility of pulling out the insert and stripping the cladding when using force to remove the tube bundle particularly when the material of the cladding is non-ferrous

SECTION 4 INSTALLATION, OPERATION AND MAINTENANCE

E-2.1.2 FOUNDATIONS

Add to this clause:

1. SUPPLIER shall furnish heat exchanger foundation load data (Shear force and Moments) considering all load combinations including hydro-test weight, operating weight, bundle pull out (150% of tube bundle weight) load, empty condition with seismic, wind load, frictional force and thermal expansion loads whichever is governing and shall select number and size of the anchor bolts (setting bolts if mounted on structure).

2. SUPPLIER/MANUFACTURER shall adhere to the location and number of anchor bolts shown on the equipment Data Sheets (if specified). Any correction necessary shall be immediately brought to the COMPANY'S/CONTRACTOR'S attention.

E-2.1.3 FOUNDATION BOLTS

Delete this clause and replace by:

The saddle design shall provide for free thermal expansion of the heat exchanger in the longitudinal direction.

E-2.3.2 TEST CONNECTIONS

Add to this clause:

Test connections in heat exchanger nozzles are not allowed, with exception of the following:

1. For vertical reboilers with tubeside nozzle directly attached to the column, temperature indicators or pressure indicators connections on the tubeside nozzle are permitted.

2. For horizontal stacked exchangers, temperature indicators or pressure indicators connections shall be provided on nozzles of the bottom shell.

E-2.3.3 VENTS

Add to this clause:

Vent connections on shell and tube side shall be flanged. Vents shall be blinded.

E-2.3.4 DRAINS

Add to this clause:

Drain connections on shell and tube side shall be flanged. Drains shall be blinded or connected to Plant drains as per Project Philosophy.

E-3.2.5 RECOMMENDED BOLT TIGHTENING PROCEDURE

Add to this clause:

1. The requirements of hydraulic bolt tensioning equipment shall be in accordance with Pressure Vessel Specification and Design criteria for Static Equipment

2. Nozzles adjacent to shell girth flanges or horizontal shell and tube heat exchanger saddles shall be located with clearance such that bolt tightening equipment can be used on the girth flange bolts.

3. When the application of bolt-tensioning equipment is anticipated in the design stage, due attention shall be given to the clearance required to accommodate the tensioning tools.

E-4.1.4 TEST RING AND TEST FLANGE (NEW CLAUSE)

Shell and tube heat exchangers shall be provided with test flanges or test rings as follows:

1. Each exchanger with a type S or type T floating head shall be provided with a test ring with packing gland.

2. Supplier shall provide a test component consisting of a test ring and packing gland, in accordance with TEMA, Figure E-4.13-2 or equivalent, for each heat exchanger or group of similar heat exchangers with split ring floating heads (“S” type).

3. Each exchanger with a bonnet-type head, a removable bundle, and a tubesheet of diameter smaller than the outside diameter of the connecting shell flange shall be provided with a test flange.

4. Each test flange and ring shall be stamped with the equipment number.

5. Unless otherwise specified in the data/requisition sheet, each unit of identical heat exchangers performing a common duty shall be equipped as follows:
   a. One test flange or ring, for two bundles per unit,
   b. Two test flanges or rings, for three or more bundles per unit,
   c. Two test flanges or rings, for stacked exchangers with direct interconnections.

E-4.2 TUBE BUNDLE REMOVAL AND HANDLING

Delete this clause and replace by:

During removal of a tube bundle from a shell, a pulling cable shall be attached to eye bolts screwed into the tubesheet. The bundle shall be supported on the tube baffles, sliding strips, supports or tubesheets to prevent damage to the tubes. Contact surfaces shall be protected. See (G-7.2) of this specification. When tube bundle pulling equipment is used which requires special provisions, this shall be stated on the equipment Data Sheets and on “as-built” SUPPLIER/MANUFACTURER drawings, as part of the equipment code data books.

Add the following Clauses:

All the necessary eye bolts shall be provided.

Removable threaded plugs shall be provided to protect the eye bolt holes during operation; they shall be of a same material of tubesheet. For clad tubesheets, it shall be same material as that cladding

E-4.33 POST CLEANING PRECAUTIONS (NEW CLAUSE)

Channel and floating head pass partitions shall be arranged such that tube side of each exchanger is self-draining. Pass partition plates may require weep holes. For multi tube-side pass vertical exchangers, provision for draining and venting of each tube side pass shall be envisaged.

After cleaning, tube bundles shall be placed in a self-draining position.

E-4.5 GASKET REPLACEMENT

Add to this clause:

When a heat exchanger is dismantled for any cause, it shall be reassembled with new gaskets of the same type and material.

E-4.7 SPARE AND REPLACEMENT PARTS

Delete the last sentence and add

1. Spares for erection, pre-commissioning and commissioning.
   The SUPPLIER shall provide following minimum commissioning spares for each equipment:

   a. 10% of bolting or minimum 2 sets of each type.
   b. 200% gaskets including gasket for girth flanges, blind flange, test rings, internal flange connection, intermediate process nozzles for the stacked heat exchangers

2. Initial Spares for first year of operation:

   SUPPLIER shall submit an itemised priced list of recommended spares for first one year of operation. It is not included in the basic scope of supply. These spares shall be purchased by the COMPANY.

3. Spares for 2 years of normal operation and maintenance (After first year operation):

   SUPPLIER shall submit a priced list of spares in SPIR form for review and order placement by the COMPANY. The 2 year spare parts are excluded from the base scope of supply.

   Spare parts and interchange-ability records shall be completed for each exchanger/service. Spare part kits shall be detailed to identify each individual item. Detailed documentation for spare parts (sectional drawings with parts list) shall be submitted with spare parts list.

4. Special tools as required in the datasheet:
   a. Hydraulic bolt tensioning device
   b. Bundle pulling/extracting device
   c. Test flanges or Test rings assembly device

SECTION 5 MECHANICAL STANDARDS TEMA CLASS RCB

RCB-1 ADD NEW PARAGRAPH:

Heat exchangers in process/hydrocarbon service shall be supplied in accordance with TEMA R construction. Heat exchangers in non-hazardous utility service as part of package may be supplied in accordance with TEMA C construction.

RCB-1.2 DESIGN PRESSURE

Add to this clause:

Minimum design pressure shall be identified on data sheets. Design Pressure and Tube Rupture Protection of Heat Exchanger shall be in accordance with Process Design Criteria.

Exchanger design shall allow for full independent hydrostatic testing of the tube and shell side.

Unless otherwise stated in the datasheet, shell and tube heat exchanger shall be designed for full vacuum when steam out cleaning is required. Design temperature for full vacuum design shall be based on steam conditions.

All parts of the tube bundle including floating head shall be designed for either full tube side internal pressure with atmospheric pressure or vacuum externally (if applicable) or full shell side pressure acting as external pressure with atmospheric pressure or vacuum internally (if applicable), whichever condition is controlling and results in the greater thickness of the part. The most unfavourable combination of design pressures on shellside and tubeside shall be used in calculations. Differential pressure shall not be used as design basis unless specified.

Stacked shell and tube heat exchangers in series shall be designed for the worst case basis for each side.

RCB-1.4.2 DESIGN TEMPERATURE OF HEAT EXCHANGER PARTS

Add to this clause:

Design Temperature of Heat Exchanger shall be in accordance with Process Design Criteria

For exchangers in series, but with individual shells having different design temperatures, measures shall be taken to prevent incorrect line-up..

Design Temperature (DT) and Minimum Design Metal Temperature (MDMT) shall be as identified on the equipment Data Sheets.

For heat exchangers in series, individual shells of a unit may have different design temperatures for economy in material selection. Where this applies, measures shall be taken to prevent incorrect line-up of shells within the unit.

RCB-1.5 STANDARD CORROSION ALLOWANCES

Corrosion allowances for shell side and tube side shall be as specified on data sheets.

For all exchanger parts, except tubes, the materials of construction and corrosion allowance shall be selected to give exchangers a design service life of 30 years being in accordance with project specifications.

Corrosion allowance for nozzles and manholes shall be equal to that specified for shell/head. Standard corrosion allowance for carbon and low alloy steels shall be 3 mm. Where a larger corrosion allowance is required this will be shown on the data sheets

The corrosion allowance shall be determined by its intended service and shall be added to all pressure parts and non-removable internal parts (partition plates, etc., on all surfaces exposed to the fluid.

Minimum corrosion allowance shall be as mentioned in datasheet. Parts or surfaces which are fabricated of or surfaced with corrosion resistant alloy (CRA) material shall not require corrosion allowance, normally.

RC-1.5.4 LINING, CLADDING AND WELD OVERLAYS (NEW CLAUSE)

Corrosion-resistant lining, cladding or weld overlay requirements shall meet the Pressure vessel specification.

The requirement of corrosion-resistant lining or cladding specified in the equipment Data Sheets/Drawings shall apply for all exposed (wetted) surfaces including the surface of pass partition plates and the side and bottom of gasket grooves, but excluding the tubes.

For exchangers in seawater service, tube and tubesheet / tubesheet cladding shall be of the same metallurgy. A dissimilar metal interface is not acceptable.

In expanded type tubesheet which is constructed with integrally clad plate or with applied corrosion resistant facings, one groove shall be in the center of the cladding/facing material layer.

RCB-1.6.2 EXTERNAL PACKED JOINTS

This clause is not applicable to this specification.

RCB-1.7 ANODES

When specified on Data Sheets, corrosion protection by means of sacrificial anodes/plates shall be provided inside the heat exchangers, in addition to specified corrosion allowance. Sacrificial anode/plate shall not obstruct tube side flow.

They shall be in accordance with respective COMPANY Standard Drawings as appropriate.

Material of anodes shall be based on medium of flow in heat exchanger.

Anode quantity shall be calculated based on surface area to be protected, operating temperature and interval of replacements.

Only rod type anodes shall be screwed to a threaded plug fitted on inside of channel or floating head. If fitted on channel, channel shall be provided with removable cover.

The weight of anodes shall be divided between the passes and proportionate to each of the pass area approximately.

The flow area shall be adjusted in the channel to avoid flow restriction due to anodes.

RCB-2.1 TUBE LENGTH

Add to this clause:

Supplier shall specify the tube length in the equipment datasheet. For 'U' tubes, straight tube length up to tan line shall be specified.

Standard straight lengths for tubes shall be as follows

Table Part II - RCB-2.1 – Tube Length

Standard Straight lengths for tubes shall be as follows:

Millimeters	2438	3048	3658	4877	6096	7315
(Feet)	(8)	(10)	(12)	(16)	(20)	(24)

The maximum length of removable tube bundles should be 7315 mm (24 ft) nominal tube length unless otherwise approved by the COMPANY. The acceptability of the use of large removable tube bundles is subject to the maintenance and handling capabilities of the site. The ratio of tube length to tube bundle outer diameter for removable bundles shall not exceed 12:1.

No size limits are placed on fixed tube sheet exchangers.

Vertical thermosiphon reboilers should be limited to a maximum nominal tube length of 4877 mm (16 ft), unless otherwise approved by the COMPANY

RCB-2.2.1 BARE TUBES

Delete the clause and table RCB-2.2.1 in TEMA

Tubes shall be seamless.

Tube wall thickness shall be calculated in conformance to the applicable pressure vessel code, depending on the MAWP.

Minimum tube wall thickness shall be as listed in Table-RCB-2.2.1. For materials not listed, tube wall thickness shall be selected following a review of applicable design factors (design

pressure, tube diameter, corrosion characteristics, etc.) and current conventional / best practice.

Table Part II – RCB-2.2.1 - Minimum wall thickness of tubes

Tube Material	Minimum wall thickness (Note 1), (Note 2) Millimetres (inches)
Carbon steel	2.11 (0.083)
Low or medium alloy steel	2.11 (0.083)
Aluminium brass	2.11 (0.083)
Aluminium bronze	2.11 (0.083)
Aluminium	2.11 (0.083)
Austenitic stainless steels	1.65 (0.065)
Ni-Fe-Cr alloys	1.65 (0.065)
Admiralty brass	1.65 (0.065)
Cupro-Nickel	1.65 (0.065)
Copper	1.65 (0.065)
Monel, Zirconium or Hastelloy	1.25 (0.049)
Titanium	1.25 (0.049)
Duplex stainless steel	1.25 (0.049)
Super duplex stainless steel	1.25 (0.049)

Notes :

1. For low-fin tubing, this shall be the minimum thickness at the root diameter
2. Average wall basis can be used provided the wall thickness is not less than that specified above

The minimum tube outside diameter should be 19.05 mm (3/4 in). Use of 31.75-mm OD or above tubes requires prior approval by COMPANY.

Tubes with an outside diameter of 19.05 mm (3/4 inch) should be used where the tube-side medium is clean.

Heat exchangers where the tube side fluid has a medium fouling tendency, straight tubes of non-carbon or low alloy steel materials are used.

Tubes with an outside diameter of 25.4 mm (1 in) or larger should be used for where the tube-side fluid has a medium or higher fouling tendency with a fouling resistance.

RCB-2.2.2 INTERALLY -FINNED TUBES

Add to this clause:

Wolverine type S/T (or equal) low and medium height integral fin tubes are acceptable under the following conditions, but require COMPANY approval:

1. The shell side fouling resistance using low fin tubes does not exceed 0.0002 m²hr°C/kcal. Medium height fin tubes are to be used only in gas services with fouling not greater than 0.0002 m² m °C/kcal.
   a. The shell side stream is boiling or in the turbulent regime.
   b. The shell side stream is a clean cooling/condensing service.

2. For circumferential low-fin tubes, the fin density shall not exceed 1181 fins per meter (30 fins per inch).

3. Their application is economically attractive. As a general guideline, the heat transfer coefficients, when corrected for fouling, show the shell side controlling by a ratio of 2:1 or more for low fin tubes and 3:1 or more for medium high fin. To avoid fretting of the tubes in baffle/support plates, the baffle, support plates shall have a thickness in accordance with TEMA Table R-4.41; however, the minimum thickness shall not be less than 13 mm.

4. High-finned tubing is not permitted.

5. Circumferentially finned tube shall not be finned at the U-bends.

6. Use of integrally low fin tubes as per ASTM A 498 (ferrous) or B 359 (Cupper and Copper alloy) is permitted For low fin Ti Tubes.

7. Surface cracking at the fin or wall shall not be accepted.

8. Low finned tubes shall be eddy current tested at the mill.

RCB-2.2.3 LONGITUDINALLY-FINNED TUBES (NEW CLAUSE)

Longitudinally-finned tubes are not permitted for shell and tube heat exchanger.

RCB-2.3 U-TUBES

Add to this clause:

1. Tubes shall be formed from a single length and shall be seamless without circumferential welds. U-tubes shall not be constructed by welding U-bends to straight tubes.

2. U-tube bundle heat exchangers are used to allow for differential thermal expansion between shell and tube bundle.

3. U-tube bundle heat exchangers may be used only in services where at least one of the following conditions are satisfied:
   a. Tube side fluids in clean service.

   b. For tube side fluids with a fouling tendency, a minimum nominal tube diameter of 25.4 mm (1 in) should be used with a centre-to-centre distance between the parallel legs of the U-tube is at least 4 times the tube outside diameter. Tubes with a nominal tube diameter of 19.05 mm (¾ in) should be used with a centre-to-centre distance

between the parallel legs of the U-tube is at least 150 mm (6 in) may be used when approved by the CONTRACTOR AND COMPANY.

Where chemical cleaning is proven effective for medium and high fouling factors, such cases shall be identified and approved by COMPANY. Once approved, they shall be treated as Clean Service.

RCB-2.3.1 U-BEND REQUIREMENTS

Add to this clause:

Bends with radius R < 1.5 (one and a half) times nominal tube OD are not permitted.

RCB-2.3.2.1 CENTER-TO-CENTER DIMENSION

Add to this clause:

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

a. ± 1.0 mm; when the distance is less than 5 times the nominal tube OD.

b. ± 1.5 mm; when the distance is more than 5 times the nominal tube OD.

Flattening at the bends shall not exceed 10% nominal outside diameter of tube at the straight portion

RCB-2.3.3 HEAT TREATMENT

Add to this clause:

1. Postweld Heat Treatment shall be implemented when required by ASME Code Section VIII, Div. 1, this Specification, datsheet, other Project Specifications referenced on Data Sheets, or when specified on Data Sheets.

2. All Carbon Steel U-bends (up to 10 times tube OD bend diameter, minimum diameter 3 times tube OD) shall be stress relieved after bending over U-tube plus 300 mm minimum beyond the point of tangency.

3. All Austenitic Stainless Steel U-bends (up to 10 times tube OD bend diameter, minimum diameter 3 times tube OD) shall be solution annealed after bending over the full length.

4. For nickel alloys, the heat treatment procedure for U-tubes shall be agreed with the COMPANY.

5. Titanium tubes shall not be stress -relieved.

6. 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 bend.

7. Unless otherwise agreed with the COMPANY, heat treatment shall be applied to bonnets and floating head cover if there are 4 or more tube side passes and the partition plates are in two different planes.

R-2.5 TUBE PITCH

Add to this clause:

1. Tube pitch shall be minimum 1.25 times the tube O.D but with a minimum nominal ligament of 6.35 mm.

2. Triangular pitch may be considered for clean and low heat flux services. Triangular or rotated triangular pitch shall not be used for retractable tube bundles.

3. For horizontal reboiler or vaporising services, square pitch shall be considered for tube arrangement.

4. Rotated square layouts (45°) are preferable for Laminar Flow. In turbulent flow, especially for pressure drop-limited cases, square layout (90°) is preferred.

5. The following shall be observed while considering the minimum tube pitch over the pass partition lane:

    a. The difference between the thickness of the partition plate (at the tapered end) and the width of the gasket groove shall result in a clearance of 3.2 mm with a tolerance of ± 0.5 mm.
    b. The minimum distance between the edge of the gasket groove and the tube hole shall be 1.5 mm for expanded tube-to-tube sheet joints, and 3.2 mm for strength-welded tube-to-tube sheet joints.

    In other cases an even greater distance may be required.

RC-2.6 TUBE LAY-OUT (NEW CLAUSE)

The tube lay-out shall ensure that the allowable stresses in the tubes due to temperature differences between tubes in adjacent passes are not exceeded.

For shell side heat transfer and the mechanical construction of the pass partition plates, a minimum of two tube rows per pass are required.

RCB-3.1.1 SHELL DIAMETER

Add to this clause:

Up to and including a nominal diameter of 500 mm (20 in.) seamless pipe shall be used.

For shells rolled from plate, the nominal shell diameter is the shell inside diameter.

The maximum removable bundle weight shall be 20,000 kg. The acceptability of the use of large removable tube bundles is subject to the maintenance and handling capabilities of the site.

No size limits are placed on fixed tube sheet exchangers.

The ratio of tube length to bundle outer diameter for removable bundles shall be less than 12:1. A list of dimensions for TEMA type R heat exchangers, using pipe for shell, is shown in the table R-3.11:

Table Part II – R-3.1.1 - Dimension for Carbon steel pipe

Nominal Shell Diameter		Shell Inside Dia.	Wall Thickness	Schedule No.
Mm	inch	mm	mm	
150	6	146.3	10.97	80
200	8	193.7	12.7	80
250	10	254.5	9.27	40
300	12	303.2	10.31	40
350	14	336.6	9.53	30
400	16	387.4	9.53	30
450	18	438.2	9.53	-
500	20	489.0	9.53	20

RCB-3.1.3 MINIMUM SHELL THICKNESS

Add to this clause:

The minimum wall thickness of any pressure containing part like Shell / Channel / Shell cover shall be as per Pressure vessel specification.

RCB-3.2 SHELL COVER THICKNESS

Add to this clause:

Shell cover heads shall be of true semi-ellipsoidal shape, ratio 2 : 1 and minimum wall thickness shall be as per Pressure vessel specification.

RCB-4.1 TYPE OF TRANSVERSE BAFFLES

Add to this clause:

1. Unless specified in equipment Data Sheets, the baffle selection shall be considering below:
   a. For single-phase fluid flow, horizontally cut baffles shall be used. For two-phase fluid flow, baffles with a vertical cut shall be used.
   b. For draining heat exchanger shells, all baffles and support plates shall have a V-notch, 20 mm wide and 17 mm high, at the lowest point. All baffles and support plates

used in two-phase or vapor flow shall have same size notch on top as well, to allow venting

2. The orientation of nozzle and segmental baffle shall not allow bypassing any of the shell passes.

3. Permissible types of transverse baffles are segmental, double segmental and the segmental type having no tubes in the window area.

4. Single segmental is preferred. Double segmental or no tube in window may be used when shellside pressure drop is limited

5. Vertical cut should be used for condensing services, vapourizing services, liquids containing suspended solids, and in TEMA F, G and H shells. Regardless of baffle orientation, vaporizing flow in the shellside should be designed to be in shear flow rather than gravity flow.

6. Horizontal cut segmental baffles are not acceptable for systems where the shellside fluid is two phase or contains suspended solids.

7. Baffle cut perpendicular to nozzle centerline (normally horizontal cut) is preferred for single phase fluids. Where shellside inlet nozzle has 180° rotation from shellside outlet nozzle, the number of shellside crosspasses must be odd for segmental baffles.

8. All U-tube bundles shall have full support plate at U-bend. The full support plate shall be trimmed to the extent defined by the baffles outline (on top and bottom) but covering the full tube layout. Otherwise the full support plate shall be provided with central openinig for the fluid circulation.

RCB-4.3 TRANSVERSE BAFFLE AND SUPPORT CLEARANCE

Add to first paragraph:

Unless otherwise specified in the equipment datasheet, the clearance between Transverse baffles and supports shall be as specified in TEMA RCB-4.3.

RCB-4.4.1 TRANSVERSE BAFFLES AND SUPPORT PLATES

Add to this clause:

Minimum thickness of transverse baffles and support plates shall not be less than twice the specified shellside corrosion allowance or the thickness specified in latest edition of TEMA RCB-4.41 whichever is greater.

RCB-4.5.2 MAXIMUM SPACING

Replace first sentence:

1. Tube support plates shall be so spaced that the unsupported tube span does not exceed 0.8 times the value indicated in Table RCB-4.52 for the tube material used.

2. It should be noted that this unsupported tube length limit is to stop tube sagging and creep in the bundle. Tube Vibration must be assessed separately.

RCB-4.6.1 SHELL SIDE IMPINGEMENT PROTECTION REQUIREMENTS

Add to this clause:

4.6.1.1. Unless specified on equipment Data Sheets the following shall be adhered to:

1. Steam heaters with steam on the shell side shall always have impingement protection.
2. For non-corrosive, non-abrasive, single-phase fluids, increasing the nozzle diameter to reduce line velocities at shell entrance is preferred to impingement protection.

4.6.1.2. Impingement protection requirements shall be as follows:

1. Impingement plate shall not be used when the diameter of the impingement plate exceeds 50% of the inlet baffle spacing. Instead impingement rod shall be used

2. Impingement rods shall be used instead of impingement plates for the following cases:
   a. When required by 4.6.1.2.1 above
   b. With 'No tube in Window (NTIW)' baffle design
   c. When the inlet baffle spacing is 10% or more of the effective tube length

4.6.1.3 The clearance between the impingement plate and the nearest tubes shall not be less than 3 mm.

4.6.1.4 When impingement plate is used, it shall be a non-perforated plate, which may be rectangular, square or circular, extending at least 25 mm beyond the projection of the nozzle bore, and having a thickness of not less than 6 mm. They shall not be used when the diameter of the plate exceeds 50 % of the inlet baffle spacing.

4.6.1.5 Where an impingement plate is specified with nozzle diameters of NPS 20 or larger, three tie rods/spacers shall be used for support.

4.6.1.6. Vapour or annular distributors may be used to reduce the diameter and weight of the shell

4.6.1.7 Minimum requirement of Impingement rod is specified below

4.6.1.8. When Impingement rods are required, Impingement rods shall have the same OD and pitch as the tubes. They shall extend from the tubesheet to the first baffle and across the full chord length. For staggered tube layouts provide two rows of rods. For 90 degree (inline) tube layouts provide one row of rods.

RCB-4.6.3 TUBE SIDE

Delete this clause and replace by:

1. For gases and vapors, the ρV2 in tubes shall be less than 7000 kg/m-s2 (4700 lb/ft-s2). If it exceeds consideration shall be given to the need for special devices to prevent erosion of the tube ends

2. For liquids other than water, the ρV^2 shall not exceed 8900 kg/(ms² (5980 lb/ft-s2).

3. For two-phase flow, the ρV2 in the tubes shall be checked carefully against the danger of erosion of the tube ends. In such a case, the velocity and density shall be based on a homogenous gas/liquid mixture.

R-4.7.1 NUMBER AND SIZE OF TIE RODS

1. Unless specified on the Project equipment Data Sheets, tie rods and spacers shall be equally divided around the circumference of the baffles.

2. Additional tie rods may be required in order to prevent internal bypassing through partition lanes.

3. In shellside toxic service, spacers are not permitted.

4. Unless specified on Project equipment Data Sheets, the minimum number of tie rods, the minimum diameter of the solid rod and the spacer pipe OD for various sizes of heat exchanger and tube OD's shall be as follows:

Table Part II – R-4.7.1 – Number of Tie Rods and Spacers

Nominal Shell Diameter		Tube OD of 19.05 mm (3/4 in.) and less		Tube OD of 25.4 mm (1 in.) and larger		Minimum Number of Tie Rods
		Solid Rod minimum diameter	Spacer Pipe OD (Schedule 80)	Solid Rod minimum diameter	Spacer Pipe OD (Schedule 80)	
Mm	(inch)	(mm)	(mm)	(mm)	(mm)	
132 – 393	(6 – 15)	12	17.15	12	17.15	4
394 – 698	(16 – 27)	15	17.15	15	17.15	6
699 – 850	(28 – 33)	15	17.15	19	21.34	6
851 – 1231	(34 – 48)	15	17.15	19	21.34	8
1232 - 1537	(49 – 60)	19	21.34	22	26.67	10
1538 - 2540	(61 – 100)	19	21.34	22	26.67	12

5. The screw thread connection of the tie rod in the tube sheet shall have a diameter that is equal to, or slightly smaller than, the diameter of the tie rod.

6. The baffles shall also be supported by solid rods welded to the baffles (where spacers are not allowed) or by spacer pipes, keeping the baffles at distance, with supporting rods inside.

RCB-4.8 BYPASS SEALING

Add to this clause:

1. Sealing strips shall be provided for shell and tube heat exchangers where tubes have been omitted to provide adequate entrance and exit areas.

2. Sealing strips shall be securely attached to longitudinal sides of the baffle plate adjacent to shell wall.

3. Sealing strips shall be provided for all shell and tube exchangers, except in the case of fixed tubesheet and U-tube bundles with a diametric bundle to shell clearance of less than 19 mm (3/4 inch).

4. Sealing strips shall be fixed as close to the baffle-cut line as possible but in no case shall they be placed more than 32 mm or one tube pitch (whichever is smaller) from the baffle cut line.

5. Sealing strips, impingement baffles, sliding strips and tie rods shall not block the entrance or exit areas under the nozzle and cleaning lanes.

6. Sealing strip shall extend from 1st to last baffle.

7. For floating head bundles, one pair of sealing devices shall be provided for every 5 to 6 rows of tubes in the cross flow area. The sealing strips shall not protrude beyond the periphery of the baffles.

8. The sealing devices shall not obstruct the tube lanes or pass partition lanes for tube patterns of 45 or 90 degrees.

9. Sealing strips shall be a minimum 6mm thick continuously welded

R-4.10 SLIDING STRIPS (NEW CLAUSE)

Unless specified on the equipment Data Sheets, the following shall be adhered to:

1. Sliding strips shall be provided to facilitate pulling the tube bundle.

   Sliding strips and sealing strips may be counted as tie rods if properly seated in the baffles, secured with a complete fillet weld and attached to the stationary tube sheet with a full penetration weld.

   Sliding strip shall extend from tubesheet to support plate / last baffle.

2. The sliding strips shall be rigged to ensure their functioning during bundle handling.

3. Sealing and sliding devices should be located in such a way as to minimize the force exerted by the hoisting band on the outer tubes of the bundle.

4. For heavy bundle, rolling system shall be integrated to the bundle to make easier the bundle movable.

5. Sealing strips, impingement baffles, sliding strips and tie rods shall not block the entrance or exit areas under the nozzle and cleaning lanes.

6. Kettle type exchangers shall be provided with “riding rails” (or tracks), fully welded to shell sides, to support and guide the tube bundle.

7. Minimum required size for sliding strips are proposed on each standard tube bundle.

8. Kettle type reboilers, sliding rails shall be fully seal welded to shell to support and guide tube bundle

9. For vertical exchangers, four sliding strips shall be provided, evenly divided around the circumference of the bundle.

10. To avoid damage to the baffles during bundle pulling and replacement, the sliding strips shall protrude 1 to 2 mm beyond the periphery of the baffles.

11. The sliding strips shall not obstruct the tube lanes or pass partition lanes for tube patterns of 45 and 90 degrees (or hinder the liquid inflow to the center tube rows in a kettle-type reboiler).

12. Sliding strips attached to the stationary tubesheet and all baffles with a full penetration weld

Table Part II – R-4.10 - Minimum Required Size for Sliding Strips

Nominal Shell Diameter		Sliding Strip dimensions (minimum)		
		Height	Thickness	
Mm	(inch)	mm	mm	(inch)
132 – 393	(6 – 15)	30	6.0	(1/4)
394 – 698	(16 – 27)	40	10.0	(3/8)
699 – 850	(28 – 33)	50	12.0	(1/2)
851 – 1231	(34 – 48)	60	12.0	(1/2)
1232 – 1537	(49 – 60)	75	15.0	(5/8)
1538 - 2540	(61 – 100)	75	19.05	(3/4)

RCB-5 FLOATING END CONSTRUCTION

Add to this clause:

1. The nominal wall thickness of floating head covers shall be at least equal to the minimum wall thickness of the appropriate nominal shell diameter given in Table R-3.13.

2. On floating heads, the depth of the cover at the crown shall not be less than 6in (150 mm), and the cross over area in each pass shall not be less than 3 times the maximum tube pass area.

3. Packing boxes are not acceptable.

4. The use of exchangers fitted with a floating head and internal bellows is subject to Agreement with CONTRACTOR and COMPANY. If the use of internal bellows is agreed in writing by CONTRACTOR and COMPANY, the details of the proposed floating head and the bellows shall be agreed prior to fabrication.

RCB-5.1.6 FLOATING HEAD NOZZLES

Delete this clause and replace by:

1. Packed floating head nozzles and packing boxes are not permitted.

2. Shell and channel nozzles shall not protrude beyond the inside contour of the shell or channel.

RCB-5.2 OUTSIDE PACKED FLOATING HEADS (TYPE P)

Paragraphs RCB-5.2.1 through RCB-5.2.5 of the TEMA Standards are not applicable since Type P is not permitted.

RCB-5.3 EXTERNALLY SEALED FLOATING TUBESHEET (TYPE W)

Paragraphs RB-5.3.1 through RCB-5.3.4 of the TEMA Standards are not applicable since Type W is not permitted.

ADD

Single pass tube bundle with floating head and having packed gland in shell cover is acceptable only for water tube flue gas heat recovery exchanger units subject to COMPANY approval.

RCB-6.1 TYPE OF GASKETS

Add to this clause:

1. The gasket type and materials for blinded nozzle flanges, external girth flanges and floating head flanges shall be specified in equipment datasheet

2. Gaskets for intermediate process nozzles of the stacked exchangers shall be in accordance with the applicable piping class and as indicated on the exchanger datasheet.

Table Part II – RCB-6.1 - Type of Gaskets

Type	Gaskets	Minimum width		Minimum thickness	
		mm	inch	mm	inch
1	Spiral-wound with graphite filler	10.0	3/8	4.5	3/16
2a	Serrated metal gasket with soft facing ; Shell diameters up to 1000 mm (40 inch)	12.0	½	3.0	1/8
2b	Serrated metal gasket with soft facing ; Shell diameters greater than 1000 mm (40 inch)	16.0	5/8	4.0	5/32
3	Corrugated metal gaskets with soft gasket seal facings	12.0	‘1/2	1.5	1/16
4	Double-jacketed with graphite filler	12.0	‘1/2	3.0	1/8

1. The minimum width and thickness of the peripheral ring portion of approved gasket types shall be in accordance with Table RCB-6.1.

2. The minimum width of all pass partition groove gaskets shall be 10 mm (3/8 in).

3. When lip seal or diaphragm joints are specified instead of gasketed joints, an engineering analysis shall be performed to ensure that lip seal/diaphragm design can accommodate the differential thermal growth.

   a. The design and selection of the lip seal/diaphragm shall be subject to approval by the COMPANY.

4. Gaskets for permanently blinded nozzles, such as vents and drains, manways, and for interconnecting nozzles of stacked exchangers, shall be in accordance with the following.

   a. Spiral wound, graphite-filled gaskets, with centering and inner rings for raised face flanges.
   b. To avoid overstressing of the spiral-wound gasket, an inner and centering ring will be required. An outer centering ring is not required when the flange is recessed to provide confinement on the OD of the gasket. For nominal shell inside diameters 150 mm to 600 mm, gaskets shall be not less than 10 mm wide with thickness of 4.5 mm and centering ring thickness of 3.2 mm. For nominal inside diameters of more than 600 mm, the width of the circumferential part of the gasket shall be 25 mm, the thickness 7.2 mm and it shall have a 4.8 mm thick inner and/or centering ring with a width of 16 mm minimal.
   c. When a connection type other than a raised face flange is specified for either the shell or the tube side inlet and outlet connections, the type of flange and gasket used for permanently blinded nozzles on the shell or tube side shall be specified by the Contractor.

RCB-6.2 GASKET MATERIALS

Delete this clause and replace by:

1. The selection of gaskets depends on the design temperature and pressure, and the corrosive conditions of the service as per table RCB 6.2 to which the flange and gasket are exposed.

Table Part II – RCB-6.2a - Gasket Service Condition

Service Conditions	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 maximum operating temperatures above 230 °C (450 °F)
III	Hydrocarbon streams containing sulphur compounds and naphthenic acids with an acid value exceeding 0.3 mg KOH/g, and maximum operating temperatures above 330 °C (625 °F)
IV	Hydrocarbon streams containing hydrogen and very toxic (acute) services
V	Cooling water operating below 50 ° (125 °F)
VI	Any other corrosive environment
VII	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 VI)

Table Part II – RCB-6.2b - Gasket for Service

Service Condition	Design Temperature °C (°F)	Design Pressure MPag (psig)	Preferred type (Note 1)	Alternative type (Note 1)
I	-200 to 450 (-330 to 850) -200 to 450 (-330 to 850) ≤ 550 (1025)	≤ 2.1 (300) ≤ 5.0 (725) ≤ 10.3 (1500)	3 2 2	2, 1 1 1
II	230 to 450 (450 to 850) 230 to 550 (450 to 1025) 551 to 815 (1026 to 1500)	≤ 2.1 (300) ≤ 5.0 (725) ≤ 10.3 (1500)	2 2 2	1 1
III	330 to 550 (625 to 1025) 551 to 815 (1026 to 1500)	≤ 10.3 (1500) ≤ 10.3 (1500)	2 2	
IV	≤ 260 (500) 261 to 815 (501 to 1500)	≤ 10.3 (1500) ≤ 35.0 (5075)	2 Note 2	
V	0 to 150 (32 to 300) 0 to 150 (32 to 300)	≤ 2.1 (300) ≤ 8.0 (1150)	3 2	2, 1 1
VI			Note 2	
VII	0 to 550 (32 to 1025) 551 to 815 (1026 to 1500)	≤ 35.0 (5075) ≤ 35.0 (5075)	2 2	

Note 1: Refer to Table RCB-6.1 – Type of Gaskets for gasket type
Note 2: CONTRACTOR/MANUFACTURER to suggest suitable gasket selection in these services for COMPANY approval

2. For design temperatures and pressures, and service conditions other than those given in the tables, gasket selection shall be as agreed between COMPANY/CONTRACTOR and VENDOR/ MANUFACTURER.

3. When approved by the COMPANY, double-jacketed gaskets may be used for services unless prohibited by API STD 660 clause 7.10.2.

4. The use of corrugated metal gaskets with soft gasket seal facings shall be limited to exchangers with a nominal diameter less than 1000 mm (40 in).

5. The use of spiral wound gaskets shall be limited to exchangers with a nominal diameter less than 1525 mm (60 in).

6. When gasketed joints are used on both sides of a stationary tubesheet, both gaskets shall be specified to be of the same type, and chosen based upon the fluid with the more severe operating conditions.

7. The COMPANY AND CONTRACTOR shall be consulted on the gasket selection for flanges which are subjected to cyclic or intermittent service.

8. Lip seal or diaphragm gaskets should be considered for use in high-pressure hydrogen service with design pressures exceeding 10.3 MPag (1500 psig) and design temperatures exceeding 260 °C (500 °F).

9. Only gaskets containing non-asbestos materials are permitted.

10. Hardness of solid metal gasket shall be 20BHN less than then hardness of flange face.

11. For sea water applications materials other than graphite filler or graphite layer should be considered.

12. Gaskets for blinded nozzles shall be stainless steel, spiral wound, unless specified otherwise.

13. The gasket metallurgy shall be according to shell and tube heat exchanger and/or cladding metallurgy. If the shell and tube heat exchanger has SS316L cladding, the gaskets shall be to SS316 or if the shell and tube heat exchanger has inconel 625 cladding, gaskets shall be to inconel 625, or if the shell and tube heat exchanger is from carbon steel, they shall be from soft iron. If any special materials other than these are required, they shall be indicated on Contractor's drawings/datasheets and subject to COMPANY approval.

14. NACE MR0175/ISO 15156 shall apply for gasket material in sour service (hardness and chemistry for alloy gaskets, hardness only for CS gaskets). The gasket hardness and finish shall be compatible with hardness and finish of the sealing surfaces of the flanges to ensure sealing. Consultant/Contractor shall define the hardness requirement of gasket and gasket seating surface of the flange in the mechanical datasheet. Metal gaskets used for equipment under "lethal" and/ "wet sour" service, where hardness is restricted

by NACE, hardness tests shall be conducted on the gaskets and reports provided in final documentation.

15. When two gasketed joints are compressed by the same bolting, gasket selection and area of gasket facing shall be such as to ensure effective sealing of both joints without crushing of the gasket under the required bolt load.

RC-6.3.1 GASKET MINIMUM WIDTH

Delete this clause and replace by:

The minimum width of peripheral ring gaskets shall be in accordance with Table RCB-6.1 of this specification for the type of gasket selected.

Add new clause

R-6.3.3 GASKET CONTACT SURFACE

The arithmetic average roughness, Ra, which determines the flange face surface finish required for each type of gasket and flange size

Flange Face Finish shall be as follow:

1. For spiral wound and flexible graphite based gaskets, the gasket contact surfaces shall have concentric or spiral grooves, resulting in a roughness height within the range of 3.2-6.3 µm Ra (smooth finish) in accordance with ASME B46.1. Minimum gasket thickness is 3.2 mm.

2. For jacketed type gaskets, the gasket contact surfaces shall be 0.8-1.6 µm Ra.

3. For solid metallic type gaskets, the gasket contact surfaces shall be 0.8 - 1.6 µm Ra.

4. Flange face finish abbreviations shall be in accordance with ASME B46.1.

RCB-7 TUBESHEETS

RCB-7.1 TUBESHEET THICKNESS

Replace the first para with

.1. The tubesheet thickness shall be per Code rules. Regardless of the pressure design code that is applied, the tubesheet thickness shall be as per ASME Section VIII, Div.1 Part UHX 9.1 Equipment of this type shall be fitted with 100% collar bolts.

.2. All exchangers with removable bundles with a B-type front head shall have tubesheets extended to equal shell flange outside diameter. Tubesheet thickness must be sufficient to allow shell side hydrotest without the need for test rings.

Add to this clause:

1. Tube sheets shall be made of forged steel. Plate material is not permitted for the construction of tubesheeets. Tubesheets shall be a single piece.

2. Divided floating heads are not permitted.

RB-7.2.4 TUBE HOLE GROOVING

Replace the first sentence with

Tube hole grooves shall be square edged, concentric and free from burrs.

Delete the last para and replace by:

For tubesheets constructed of integrally clad plate or with applied corrosion-resistant facings, one groove shall be in the centre of the cladding/facing material layer. For the minimum clad thickness of 10 mm the centerline of the first groove shall be 6.0 mm from the tubesheet's face and the distance between the centerlines of grooves shall be 9.0 mm.

Add to this clause:

The distance from the centre line of the first groove to the cover side of the tubesheet should be 9.5 mm. The distance between groove centre lines should be 9.0 mm.

Tubes shall be roller expanded into the tubesheet with a minimum of two grooves unless a strength-welded joint is required due to service conditions as specified in RCB-7.3.2

For austenitic stainless steel, duplex stainless steel, titanium, Cu-Ni, or Ni alloy tubes, the tube holes shall be in accordance with Table RCB-7.21 column (b) Special Close Fit.

RB-7.3.1.1 LENGTH OF EXPANSION

Delete this clause and replace by:

Tubes shall be expanded into the tube sheet for a length equal to four times tube outside diameter or the tube sheet thickness minus 1/8" (3mm) whichever is smaller. In addition, for tube sheets with thickness in excess of four tube diameters expand one diameter at the shell side face of the tube sheet minus 1/8" (3mm). In no case the expanded portion shall extend beyond the shell side face of the tube sheet. The expanding procedure shall provide substantially uniform expansion throughout the expanded portion of the tube sheet without a sharp transition to the unexpanded portion.

RB-7.3.1.3 TUBE PROJECTION

Delete this clause and replace by:

Tubes shall extend between 3 mm and 5 mm beyond the face of the tubesheet, except in the case of the top tubesheet of vertical reboilers when tubes shall be flush with the face of the tubesheet to facilitate drainage.

Use of tube end protection is to prevent tube end erosions shall be subject to COMPANY approval.

RCB-7.3.2.1 SEAL WELDED JOINTS

Delete this clause and replace by:

Seal-welded joints are not permitted.

RCB-7.3.2 WELDED TUBE-TO-TUBESHEET JOINTS

Add to this clause:

The tubes shall be strength welded and lightly expanded in the following cases:

a. When indicated on datasheet
b. Hydrogen service
c. Very toxic service
d. When austenitic stainless steel tubes and carbon steel tubes are used and when the metal temperature of the joint will be more than 350°C
e. When the design pressure on either shell or tubeside exceeds 50 bar g
f. When the exchanger contains a lethal service
g. When titanium and Alloy 825 tubes are used.
h. For low temperature applications when MDMT is less than -46 °C.
i. Differential pressure across tube sheet is in excess of 50 bar (725 psi) and thermal shock, thermal cycling, vibration or a difference in tube / tube sheet expansion coefficients combined with high or low operating temperature is envisaged.
j. When cross contamination between streams is not acceptable under any circumstances.

The above list is provided for guidance purposes only and is not intended to cover all cases. The requirement for a strength weld shall be considered on a case by case basis taking into account all relevant metallurgical, fabrication, operation and maintenance issues.

For all tube-to-tube sheet designs where the weld is the fundamental strength or pressure-containing element, WPS's shall be qualified and tested in accordance with ASME BPVC Section IX, QW 193, and QW 288. The SUPPLIER shall submit a complete fabrication plan(including assembly, cleaning, weld preparation, rolling and testing) to the purchaser for approval.

When strength welded tube-to-tubesheet joint is followed, it shall be "full" strength welded joint in accordance with ASME Section VIII, Division 1 paragraph UW-20.2(a) and fig UW-20.1

If the equipment datasheet specify 'welded', it shall be considered has 'strength welded'.

The welded connections between a tubesheet and the adjacent cylinder shall be in accordance with ASME Code Figure UW-13.3, Type (a) (b) or (c) or equivalent configurations. Figure UW-13.2 Type (a), (b), (c), (i), (j), (k), or equivalent, may only be used in non lethal,

non-cyclic service where the design pressure is less than 50 barg and the design temperature is less than 350°C.

Tubes shall be welded to the tubesheet in accordance with this specification and Group COMPANY specification “Welding and NDE of Pressure Vessels and Heat Exchangers” where available.

RCB-7.3.3 EXPLOSIVE BONDED TUBE-TO-TUBESHEET JOINTS

Delete this clause and replace with:

Explosive metal bonding on tubesheet and/or explosive expanding of tubes to the tubesheet is not permitted.

RB-7.6 CLAD AND FACED TUBESHEETS

Delete this clause and replace with:

Tube sheets with nonferrous or alloy cladding for corrosion protection shall meet the following requirements:

1. 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) and at least a 5 mm thickness for a strength-welded connection.

2. Bonding the cladding to the tube sheet with solder is not permitted.

3. 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 A 578, with an acceptance level of S7.

4. When Shell & Tube Heat Exchangers are manufactured from integrally clad material no credit shall be taken for the cladding thickness in the design calculations.

5. In case of weld overlay, undiluted chemistry requirement shall meet as per Pressure Vessel and Design Criteria for Static Equipment specification

6. SUPPLIER’s procedure qualifications for clad side welding overlays must include analysis of the weld deposit metallurgy to ensure adequacy of the proposed procedure.

RCB-8 FLEXIBLE SHELL ELEMENTS

Delete this section and replace by:

1. Non-removable bundle exchangers may be used in “clean” shell-side service

2. The maximum controlling differential temperature between the tube and shell-side during operation, start-up, shutdown or steam out and any other upset condition and number of

cycles of operation (for 30 years of life) shall be stated on the Process datasheet and used to determine the requirement for an expansion joint and tubesheet thickness on a fixed tubesheet heat exchanger. If design consideration result in expansion joint being required following additional requirement shall be considered.

3. When Expansion joint are used following requirements shall be followed:

   a. Expansion joints shall accommodate the greatest differential thermal movement between the shell and the tubes for all specified conditions. The design shall be evaluated and analysed for minimum 1500 full operating cycles before rupture. However, this shall be more than ten times the number of cycles expected in a 30 year period. Engineer/Contractor shall finalise no. of cycles based on the above and specify the same in the datasheet.

   b. Expansion joints shall be of single convolution thick walled (flanged and flued) type, with the same material as the shell, designed in conformance with ASME Sec.VIII Div.1 and TEMA. Use of two flanged and flued type expansion joints may be used subject to COMPANY's approval. Flanged only type shall not be allowed.

   c. If flanged and flued type expansion joints cannot accommodate the thermal differences between shell and tube bundle, thin walled bellows type expansion joints, designed in conformance with ASME Sec. VIII Div.1 and EJMA standard, may be used subject to COMPANY's approval. Material of thin walled bellows type expansion joints shall be CRA and the same shall be specified by Engineer/Contractor in the datasheet based on service of the exchanger. Thin walled bellows type expansion joints shall not be used on the shell, when the shell side is designated as any of the following:

      i. Hydrogen service
      ii. Lethal/sour service
      iii. When handling flammable fluids

   d. Expansion joints shall be of the single layer unless otherwise approved by COMPANY.

   e. Length of the expansion joints and preset shall be specified on the Supplier's drawing. The location of the Expansion joint relative to the tubesheets shall be subject to approval from COMPANY.

   f. Expansion joints shall be welded to stub ends of the same material and diameter as the exchanger shell. Expansion joint convolutions shall be welded to the outer wall of stub ends. The edges of the stub ends shall be bevelled for welding to the exchanger shell.

   g. Thin walled bellows type expansion joints shall be properly protected against damage during installation and transportation.

   h. Expansion joints should have guides that allow quick and easy mating of expansion joint end flange to its companion flange on the inside face of shell cover.

i. The expansion joints shall be hydraulically tested at Expansion joint Supplier's shop.

j. Supplier/Manufacturer/Supplier shall prepare expansion joint design and a quality plan for manufacture for COMPANY's approval.

RCB-9 CHANNELS, COVERS AND BONNETS

RCB-9.1.2 MINIMUM INSIDE DEPTH

Add to this clause:

Stationary head Type B shall consist of bonnets equipped with true semi-ellipsoidal shape, ratio 2:1.

RCB-9.1.3.2 PASS PARTITION PLATE FORMULA

Add to this clause:

1. Pass partition plates thickness shall be mechanically designed for the full pressure drop acting across the exchanger
2. Corrosion allowance shall be added at both sides of pass partition plates when corrosion allowance is specified in datasheets.

RCB-9.1.3.3 PASS PARTITION WELD SIZE

Add to this clause:

The first 50 mm of the weld from the joint face of the partition plate shall be full penetration.

R-9.1.3.5 ALIGNMENT (NEW CLAUSE)

The free edge of pass partition plates shall be recessed with 0.2 mm max. measured from the joint face of the head flange, in order to allow full tightening of the flange bolting.

A positive means of alignment with tubesheet grooves such as dowel pins shall be provided to prevent misalignment of multiple pass exchangers.

R-9.1.3.6 DRAINING (NEW CLAUSE)

Drain holes shall be provided in pass partition plates to facilitate drainage. Drain holes shall have a maximum diameter of 6 mm (1/4 in). The location, size, and number of drain holes shall be indicated on the fabrication drawings and subject to the approval of the CONTRACTOR and COMPANY.

RCB-10.1 NOZZLE CONSTRUCTION

Add to the clause:

1. The construction of flanged nozzles and connections shall be in accordance with ASME B16.5. Supplier shall refer to Pressure vessel specification, Design criteria and COMPANY standard drawing for Nozzle projections, minimum Nozzle sizes, flange finish, reinforcement requirements etc.

2. Reinforcing pads are not allowed on shellside nozzles, if their use will increase the inlet or outlet baffle spacings by moving the nozzles' location away from the body flanges.

3. Shell or channel nozzles not directly connected to internals shall not protrude beyond the inside contour of the shell or channel. Packed floating head nozzles and packing boxes shall not be used.

4. The alternate tongue and groove joint arrangement shown in TEMA Figure F-3 shall not be used.

RCB-10.3.1 VENT AND DRAIN CONNECTIONS

Add to this clause:

1. All shell and tube exchangers, including vertical units, shall be provided with vents and drains allowing complete draining and venting of shellside and tubeside of exchangers, after hydrotest at shop and "in-situ".

2. Vertical units shall have vent and drain passages drilled through their stationary tubesheets (including bottom tubesheet of nonremovable bundle), exiting out the outside edge and provided with flanged vents and drain nozzles, with blinds and service gaskets. For multi tube side pass vertical exchangers, provision for draining and venting of each tube side pass shall be envisaged.

3. For stacked exchangers of the same service, hydrotest "in-situ" can be performed in stacked position, but each shell shall be completely drainable and ventable.

   For stacked "S" type shells the drain of the top shell cover and vent of the bottom shall be provided.

4. Separate vents and drains on exchangers are not necessary if hydrotest "in-situ" and subsequent draining and venting of exchangers can be accomplished through piping connections or line breaks.

5. Total condensers shall be fitted with suitable vents for non-condensables.

6. For horizontal condensers, shellside vents shall be positioned on top of the shell and located at the furthest point from the shell inlet. Tubeside vents shall be located in the channel at the highest point at the end of the flow path.

7. For vertical shellside condensers, more than one vent may be required (a high point vent for purging the underside of the tubesheet, and a low point vent for use during start-up). The requirement for, and positioning of, vents on vertical exchangers shall be reviewed on a case by case basis.

8. For steam heated vertical reboilers, adequate provision for venting shell side pass shall be envisaged.

9. For multi tube side pass vertical exchangers, provision for draining and venting of each tube side pass shall be envisaged.

10. Vents shall be provided at the highest point and drains at the lowest point of a Shell and tube heat exchanger or compartment. Where process connections are positioned at these points, they shall be used for test purposes. Operational vents and drains will then be incorporated as part of the piping, unless otherwise stated on the Shell and tube heat exchanger data sheet.

11. All Vent and Drain connections shall be flanged and provided with a blind flange unless otherwise noted in the data/requisition sheets. The minimum connection size shall be DN 50 (2 inches).

12. If a vent or drain connection is used as cleaning connection the minimum connection size shall be DN 50.

13. The design of the Shell and tube heat exchanger shall allow for complete venting, draining and access to carry out unrestricted in-service inspections on all areas of the Shell and tube heat exchanger.

R-10.3.2 PRESSURE GAUGE CONNECTIONS

Delete this clause and replace by:

If required, pressure gauge connections shall be specified on equipment Data Sheets. Pressure gauge connections in heat exchanger nozzles are not permitted, except as defined in paragraph E-2.3.2 of this Specification.

RB-10.3.3 THERMOMETER CONNECTIONS

Delete this clause and replace by:

If required, temperature instrument connections shall be specified on equipment Data Sheets. Temperature instrument connections in heat exchanger nozzles are not permitted, except as defined in paragraph E-2.3.2 of this Specification.

RC-10.3.4 CLEANING CONNECTIONS (NEW CLAUSE)

When exchangers require in service cleaning with hot water, steam, solvents or other chemical methods, suitable flanged nozzle connections of DN 50 (2 inch) minimum size shall be provided on the shell. Cleaning connections are not permitted on exchanger nozzles; however, they may be located on the connecting piping.

RC-10.3.5 SAFETY/RELIEF VALVE CONNECTIONS (NEW CLAUSE)

A nozzle for pressure relief shall be provided if specified on heat exchanger data sheets. Flanges for safety/relief valve nozzles shall have a minimum rating of class 300

RCB-10.6 NOZZLE LOADINGS

1. Piping shall not be supported off the exchanger nozzles to allow easy removal of channels or shells (after disconnecting the piping lines)

2. During operation, the process nozzles shall be able to withstand piping nozzle load in accordance with Pressure Vessel specification and Design Criteria.

RCB-11 END FLANGES AND BOLTING

Add to this Clause:

1. End flanges shall be forged welding neck type and designed as per Pressure Vessel specification and Design Criteria for Static Equipment. Floating head cover flanges need not be weld neck type.

2. Nuts shall have a height equal to the bolt diameter.

3. Slip on flanges are not acceptable.

RCB-11.2.4 BOLT ORIENTATION

Delete the last sentence from this clause and replace with:

Bolt holes in all fixed flanges shall straddle the natural centerlines.

RCB-11.6 BOLTING ASSEMBLY AND MAINTENANCE

Dowel pins shall be provided to prevent mis-assembly of the following bolted joints:
1. Floating-head cover to tubesheet;
2. Channel to tubesheet;
3. Grooved channel cover to channel;
4. Stationary tubesheet to shell

RCB-11.8 COLLAR BOLTS

Delete the clause and replace with

All exchangers with TEMA type B heads shall have the stationary tubesheet outside diameter (OD) equal to the shell flange outside diameter. The tubesheet extended part shall be attached by collar bolts designed to carry out shell side hydrotest with Bonnet removed. Quantity of Collar bolts to be provided is 4 nos or 25% of total number of bolts whichever is greater. Tubesheet thickness must be sufficient to eliminate a need for test rings during hydrotest.

When collar bolts are used, use type I collar stud (solid type) figure RCB-11.8.1. Type II collar stud (nut type) to be used only after approval of the COMPANY AND CONTRACTOR.

SECTION 6 FLOW INDUCED VIBRATION

V-1 SCOPE

Add to this clause:

1. The tubes shall be free of tube vibration. Flow induced vibration analysis report shall be submitted by Supplier. The analysis shall be performed for the exchangers with the following design principles to prevent tube vibration occurring:

    a. The latest versions of HTRI software for verification that designs are free from tube vibration.
    b. The thermal designer should analyze the vibration warnings generated by the program and incorporate the appropriate measures into the design of exchangers.

2. Heat exchangers shall be free of potential damage from mechanical or acoustic vibration under design conditions specified on data sheets.

3. The following design principles shall be used to prevent tube vibration occurring:
    a. The latest versions of either HTRI for verification that designs are free from tube vibration.
    b. Maximum unsupported tube length less than 80% of the values specified in TEMA, Table 4.52.
    c. For all process cases, the shell or bundle entrance and exit area does not produce a value for density multiplied by velocity squared (ρ,V^2) that exceeds 80% of the recommended value in clause RCB 4.62 of TEMA [i.e., 4 762 kg/m s2 (3 200 lb/ft s2)].

4. Mechanical bundle design:
    a. Mechanical design of the tube bundle allowing up to 110% design shell side flow rate without tube vibration.
    b. If there is risk of slugging flow on the shell side of the exchanger, mechanical design allowing up to 200% design shell side flow without tube vibration. Slug flow due to boiling does not require additional allowance on flow unless specified on the datasheet.

V-2.5 ACOUSTIC VIBRATION

Add to this clause:

When detuning baffle or deresonating baffles are fitted parallel to the flow to change the acoustic frequency, this detuning baffle shall extend at one side of the bundle as far as possible to the shell wall. Tube layout needs to be adjusted to allow extra space to accommodate the detuning baffle.

SECTION 7 THERMAL RELATIONS

T-4.7 MAXIMUM TUBE WALL AND BULK FLUID TEMPERATURES (NEW CLAUSE)

4.7.9.1 Maximum bulk water and tube temperatures shall be calculated in a clean exchanger condition with the minimum water flow and the lowest and highest water supply temperature.

SECTION 8 PHYSICAL PROPERTIES OF FLUIDS

1. A complete of the physical properties of the fluids to be provided in the datasheet. Requirement in process design criteria 'Process Design Criteria' shall be followed.

2. In addition to heat duty, fluid identity, flow rates, design pressures and temperatures, operating pressures and temperatures, allowable pressure drops, material of construction and exchanger type and setting, the process data shall include but not be limited to the following:

   2.1. Sensible Heat Transfer Service

      a. Vapor and Gas - Density, thermal conductivity, specific heat and viscosity at two reference temperatures (inlet and outlet), molecular weight and hydrogen partial pressure.

      b. Liquid - Density, thermal conductivity, specific heat and viscosity at two reference temperatures. For liquid streams having a high viscosity, a third viscosity data point at an intermediate temperature or viscosity/temperature correlation is desirable, except that when the viscous liquid is being cooled, the third data point should be at the average temperature of the opposing stream.

         i. Physical properties of hydrocarbon streams shall be weighted to include the effect of miscible water, and shall be so specified.
         ii. Immiscible or free water shall be shown on the Data Sheet. Fluid properties shall not be weighted to include immiscible water.

   2.2. Condensing Service

      a. Physical property requirements shall be the same as for sensible heat transfer plus the bubble point, dew point, latent heat, quantity and molecular weight of noncondensible gas and quantity of steam when present. Vapor physical properties shall be weighted for the entire vapor phase mixture. For cases where H2 content is more than 10 mol percent, vapor mixture physical properties shall be given under three referenced temperatures. Latent heat for a steam/hydrocarbon mixture shall be for the hydrocarbon only.

      b. Data sheets shall state if condensation is linear, unless heat release data is provided.

      c. For non-linear heat release services, a plot with duty, liquid surface tension, weight percent vapor, all fluid properties and molecular weight versus temperature shall be provided.

      d. When fluid-entering exchanger is a vapor mixture at its dew point temperature, liquid properties shall also be given at that temperature unless sensible heat is 10 percent or less of total duty.

2.3. Boiling Service

a. Physical property requirements shall be the same as for sensible heat transfer plus liquid surface tension, mixture bubble point and dew point, critical pressure and temperature and latent heat.

b. The Process Engineer shall provide tables or curves showing vapor temperature and fraction vaporized at two constant reference pressures between bubble point and dew point, with three additional points between. The three additional points must be close to the operating range. For pure components or in cases with very narrow boiling ranges only vapor pressures at two temperatures need be provided.

c. For non-linear heat release services, a plot with duty, molecular weight and weight percent vapor versus temperature shall be provided.

d. For kettle reboilers, the required entrainment ratio (kg liq/kg vapor) shall be provided, including steam purity for steam generators.

e. For thermosyphon reboilers complete piping geometry between the fractionating column and the reboiler must be analyzed, together with the available static head.

f. For thermosyphon reboilers, the heat release data mentioned in clauses ‘b’ & ‘c’ above, as a minimum, be provided at the column liquid level pressure, and at a second higher pressure (e.g. column liquid pressure + 0.5kg)

SECTION 9 GENERAL INFORMATION

Reference data in section 9 of TEMA may be used; unit measurement shall be according to the agreed unit for all the specifications.

SECTION 10 RECOMMENDED GOOD PRACTICE

RECOMMENDED GOOD PRACTICE (RGP) SECTION

Add to this clause:

For the purpose of this specification, this section 'Recommended Good Practice' sets out the requirements, which shall be considered as additional to the requirements of the corresponding paragraphs in the main sections of the TEMA Standards, whether or not amended by this specification.

RGP-RCB-2 PLUGGING TUBES IN TUBE BUNDLES

Add to this clause:

If tubes have to be plugged, defective tubes shall be cut in accordance with the method approved by the COMPANY AND CONTRACTOR.

Plugging of faulty tubes for hydrogen and/or LETHAL Service is not permitted. In these cases, each tube shall be removed and be replaced by two solid rods. The rods shall be welded to the tubesheet and shall fill the holes in the baffle plates (to avoid process fluid leakage), where accessible.

RGP-T-2.4 DESIGN FOULING RESISTANCES

Delete this clause and replace by:

Typical fouling resistances, with reference to the surface on which they occur, shall be specified on equipment Data Sheets. When specific data for setting proper resistances are not stated on the Data Sheets, the COMPANY and CONTRACTOR shall be consulted.

Fouling factor and Mechanical Cleaning requirements should be identified on Data sheets. TEMA fouling factors are now considered to be over-conservative, with emphasis put on COMPANY experience of actual fouling to guide the value used in the design.

Experience has shown that fouling may be mitigated for many services through proper heat exchanger design and operation. For the experienced designer, fouling resistances are not used when operating data for identical or similar services is available. In these cases, designing with the proper attention to velocity (or shear stress) and wall temperature can prevent significant fouling whereas the mere use of a high fouling factor will generally engender a high degree of fouling.

RGP-T-2.5 FOULING MITIGATION DESIGN METHOD-DESIGN MARGIN

Over design margin on the thermal design of the exchanger shall be as per Process Design Criteria

Exchanger shall be designed with a minimum over design margin on duty and flow rate as per process design criteria or allow plugging of 5% tubes for maintenance, whichever is maximum

Deign margins come in several varieties. Process margins on flow or duty are to safeguard the process and ensure that the nameplate production of product is achieved. This is always to be respected in designing the heat exchangers.

Fouling factors are a safety factor. The rate of build up of fouling on surfaces is not known, and will vary with different feedstocks and the way the exchanger and plant is operated. The value used should represent the COMPANY's or Licensor's experience with the process. (TEMA fouling values are worst case values, and are therefore very conservative and should be avoided). Exchangers are designed to provide the required duty with the specified fouling, therefore they will work throughout their operating cycle.

A.1.4.1 OUTSIDE PACKED FLOATING HEAD (TYPE P)

Paragraph RCB-7.141 and sub-paragraphs RCB-7.1411 and RCB-7.1412 of TEMA Standards are not applicable. Type P is not permitted.

A1.4.2 PACKED FLOATING TUBESHEET WITH LANTERN RING (TYPE W)

Paragraph RCB-7.142 of TEMA Standards is not applicable. Type W is not permitted

APPENDIX – 1: WELDING OF TUBE-TUBESHEET CONNECTIONS

SECTION - 1: WELDING OF TUBE-TUBESHEET CONNECTIONS

1.1 INTRODUCTION

The integrity of a heat exchanger greatly depends on the welding methods used to attach tubes to tube plate. weld details as shown below in section 2.

1.2 PREPARATION OF TUBES AND TUBE PLATES

The ends of the tubes which are to be welded shall be cleaned and degreased with a suitable nonresidue forming solvent, both inside and out, for a length equal to the Tube Sheet thickness plus not less than 25 mm. The solvent used for degreasing materials should be chloride free, e.g. acetone. For welding with the GTAW process, the outside ends of the tubes for a minimum distance of 13 mm shall be finished to bright metal, e.g. by finishing or power brushing. For metal arc welding, the tube ends may be grit blasted prior to cleaning and degreasing as agreed. Tubes with score marks or any other surface irregularities at the ends shall not be used if considered to be detrimental to the production of sound welds.

The Tube Sheet shall be machined and the tube holes bored or drilled as required by the design; the holes so formed shall be normal to the Tube Sheet surface, parallel, circular and shall have smooth internal surfaces. They shall be free from burrs and the shell side edges of the tube holes shall be chamfered or rounded to 1.5 mm approximately. The limits of tolerance of tube holes shall not exceed those defined by TEMA. Immediately prior to assembly, the Tube Sheet shall be thoroughly cleaned and degreased using a nonresidue forming solvent.

The face of the Tube Sheet, the holes and the tubes shall be free from dirt, grease, scale and other foreign matter when they are assembled. To avoid possible damage during assembly or entrapment of contaminants, baffle and support plate holes should be free from burrs and effectively cleaned prior to the commencement of tube threading.

1.3 WELDING PROCEDURE QUALIFICATION

1.3.1 General

No production welding shall be carried out until the proposed welding procedures have been evaluated and authorized by the COMPANY AND CONTRACTOR in accordance with the requirements of this Specification. Any change of major variable, but not a replenishment of any consumable, i.e. gas cylinder or electrode, shall require requalification of procedure.

1.3.2 Procedure Test Piece

The test pieces shall be in accordance with APPENDIX -1 Section II

The procedure test shall be welded in the same position as the actual welding shall be done, i.e. vertical or down hand. Also the welding sequence/configuration shall be part of the procedure qualification.

All tubes used for procedure testing shall be of the same diameter, wall thickness and nominal chemical composition as those proposed for production. Plate material to be used for the procedure test shall also be of the same nominal composition as that to be used in manufacture. The thickness of the sample tube plates shall equal that of the plate to be used in production, except that it need not exceed 35 mm thickness. If tube expansion after welding is specified, it may be necessary for a sample of full plate thickness to be employed. The test piece shall be at least 25 mm greater in size all round than the limits of the tube hole array.

1.3.3 Examination of Test Pieces

The completed test pieces shall be examined as follows:

a. Visual examination
b. Macroscopic examination as shown in section 3, with hardness measurements where appropriate.
c. The weld quality shall meet the requirements of paragraph 1.3.5 and 1.3.6 of this section.
d. Weld strength test, see section 3 and 4.

1.3.4 Welder Qualification

Every welder employed on tube end welding shall demonstrate his competence by making a test piece in accordance with paragraphs 1.3.1 and 1.3.2 of this section and section 2, using the same tube dimensions, materials and welding procedures as will be involved in production welding. Welders whose authorized test pieces meet the requirements of paragraph 1.3.2 of this Attachment, are qualified for production welding.

When a welder has successfully passed the appropriate qualification tests within the last 6 months and has been regularly employed in this type and size of weld since passing his test, and there is evidence that the welder has continued to make satisfactory welds, he may be accepted without further qualification at the discretion of the CONTRACTOR'S inspecting engineer or his nominee.

1.3.5 Weld Quality Requirements

For a summary of tests required, see table below.

Test Required |Procedure Qualification | Welder Qualification

Visual Examination | Yes | Yes

Macro Examination |Yes | Yes

1.3.6 Weld Quality

The specified tests shall be carried out to the satisfaction of the COMPANY'S Inspection Engineer or nominee and the following defects shall be cause for rejection:

a. cracks: NA
b. lack of fusion NA
c. burn through of the tube bore NA

d. excessive weld spatter/overhang NA
e. effective weld thickness of less than 0.7 t NA
NA = not allowed

1.4 EXAMINATION OF PRODUCTION WELDS

After each weld run, the weld and internal tube surface for at least 3 mm beyond the fusion zone shall be thoroughly cleaned, wire brushed, and examined. All defects such as cracks, slag, and lack of fusion or gross porosity shall be repaired.

When agreed for austenitic materials, each weld run shall be dye penetrant tested using commercially approved materials and techniques. The soak time for the penetrant shall not be less than 10 minutes. After dye penetrant testing and before any further welding is carried out, all traces of dye, developer and solvents shall be removed.

1.5 LOW PRESSURE PNEUMATIC TEST

After welding and before hydraulic testing, the assembly shall be tested for leaks by applying a pressure of 0.51 bar (G).

While the shell is under pressure a simple soap or detergent test shall be used to indicate escapes of air from leaks. Generally, 1 to 2% solution by volume of a suitable foaming agent in water is effective.

When specified, a tracer such as halogen gas/helium may be added to the pressurizing gas, and a suitable detector used to locate leakages.

When specified on the order, leak testing shall be carried out after the completion of each run in multi-run welds.

All suspect weld locations shall be marked for repair. Since no completely reliable non-destructive test exists at present to establish weld tightness, defective welds found during testing shall not exceed 1% of the total number of welds on any Tube Sheet.

1.6 REPAIRS

On completion of a gas leak test required by paragraph 1.5 of this section, any leaks disclosed shall be repaired and re-tested until all faults are remedied.

Where practical, faulty welds shall be completely removed to sound metal and repaired using the qualified procedure. Departure from this procedure shall be as agreed by the CONTRACTOR and may be subject to repair procedure testing.

Minor faults associated with fully automatic GTAW welding with incorrect settings or tracking, may be rectified by rewelding at corrected settings. If the welds still remain defective, they shall be removed and repaired manually by the TIG process using appropriate filler metal addition. When any defects occur, particularly cracking, the cause shall be established prior to repair.

1.7 EXPANDING AFTER WELDING

Where expansion after welding is specified, it shall not be carried out until after the successful completion of the low pressure pneumatic test and where post weld heat treatment is specified after that heat treatment. For services where stress corrosion cracking may occur, expansion should be carried out before PWHT.

The expansion shall be lightly done with the objective of sealing the back face crevice in the tube hole. The expanded region shall lie within a zone extending for the various joint types.

The expanding equipment shall have limiting controls which will ensure that tube wall thinning is between 3% and 5% of original wall thickness.

1.8 HYDRAULIC TESTING

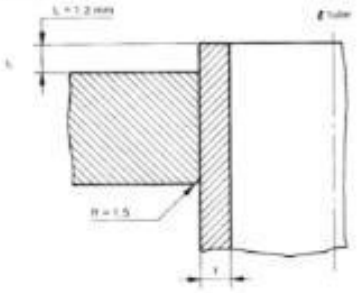
The hydraulic test shall be carried out after all welding, pneumatic tests, tube expansion and heat treatment has been completed. The complete exchanger shall be hydro tested in accordance with paragraph 16.0 of this Specification.

SECTION 2: TUBE TO TUBESHEET CONNECTION

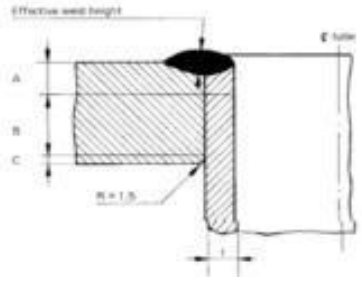
APPENDIX 2 TUBE - TUBESHEET CONNECTION

Joints for t > 2.5 mm

GTAW



- Materials: C/Mn steel, stainless steels
- Automatic GTAW welding can be used
- For tube fixation a 3-points expander may be used



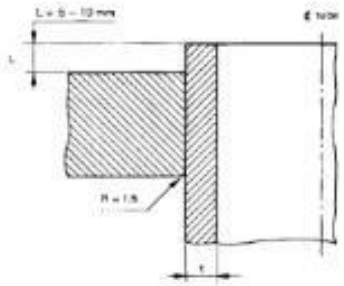
A = minimum 5t
B = effective rolling length
C = minimum 2t

- Tube expansion after welding only when specified

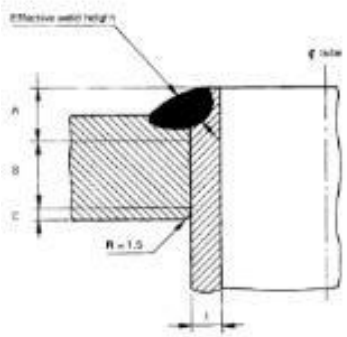
TUBE - TUBE SHEET CONNECTION

Joints for t < 2.5 mm

GTAW



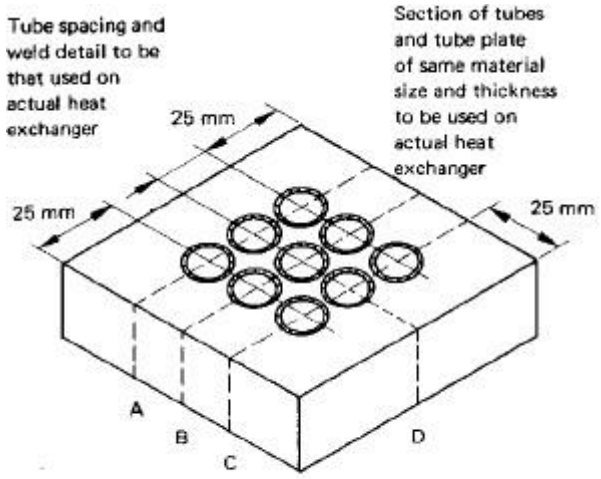
- Materials: C/Mn steel, stainless steels
- Minimum distance between tubes 2.5 x t or 8 mm
- Tubes may not be fixed by either rolling or tack welding when GTAW is applied
- Not suitable for application of stoving lacquer



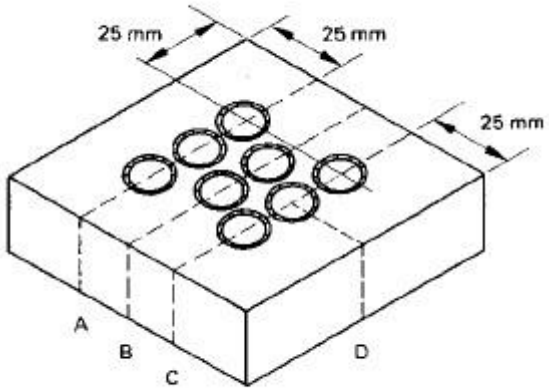
A = minimum 5t
B = effective rolling length
C = minimum 2t

- Tube expansion after welding after first layer only when specified

SECTION 3: EXAMINATION OF PROCEDURE AND WELDING QUALIFICATION TEST PIECES



Test specimen for square pitch.



Test specimen for triangular pitch

Macroscopic Examination

Each weld region on one surface of each of the saw cuts A, B and C shall be carefully prepared by emerying to a minimum 180's grit emery finish, and then etched in a suitable reagent to reveal the weld structure.

Saw cut D shall be made at a stop/start position.

The effective weld height shall be measured on all sections. Using an electronic calculator or by plotting the values on probability paper, the average effective weld height and the 1% minimum weld height can be determined.

A welding procedure can be considered of good quality when average and minimum weld height values are not much different.

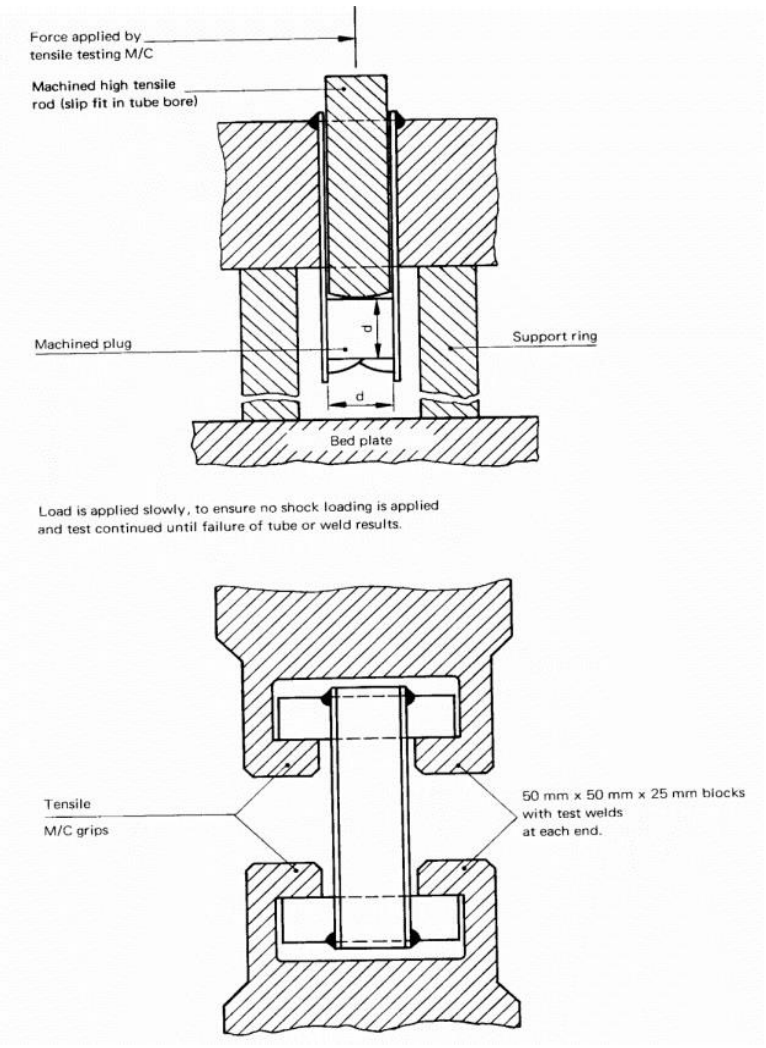
Weld Strength Tests

If a test of weld strength is specified, it is recommended that the tube should be pulled out through the back of the tube plate and the breaking load recorded (see section 4).

The minimum acceptable strength shall be as agreed between COMPANY and MANUFACTURER. Where fracture occurs in the weld, this shall not necessarily be cause for rejection; but the fracture should be examined for any evidence of faulty workmanship. “Push through” tests, where the tube is pushed from the back and through the face of the tube plate, are unreliable; they may indicate exceptionally high strength due to the deformation of the tube under high compression stress,

resulting in the tube expanding into the tube plate and developing a high frictional force in addition to the force required to cause failure of the weld joint.

SECTION 4: RECOMMENDED ALTERNATIVE DETAILS OF WELD STRENGTH TESTS



ANNEXURE 1: ADNOC GAS PROCESSING ADDITIONAL REFERENCES AND REQUIREMENTS

The following reference documents, form a part of this specification and are additional requirements to be followed for all Shell and Tube Heat Exchanger Equipment to be procured/installed in ADNOC Gas Processing facilities. Latest Revision as time of contract shall be followed. CONTRACTOR shall advise COMPANY of any changes to Reference Documents after the EFFECTIVE DATE. CONTRACTOR shall comply with COMPANY instruction to comply with any changed Referenced Documents. CONTRACTOR shall advise of conflict among any Reference Documents and any technical specification, and COMPANY will determine which shall govern.

Specification

DGS 0000-001	Positive Material Identification of Equipment And Piping
DGS 0000-002	Material For Sour Environment
DGS 0000-003	Minimum Shop Inspection and Certification Requirements
DGS 0000-004	Criticality Rating System
DGS 6300-003	Welding and NDE of Pressure Vessels and Heat Exchangers
DGS 1300-060	Piping Flexibility Analysis
DGS 6500-010	Hot Insulation for Piping and Equipment
DGS 6500-020	Cold Insulation for Piping and Equipment
DGS 6600-010	Painting
DGS 6710-001	Preservation and Export Packing

STANDARD DRAWINGS

STD - 0400 - 103	Tray Support Tolerances
STD - 0400 - 104	Manufacturer Nameplate
STD - 0400 - 106-1	Nameplates Mounting Bracket
STD - 0400 - 202	Projection of Nozzles
STD - 0400 - 203	Typical Details of Clad Plate Weld Joint Preparation
STD - 0400 - 204	Typical Detail of Weld Overlay and Alloy Clad Nozzles
STD - 0400 - 501-1	Hot Insulation Supports (Vertical Vessels)
STD - 0400 - 501-2	Hot Insulation Supports (Hor. Vessels)
STD - 0400 - 503	Cold Insulation Supports
STD - 0400 - 505	Earth Connection
STD - 0400 - 512	Schedule - AC/SS/CLAD
STD - 0400 – 905	Reinforcement Standard
STD – 0600 – 120	Supports Saddles for Horizontal Exchangers
STD – 0600 – 125	Stacked Exchanger Supports
STD – 0600 – 127	Brackets for Vertical Exchangers
STD – 0600 – 130	Set of Wedges for Stacked Exchangers
STD – 0600 – 135	Lifting Lugs
STD – 0600 – 145	Jack Screw and Stop
STD-1781-002-001	Anchor Bolts – Materials – Fabrication - Marking

ANNEXURE 2: ADNOC REFINING ADDITIONAL REFERENCES AND REQUIREMENTS

The following reference documents, form a part of this specification and are additional requirements to be followed for all Shell and Tube Heat Exchanger Equipment to be procured/installed in ADNOC REFINING facilities. Latest Revision as time of contract shall be followed. CONTRACTOR shall advise COMPANY of any changes to Reference Documents after the EFFECTIVE DATE. CONTRACTOR shall comply with COMPANY instruction to comply with any changed Referenced Documents. CONTRACTOR shall advise of conflict among any Reference Documents and any technical specification, and COMPANY will determine which shall govern.

Standard Specifications

Standard specifications listed below shall be used as referenced herein or on Project vessel Data Sheets/drawings:

DGS-MN-001	Insulation
DGS-MU-002	Preservation and Export Packing
DGS-MU-003	Spare Parts
DGS-MU-013	Criticality Rating System
DGS-MU-014	Minimum Shop Inspection and Certification Requirements
DGS-MW-001	Welding, NDE and Prevention of Brittle Fracture of Pressure Vessels and Heat Exchangers
DGS-MW-004	Materials and Fabrication Requirements for Carbon Steel Piping and Equipment in Severe Service
DGS-MW-005	Materials and Fabrication Requirements for Cr-Mo Alloy Steel High Pressure Equipment
DGS-MW-006	Positive Material Identification of Equipment and Piping
DGS-MX-001	Painting
DGS-PU-005	Piping Flexibility Analysis
DGS-PE-010	Basic Engineering Design Data Abu Dhabi Refinery
DGS-PE-011	Basic Engineering Design Data Ruwais Refinery East
DGS-PE-012	Basic Engineering Design Data Ruwais Refinery West
DGS-PU-009	Bolt Torquing/Tensioning Procedure for Flanged Connections
DGS-MW-008	Metallic Material- Selected Standards

Standard Drawings

Standard drawings listed below shall be used as referenced herein or on shell and tube exchanger DataSheets/drawings:

STD-M01-007	Bolting Non-Standard Flange with Unified Inch Screw Threads
STD-M01-010	Equipment Nozzles
STD-M01-011	Typical Details for Bush-Lined, Overlay Welded and Clad Steel Nozzles
STD-M01-013	Nameplate with Bracket for Vessel and Heat Exchanger Equipment
STD-M01-025	Earth Connection for Tanks, Vessels and Support Structure
STD-M02-001	Brackets for Standard Vertical Reboilers, Nom Dia 350 – 1100 mm
STD-M02-002	Sacrificial Anodes for Tubulars
STD-M02-003	Steel Sacrificial Plates for Tubulars 350mm Nom Dia and Larger
STD-M02-004	Saddles for Horizontal Shell and Tube Heat Exchangers
STD-M02-005	Warning Nameplate

ANNEXURE 3: BOROUGE ADDITIONAL REFERENCES AND REQUIREMENTS

The following reference documents, form a part of this specification and are additional requirements to be followed for all Shell and Tube Heat Exchanger Equipment to be procured/installed in Borouge facilities. Latest Revision as time of contract shall be followed. CONTRACTOR shall advise COMPANY of any changes to Reference Documents after the EFFECTIVE DATE. CONTRACTOR shall comply with COMPANY instruction to comply with any changed Referenced Documents. CONTRACTOR shall advise of conflict among any Reference Documents and any technical specification, and COMPANY will determine which shall govern.

Specifications

BGS-MN-100	Thermal Hot Service Insulation
BGS-MU-002	Preservation and Export Packing
BGS-MU-003	Spare Parts
BGS-MU-013	Criticality Rating System
BGS-MU-014	Minimum Shop Inspection and Certification Requirements
BGS-MW-001	Welding, NDE and Prevention of Brittle Fracture of Pressure Vessels and Heat Exchangers
BGS-MW-002	Welding, NDE and Prevention of Brittle Fracture of Piping
BGS-MW-004	Materials and Fabrication Requirements for Carbon Steel Piping and Equipment in Severe Services
BGS-MW-005	Materials and Fabrication Requirements for Cr-Mo Alloy Steel High Pressure Equipment
BGS-MW-006	Positive Materials Identification of Equipment and Piping
BGS-MX-001	Painting
BGS-LU-005	Piping Flexibility Analysis

Standard Drawing

BTD-MD-00017	Bolting for Non-Standard Flanges with Unified Inch Screw Threads
BTD-MD-00020	Nozzles to Apparatus
BTD-MD-00022	Typical Details of Bush Lined, Overlay Welded and Clad Steel Nozzles
BTD-MD-00024	Nameplate with Bracket for Vessel and Heat Exchange Equipment
BTD-MD-00040	Earthing Clips for Tanks, Vessels and Supporting Structures
BTD-ME-00001	Bracket for Standard Vertical Reboilers, Nom. Dia. 350 mm up/incl. 1100 mm
BTD-ME-00002	Sacrificial Anodes for Tubulars
BTD-ME-00003	Steel Sacrificial Plates for Tubulars 350 mm Nom. Dia. and Larger
BTD-ME-00004	Bottom Part for 14”-16” and 18” Diameter Reboiler with Floating Head with Expansion Joint of Nominal Diameter 100
BTD-ME-00005	Bottom Part for 20”-24” and 26” Diameter Reboiler with Floating Head with Expansion Joint of Nominal Diameter 100
BTD-ME-00006	Bottom Part for 24” -26” -30” -32” and 36” Diameter Reboiler with Floating Head with Expansion Joint of Nominal Diameter 200
BTD-ME-00007	Bottom Part for 30” -32” -36” -40” and 42” Diameter Reboiler with Floating Head with Expansion Joint of Nominal Diameter 300
BTD-ME-00008	Saddles for Horizontal Shell and Tube Heat Exchangers

ANNEXURE 4: ADNOC ONSHORE ADDITIONAL REFERENCES AND REQUIREMENTS

The following reference documents, form a part of this specification and are additional requirements to be followed for all Shell and Tube Heat Exchanger Equipment to be procured/installed in ADNOC ONSHORE facilities. Latest Revision as time of contract shall be followed. CONTRACTOR shall advise COMPANY of any changes to Reference Documents after the EFFECTIVE DATE. CONTRACTOR shall comply with COMPANY instruction to comply with any changed Referenced Documents. CONTRACTOR shall advise of conflict among any Reference Documents and any technical specification, and COMPANY will determine which shall govern.

COMPANY PROCEDURES, STANDARDS AND AMENDMENTS TO SHELL DEP

EP 30.99.90.0024	Preparation of Supplier's/Vendor's Engineering Drawings and Documents.
EM 30.99.95.0006	Guidelines for Submission of Electronic Documentation.
EP 30.99.90.0001	Drawing Design and Numbering Systems.
EP 30.99.00.0001	Engineering Specification for Tag Plates for Field & Indoor Equipment
EP 30.99.90.0002	Procedure for project drawing as built mark-up and master drawing
ES 30.99.00.0102	Corrosion control and Material selection Philosophy
ES 30.99.37.0013	Specification for Painting & Coating of New Equipment
EP 30.99.97.0006.1	Project Quality System Requirements

Shell DEP's Standards

31.22.00.30-Gen	Equipment Criticality for use in pressure vessel design
20.21.00.31-Gen	Fouling Resistance for Heat Transfer Equipment
32.31.09.32-Gen	Heat Exchange instrumentation requirements for performance assessment
30.48.00.31-Gen	Protective coating for onshore & offshore facilities
39.01.10.12-Gen	Selection of materials for life cycle performance (upstream facilities) – Equipment
30.10.02.11-Gen	Metallic Materials – Selected Standards
30.10.02.31-Gen	Metallic Materials – prevention of brittle fracture in new assets
30.10.60.18-Gen	Welding of Metals (amendments / supplements to API RP 852)
30.10.02.17-Gen	Wet H2S requirements for downstream pressure vessels and piping
30.10.60.31-Gen	Oxidation of stainless steel weldments
30.10.02.15-Gen	Materials for use in H2S Containing Environments in Oil and Gas Production (Amendments and supplements to ISO 15156:2009)
30.10.02.13-Gen	Non-Metallic Materials – selection and application
30.48.00.32-Gen	Coating of fasteners
31.22.10.35-Gen	Manufacturing Report for Pressure Vessels
31.10.00.10-Gen	Positive Material Identification (PMI)
31.10.00.31-Gen	Noise Control
30.46.00.31-Gen	Thermal insulation for hot services
80.47.10.30-Gen	Assessment of fire safety of onshore installation
80.47.10.31-Gen	Active fire protection for onshore facilities
34.19.20.11-Gen	Passive fire protection for onshore facilities
61.10.08.11-Gen	Field Inspection prior to Commissioning of Mechanical Equipment
70.10.70.11-Gen	The preservation of Old and New Equipment
70.10.90.11-Gen	Spare Parts
82.00.10.10-Gen	Project Quality Assurance
S 10.101	Equipment Nozzle

S 10.103-001, 002	Typical details of bush-lined, overlayed, clad steel, solid alloy nozzles
S 10.108	Strip lining details
S 10.114-001, 002	Nameplate with Bracket for Vessels and Heat Exchange equipment
S 10.116	Bolting for non-standard flanges with metric screw threads
S 20.003-001 to 004	Support rings for insulation on vessel and heat exchangers
S 21.017	Bracket for standard vertical reboilers nom. Dia. 350 mm up/incl. 1100 mm
S 21.072	Sacrificial anodes for tubular
S 21.073	Steel sacrificial plates for tubular 350 mm nom. Dia. and larger
S 22.001, 002	Saddle for horizontal vessels – shell dia. nom. 150 up to and incl. 3600 mm OD
S 22.003	Sliding plate for saddles of horizontal vessels
S 68.004	Earthing Boss for Steel Structures

ANNEXURE 5: FERTIL, ADDITIONAL REFERENCES AND REQUIREMENTS

The following reference documents, form a part of this specification and are additional requirements to be followed for all Static Equipment to be procured/installed in FERTIL facilities. Latest Revision as time of contract shall be followed. CONTRACTOR shall advise COMPANY of any changes to Reference Documents after the EFFECTIVE DATE. CONTRACTOR shall comply with COMPANY instruction to comply with any changed Referenced Documents. CONTRACTOR shall advise of conflict among any Reference Documents and any technical specification, and COMPANY will determine which shall govern.

Standard Specifications

Standard specifications listed below shall be used as referenced herein or on Project vessel Data Sheets/drawings:

F2-00-MS-SPC-1001	Painting
F2-00-MS-SPC-1002	Insulation
F2-00-MS-SPC-1004	Supports For Pressure Vessel
F2-00-MS-SPC-1005	Hydrogen and/or Sour Gas Service
F2-00-MS-SPC-1006	Surface Treatment of Austenitic SS after Welding
F2-00-MS-SPC-1007	Non-destructive Testing (NDT)
F2-00-MS-SPC-1010	Preservation
F2-00-MS-SPC-1010	Material Identification Programme
F2-00-MS-SPC-1010	Welding
F2-00-PI -SPC- 0001	Piping Material Specification

Standard Drawings

Standard drawings listed below shall be used as referenced herein or on vessel Data Sheets/drawings:

F2-00-ST-SDG-0001	Standard Drawing General Notes(1/2)
F2-00-ST-SDG-0002	Standard Drawing General Notes(2/2)
F2-00-ST-SDG-0008	Standard Drawing Anchor Bolts Detail
F2-00-ST-SDG-0009	Standard Drawing Base Plate - Hinge Support
F2-00-ST-SDG-0021	Standard Drawing Steel Stair Detail
F2-00-ST-SDG-0022	Standard Drawing Ladders & Safety Gate Detail
F2-00-ST-SDG-0023	Standard Drawing Handrail Detail
F2-00-ST-SDG-0024	Standard Drawing Grating, Floor Plates & Joist Detail

ANNEXURE 6: ADNOC OFFSHORE ADDITIONAL REFERENCES AND REQUIREMENTS

1. SCOPE

Below are ADNOC Offshore specific additional requirements which shall be followed and assume priority over main specification wherever conflicts exist.

2. REFERENCES:

APPENDIX-A: ABBREVIATIONS

Abbreviation	Description
ADNOC Offshore	Abu Dhabi Company for Offshore Petroleum Operations
ADNOC	Abu Dhabi National Oil Company
AISC	American Institute of Steel Construction
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BS	British Standard
CFD	Computational Fluid Dynamics
CoP	Code of Practice
CP	Cathodic Protection
CR	Criticality Rating
CRA	Corrosion Resistant Alloy
CS	Carbon steel
EN	European Norms
FOB	Freight on Board
H2S	Hydrogen Sulphide
HSE	Health, Safety and Environment
HTFS	Heat Transfer and Fluid Flow Services
HTRI	Heat Transfer Research Institute
ID	Internal Diameter
IRIS	Internal Rotary Inspection System

Abbreviation	Description
ISO	International Standards Organization
ITP	Inspection and Test Plan
KPI	Key Performance Indicators
MAP	Maximum Allowable Pressure
MAWP	Maximum Allowable Working Pressure
MDMT	Minimum Design Metal Temperature
MDR	Manufacturer's Data Report
MOC	Management of Change
NACE	National Association of Corrosion Engineers
NB	Nominal Bore
NDE	Non-Destructive Examination
NPS	Nominal Pipe Size
NPT	National Pipe Taper
OD	Outside Diameter
PIP	Process Industry Practices
P&ID	Piping & Instrument Diagram
PMI	Positive Material Identification
PO	Purchase Order
PTFE	Polytetrafluoroethylene
PWHT	Post Weld Heat Treatment
QA	Quality Assurance
QC	Quality Control
QMS	Quality Management Systems
QP	Quality Plan
RT	Radiographic Testing
RTJ	Ring Type Joint
SI	System International
SP	Specification
SRU	Sulphur Recovery Unit
SCOT	Shell Claus Off-gas Treating Unit
SS	Stainless Steel
STD	Standard

Abbreviation	Description
S&T	Shell and Tube
TPA	Third Party Agency
TSCAD	Technical Standards & Compliance Assurance Division
TSD	Technical Standard Documents
UDS	User Design Specification
UT	Ultrasonic Testing
WPS	Welding Procedure Specification
WRC	Welding Research Council

APPENDIX-B: DEFINITIONS

Term	Definition
Contractor	The firm or joint venture appointed by Company for providing Work/ Services to the Company or its nominated representative
Cyclic Service	Cyclic and dynamic reactions from any pressure or thermal loading source that require fatigue analysis per Part 5.5 of ASME Sec. VIII Div.2
Design Code	ASME Boiler and Pressure Vessel Code Section VIII Division 1 or ASME Sec. VIII Div.2
Engineer	The Engineering Company or entity responsible for specifying, on the Shell and Tube heat exchanger datasheet, the design requirements for the exchanger
General Service	Other than hydrocarbon service (e.g. Utility and non-critical services)
Hydrocarbon Service	Process streams of liquid or gaseous hydrocarbon materials (i.e. sour or lethal), including two and three phase hydrocarbon materials
Lethal Service	Equipment contents containing a concentration of poisonous gas or liquid that is dangerous to life when inhaled, such as hydrogen sulfide. Lethal service definition shall be as per Process design criteria and as specified in the Process Datasheet
Manufacturer/Supplier /Vendor/Sub-Supplier/Sub-Contractor	Any and all persons, firms, partnerships, companies, bodies, entities or a combination thereof include suppliers, sub-suppliers who are responsible for designing, fabricating and constructing the Shell and Tube heat exchangers or who are providing equipment and/or services of Shell and Tube Heat Exchanger, covered by this document
National Board	The National Board of Boiler and Pressure Vessel Inspectors, an organization whose members are the jurisdictional officials responsible for enforcing and administrating the rules of the ASME Boiler and Pressure Vessel Code Section VIII division 1 and ASME Section VIII, Division 2. Vessels meeting requirements of the Code and stamped with the Code “U” or “U2” symbol, shall be registered with the National Boar
Quality Assurance	All those planned and systematic actions (QA) necessary to ensure quality i.e. to provide adequate confidence that a product or service will be fit for its intended purpose
Quality Manual	A Document setting out the general quality policies, procedures and practices of an organization
Quality Plan	A document prepared by the Contractor/Supplier setting out the specific quality practices, resources and activities relevant to a particular project
Quality Management System	The structure organization, responsibilities, activities, resources and events that together provide organized procedures and methods of implementation to ensure the capability of the organization to meet quality requirements

Sour Service	Definition shall be as defined in Company Specification SP-1000
Authorized Inspector	An employee of an Authorised Inspection Agency who is qualified and certified to perform inspections required in ASME Section VIII Division 1 or Division 2
Utility Service	Water, air, nitrogen, etc.

APPENDIX-C: REFERENCED DOCUMENTS

Unless otherwise specified, the latest edition of the Technical Standards Documents listed below shall to the extent specified herein, represent part of this document.

Designation	Title
ADNOC Offshore	
A0-ENG-N-SL-001	Status List for ADNOC Offshore Technical Standard Documents
A0-ENG-V-STD-001	Standard Details for Static Equipment
A0-ENG-EMS-PRO-009	Procedure for Energy Efficient Design
A0-ENG-S-STD-001	Design Criteria for Fixed Offshore Structures
A0-ENG-R-GR-001	General Requirements for Packaged Equipment
A0-ENG-P-SP-004	Specification for Piping System Stress Analysis
A0-ENG-S-SP-102	Specification for Weight Control of Offshore Structures
A0-IG-L-MS-001	Lifting Integrity Management System
A0-IG-P-SP-003	Specification for Spun Hot Dip Galvanization & Polytetrafluoroethylene (PTFE) Coating of Nuts/Bolts and Fasteners
A0-IG-P-SP-004	Coating Specification for New & Existing Constructions of Offshore and Onshore Structures
A0-IG-C-SP-010	Cathodic Protection Specification for Tanks and Vessels Internal Surfaces
A0-IG-C-GDL-002	Guideline for Preservation of Production & Process Facilities
A0-IG-F-PRO-001	Procedure for Magnetic Particle Inspection
A0-IG-F-PRO-002	Procedure for Liquid Penetrant Inspection
A0-IG-P-SP-006	Specification for Thermal Insulation (Hot & Cold) of Piping and Equipment
A0-IG-P-SP-007	Specification for Passive Fire Protection
A0-IG-Z-SP-001	Specification for Integrity Requirements for Baseline Survey of New Equipment in Projects
A0-IG-J-CP-001	Code of Practice for Inspection and Testing Requirements for New Equipment and Materials in Manufacture
A0-IG-W-CP-001	Code of Practice for Symbols for Welding and Non-Destructive Testing

Designation	Title
A0-IG-F-CP-001	Code of Practice for Inspection and Testing of In-Service Static Equipment
A0-OP-R-PRO-001	Procedure for Nitrogen/Helium Leak Test
A0-Q-PQ-CP-001	Code of Practice for Project Procurement Inspection
A0-Q-PQ-SP-001	EPC Contractor Quality Personnel Requirements
A0-Q-PQ-SP-002	Requirements for Contractors Quality Systems on Major Projects
A0-Q-PQ-SP-003	Quality Assurance and Quality control requirements for construction Works
A0-OP-Z-GDL-001	Guideline for Operations, Maintenance & Integrity Philosophy for Projects
CP-00	Code of Practices for Plant Design
A0-IG-Z-CP-001	Code of Practice for Integrity Assurance in Projects
DST-003 Part 1	Data Sheets for Computerized Maintenance Management System of Mechanical Equipment
GDL-008	Guideline for Spare Parts Management
GDL-009	Guideline for Project Deliverables
GDL-012	Guideline for Material Selection
GDL-040	Guideline for Concession Request
A0-ENG-Z-PRO-002	Management of Change (MOC - Applications)
PRO-110	Procedure of Pressure Testing of Part 1: Piping System Part 2: Pressure Vessels
PRO-151	Procedure for Material Preservation
SP-1000	Specification for Materials for sour services
SP-1002	Specification for Preservation of New Materials & Equipment
SP-1021	Specification for Water Quality for Hydrostatic Test
SP-1023 Part-1	Specification for Piping Support
A0-IG-W-SP-002	Specification for Preheat and Post Weld Heat Treatment of Ferrous Materials
A0-OP-M-SP-001	Specification for Operating Manuals and Operating Procedures (OPERGUID)
SP-1131	Specification for Piping Classification
SP-1149	Specification for Sour Services Application for Offshore and Onshore Facilities
SP-1162	Specification for Duplex and Super Duplex Material

Designation	Title
STD-00 Part-1	Measurement Units
STD-00 Part-2	Site Condition and Data
STD-100	Approval of Materials of Manufacture Mechanical Equipment
STD-103	Approval of Welding Procedures and Welder Performance
A0-ENG-P-STD-001	Standard for Flanges
A0-ENG-P-STD-006	Standard for Bolting for Piping
A0-ENG-P-STD-007	Standard for Gaskets for Flanged Joints
A0-ENG-P-STD-002	Standard for Piping Fittings
STR-001	Maintenance Strategy
STR-002	Corrosion Management Strategy
STR-07	Strategy for Records Management
HSE 102	Health, Safety and Environment Regulations
HSE-111	HSE Critical Equipment & Systems Management System
Z0-TS-A-03010	ZADCO Specification New/Change/Deviation Standard Request Form
Z0-TS-M-01040	Quality Assurance and Control of Pressure Vessels, Heat Exchangers and Packaged Equipment
GD-STD-000-001	e-Manual Standard
PB-STD-000-005	e-Manual Procedure
Z0-TS-P-05010	Piping material specification
Z0000-PB-GEN-N-121	HSECS Identification and Performance Standards Procedure
Z0-TS-Y-02030	Specification for Ceramic Coated Bolting and Threaded Fasteners for High Temperature Exposure
Z0-TS-Y-03010	Specification - Thermal Insulation-Hot Services for Piping and Equipment
Z0-TS-Y-03020	Thermal Insulation-Cold Services for Piping & Equipment
Z0-TS-Z-01010	General Environmental data at ZADCO Onshore & Offshore Facilities
Z0-TS-Z-02010	Vendor Document and Data Requirements for Mechanical Equipment Packages
ADNOC	
ADNOC COP V2-03	Code of Practice on Environmental Protection

Designation	Title
ADNOC COP V6-01	Code of Practice for Identification and Integrity Assurance of HSE Critical Equipment and Systems

3. LETHAL SERVICE

Below are additional requirement to be followed for Lethal service in addition to requirements covered in this specification;

a. Hub type flanges shall be of butt welded construction.
b. Reinforcement pad for nozzle opening is not permitted. All nozzles shall be integrally reinforced.
c. Solid metal ring gaskets are preferred unless otherwise mentioned in datasheet
d. Bolt spacing requirements specified in ASME VIII Division 1 shall also be applicable to Division 2 shell and tube heat exchangers to achieve better joint design. Further, Division 1 flange design rules for lethal service shall be followed for Division 2 shell and tube heat exchangers as well. Integral type flanges shall be as per ASME VIII Div.2 Table 4.2.9 sketches (6), (7) and (8) only.

4. THERMOSYPHON REBOILERS

Also Refer Para 2.3 of Section 8 Part II for additional requirement for Thermosyphon Reboiler

a. Vertical thermosyphon reboiles shall have Type A design with packed joint for tube side inlet nozzle where heating medium is low-pressure steam. Fixed tube sheet design also may be considered after enough justification for cost/HSE
b. Where hydrogen/hydrocarbon mixture is the heating medium, vertical units may be used up to 300psig (20barg), provided a metal expansion bellow is used in place of packed joint.
c. For hydrogen/hydrocarbon mixtures above 300psig (20barg), horizontal thermosyphon reboilers shall be considered.

5. FABRICATION

5.1 Refer ADNOC Pressure Vessels Specification for fabrication requirements.

5.2 For fabrication tolerances, refer ADNOC Pressure Vessels Specification, API 660 & TEMA. Most stringent conditions shall apply.

5.3 Tube expansion

5.3.1. For certain service duties, e.g. where possible crevice corrosion or vibration fretting susceptibilities must be minimised, it may be necessary to provide far intimate contact between the O.D. of the tubes and the bores of the tube plate holes. This may be accomplished by light expansion after welding and successful leak testing but before pressure testing.

5.3.2. Tube expansion after welding shall lie within the zone from approximately 3/8 in. from the weld junction to 1/8 in. from the back of the tube plate.

5.3.3. The equipment used for tube expansion shall be of the mandrel and parallel roller type incorporating limiting controls to give a predetermined amount of tube wall thinning, e.g. controlled torque equipment.

5.3.4. The amount of tube wall thinning shall be 5 - 7% of the original tube wall thickness and the machine settings to achieve this thinning shall be determined and checked during procedure testing by micrometer measurements as follows:

Diameter of tube hole : "D" mm.
Mean outside diameter of tube : "d" mm.
Difference : "D-d"mm.
Inside diameter of tube after expansion : "T" mm.
Inside diameter of tube before expansion : "t" mm.
Difference : "T-t" mm.

$$\text{Tube Wall thinning} = \frac{(T-t)-(D-d)}{2}$$

5.4 PWHT is required for the following cases:

a. Shell and Tube Heat exchangers containing alkaline products with the design temperature exceeding 65°C or Shell and Tube heat exchangers are provided with heating coil.
b. Shell and Tube Heat exchangers containing media likely to cause stress corrosion cracking (H_2S even in small traces).
c. Cyclic service Shell and Tube heat exchangers with thickness exceeding 20mm.

5.5 PWHT of Shell and Tube heat exchangers, if required, shall meet requirements specified in A0-ENG-V-SP-004/005.

5.6 Unless otherwise agreed with the Company, heat treatment shall be applied to bonnet and floating head cover if there are 4 or more tube side passes and the partition plates are in two different planes.

5.7 Heat treatment shall be applied to the U-tube as follows :

a. For general refinery service, solution annealing heat treatment of the bend area and at least 150mm of the adjacent straight length for austenitic stainless steel U-tube bends having a mean radius smaller than 5 times the nominal tube OD.
b. For severe corrosion service, solution annealing heat treatment of the bend area and at least 150mm of the adjacent straight length for all austenitic stainless steel U-tubes, regardless of the mean radius of bend.
c. For Nickel alloys, the heat treatment procedure shall be agreed with the Company by the Contractor/Engineer.
d. If cold working induces susceptibility to stress corrosion in some materials or environments, then heat treatment shall be required. This shall be specified and clarified (e.g. required for process reasons) by the Contractor/Engineer on the datasheet.

6. RCB 7 TUBESHEET

Add

a. It is recommended to have tubesheet OD equal to girth flange OD for a tubesheet thickness of a minimum 30 mm of a retractable bundle.
b. Removable Bundles used with Type A Head do not need to have full diameter tubesheet

7. INSPECTION AND TESTING REQUIREMENTS

a. For Ferrous tubing, NDT IRIS shall be applied & for Non-Ferrous tubing, Eddy current shall be applied as part of the tube bundle baseline inspection record. Demonstration of Technical Qualification & Competency shall be done by the vendor prior to the testing for Company's verification.
b. Tubes to tubesheet welding and expansion shall be qualified on mock-up blocks similar to that of job tubesheet and tubes. Previously qualified procedures may be acceptable if all parameters are same as that of current job and subject to Company approval.
c. 100% MT / DT shall be carried out on the shell and tube exchanger head knuckle radius after forming.

Refer Pressure Vessels specification for all other requirements of NDE such as DPT, MPT, RT and UST