1. GENERAL

1.1. SCOPE

1.1.1. This Specification covers the minimum requirements for the Materials, Design, Fabrication, Inspection, Testing and Supply of Shell and Tube Heat Exchangers for the

1.1.2. This Specification shall also apply to Suction Tank Heaters or Auxiliary Heat Exchanger for Turbines, Engines, Pumps, Compressors and other mechanical equipment wherever applicable.

For such Auxiliary Heat Exchangers, the Heat Exchangers shall be designed in accordance with the Basic Design requirements in Appendix A.

1.2. CODES, STANDARDS and REGULATIONS

1.2.1. Heat Exchangers shall be Designed, Fabricated, Inspected and Tested in accordance with the requirements of the latest edition of the following Codes, Standards and Regulations listed below.

2. International Codes / Standards
    a. TEMA Standard Tubular Exchanger Manufacturers Association
    b. API Standard 660 Heat Exchangers for General Refinery Service
    c. ASME Section II Materials
    d. ASME Section VIII Div. 1 Rules for Construction of Pressure Vessels.
    e. ASME Section VIII Div. 2 Rules for Construction of Pressure Vessels – Alternative Rules
    f. ASME Section IX Welding and Brazing Qualifications.
    g. ASME B16.20 Metallic Gaskets for Pipe Flanges Ring-Joint, Spiral Wound, and Jacketed – Addenda A
    h. ASME B16.47 Large Diameter Steel Flanges
    i. ASME B16.5 Pipe Flanges and Flange Fittings
    j. ASME B1.1 Unified Inch Screw Thread
    k. ASME B16.9 Factory – Made Wrought Buttwelding Fittings
    l. WRC Bulletin 107 Local Stresses in Spherical and Cylindrical Shell due to External Loadings.
    m. WRC Bulletin 297 Local Stresses in Spherical and Cylindrical Shell due to External Loadings – Supplement to WRC 107.
    n. NACE MR 0103Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments
    o. NACE TM 0284 Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking
    p. NACE TM 0177 Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments.
    q. ASCE 7-05 Minimum design loads for building and structures- For wind load
    r. UBC-97 Uniform Building Code - For Seismic load

s. NACE RP 0472 Methods and Control to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments.

1.2.2. Unless otherwise specified TEMA Standard Class R shall be applied.

1.2.3. VENDOR shall be responsible for ensuring that all aspects of the Materials, Design, Fabrication and Testing shall conform to the requirements of PURCHASER's requisition, Data sheets, Specifications, Specified Codes, Standards and Local Regulations.

1.2.4. Where there are conflicts between the requirements in the applicable documents for this Project, the order of precedence shall be as follows:

1. Local Regulations and Laws
2. Licensor Specifications
3. Data sheets
4. Engineering Specifications
5. Codes and Standards

In such a case, VENDOR shall promptly refer the conflicts to PURCHASER in writing to obtain PURCHASER's resolution.

1.2.5. PURCHASER reserves the right that the most stringent requirement shall be applicable without any added cost.

2. DESIGN

2.1. DESIGN PRESSURE

2.1.1. Design pressure shall be as specified in Data Sheets.

In the event of two different operation cases, they shall be separately taken into consideration for the Design and shall be separately indicated on drawing and Nameplate.

For example

- Operation
  - Design Pressure 20 bar (g)
  - Design Temperature 100°C
- Regeneration
  - Design Pressure 5 bar (g)
  - Design Temperature 250°C

This only applies for cases where these operation cases occur separately. Whenever it cannot be excluded that these Pressures and Temperatures occur in combined form, then only that operation case with maximum stress shall be considered.

2.1.2. When Design Pressure of “F.V. (Full Vacuum)” is specified, exchangers shall be designed to withstand an external pressure of 101.3 kPa.

2.1.3. Unless otherwise specified, exchangers subject to Internal Pressure shall be designed to withstand an external pressure of 101.3 kPa at 150ºC.

2.1.4. Unless otherwise specified, parts in contact with both shell and tube side fluids such as Tubes, Tubesheets and Floating Heads shall be designed for the pressure on one side only or the combination of the pressure, whichever requires the maximum material thickness for the part. Use of differential design pressure is subject to PURCHASER’s approval.

2.1.5. Maximum Allowable Working Pressure (MAWP) is the maximum Gauge Pressure at each side of a completed exchanger, which is obtained from the calculation of every element of the exchanger based on the used thickness under corroded conditions. MAWP shall be calculated for each exchanger.

2.2. DESIGN TEMPERATURE

2.2.1. Design Temperature shall be as specified in the Data sheets. Two kinds of Design Temperature, one for Maximum Design Temperature (called as “Design Temperature”) and the other for Minimum Design Temperature (called as “Minimum Design Metal Temperature” or MDMT) are specified.

2.2.2. When Operating Temperature is 15°C and below, the design temperature shall be the minimum anticipated Operating Temperature.

2.2.3. When Design Temperature or MDMT cannot coincide with the Maximum Pressure, the corresponding

A193 Gr B7 for Bolts, and A194 Gr 2H for Nuts. For Design Temperature over 425°C, the Material shall be A193 Gr B16 for Bolts and A194 Gr 4 for Nuts. A320-L7 and A194-4 shall be used for Minimum Process Design Temperature colder than minus 10°C throughout minus 100°C. Internal Bolting shall be selected to be suitable for process fluid.

The plant MDMT of -18°C shall not be considered for selecting bolt material.

2.4.7. Use of stainless steel dual certificate materials is acceptable.

2.5. LOADING CONDITIONS AND STRENGTH CALCULATION

2.5.1. Any thicknesses indicated in PURCHASER's Drawings and/or Data sheets are those proposed by PURCHASER. VENDOR shall be responsible to check and confirm that such thicknesses provide the proper strength under the specified conditions. Any lesser thickness considered by VENDOR shall immediately be referred to PURCHASER. In no case shall a thickness be decreased without PURCHASER's prior approval, even if there is an extra margin beyond the offered and calculated required thickness.

2.5.2. Lining, Cladding and Weld Overlay Thickness shall not be considered to contribute to the strength of pressure parts.

2.5.3. The following Loading Conditions shall be considered in Designing Heat Exchangers including its Support and anchor/setting bolts.

1. Operating Condition

   The Loadings shall include those from:

   a. Internal or External Design Pressure
   b. Weight of Exchangers and contents at operating condition (including static head of liquids)
   c. Weight of Insulation and Fire Proofing
   d. Weight of combined equipment, if specified
   e. Reactions from Piping Systems, if specified
   f. Cyclic or Dynamic Reactions from combined equipment, if specified
   g. Wind or Seismic Load whichever is greater

2. Erection Condition

   The Loading shall include those from:

   a. Weight of Exchangers and contents at erection
   b. Weight of Other Attachments, if any
   c. Weight of combined equipment, if specified
   d. Wind or Seismic Load, whichever is greater

3. Testing Condition (in the installed position and corroded condition)

   The Loadings shall include those from:

   a. Test Pressure
   b. Weight of Exchangers and contents at Testing Condition (including static head of liquids)

3. DETAILED DESIGN

3.1. SHELLS AND CHANNELS

3.1.1. When shell diameter is 600 mm and under, pipes may be used.

3.1.2. The minimum nominal shell thickness including corrosion allowance shall be in accordance with TEMA including RECOMMENDED GOOD PRACTICE.

3.1.3. The shape of the formed head shall be as specified in PURCHASER's Drawings and/or Data sheets. 2:1 Semi-ellipsoidal or Hemispherical Heads are preferred.

3.1.4. The Nominal Thickness of 2:1 Ellipsoidal or Hemispherical Head shall be selected to assure that the Minimum Thickness after Forming shall not be less than the Minimum Design Thickness of Head. Also, the Nominal Thickness shall not be less than the Minimum Design Thickness of connecting cylindrical shell for 2:1 Ellipsoidal Head.

3.1.5. Except for Kettle and U-Tube types, exchangers with removable tube bundles shall be provided with Bolted shell covers.

3.1.6. The angle of a conical section of Kettle Type Exchangers shall generally be 30°.

3.1.7. For Fixed Tube Sheet Construction, the necessity of Expansion bellows shall be determined in accordance with the ASME and TEMA Standards. The Metal Temperatures of Shell and Tubes shall be as specified in Data sheets or PURCHASER's requisition. Unless otherwise specified, it is necessary that Expansion Bellow requirement shall be evaluated for all Operating Conditions including Hydrotest Condition.

Expansion Joint Type:

- If Thick Wall (Flanged and Flued) type is chosen, the design shall be in accordance with TEMA RCB-8 using Finite Element Analysis (FEA) method. Expansion joint material shall be of the same as shell. Construction details shall be submitted for PURCHASER's approval.
- If Thin Wall type is chosen, the design shall be in accordance with ASME Code. Expansion joint material and construction details shall be submitted for PURCHASER's approval.
- Minimum cycle life shall be 1000 cycles.

3.1.8. Girth Flanges shall have a Confined Gasket Joint to hold the gasket in place during assembling.

3.1.9. Gasket contact surface of girth flanges shall have a finish equivalent to the following in μm:

1. For Non-Asbestos Sheet Gasket: Ra 3.2
2. For Spiral Wound Gasket: from Ra 1.6 to Ra 3.2
3. For Metal Jacket, Solid Metal Gasket: Ra 1.6 and finer

3.1.10. All Girth Flanges shall be of Welding Neck construction. Number of flange bolt holes shall be in multiples of 4 (four) and they shall straddle Heat Exchanger normal centerlines.

3.1.11. Vent and drain holes of approx. 6 mm in diameter shall be provided at the highest and lowest points of each

pass partition plate.

3.1.12. Thickness of floating head backing device shall be determined from formula based on bending calculation.

3.1.13. Flatness Tolerance on Peripheral Gasket Contact Surface of Girth Flanges and Tube sheets for exchangers in Wet H2S Service, High-Temperature Service, and High-Pressure Service shall be in accordance with Table 5 of API-660.

3.2. TUBES AND TUBE BUNDLES

3.2.1. Each U-tube shall be formed from a single length, and mean radius of U-tube bend shall not be less than 1.5 times the Tube Outside Diameter.

3.2.2. Tube-to-Tubesheet Joints shall be Strength Welded followed by Heavy Rolled Expanding with two Grooves. When all of the following conditions are satisfied , Tube-to-Tubesheet joint shall be of heavy rolled expanding with two grooves:

1. Design Pressure does not exceed 5000 kPa
2. Design Temperature, both Maximum and Minimum, are from -10°C up to 350°C (The plant MDMT of -18°C shall not be considered as Minimum Design Temperature for selecting tube-to-tubesheet joint type.)
3. Hydrogen Partial Pressure is 600 kPa and smaller.

Use of Hydraulic or Explosive Expanding is subject to PURCHASER's Approval.

3.2.3. The welding procedures, welding methods and Inspection Methods of Strength Welded Tube-to-Tubesheet Joints shall be submitted for PURCHASER's approval. WPS's and PQR's for Tube-to-Tubesheet welding shall be prepared separately from other fillet type welding.

3.2.4. Thickness of Tubesheets shall be designed and provided to satisfy both TEMA and the construction code. Extended tubesheet shall be applied to Removal Type Tube Bundle.

Where a No Tube In Window (NTIW) design is used, the Proposed method of calculation of the Tubesheet thickness shall be submitted for PURCHASER's review and acceptance prior to order of the Tubesheet Material. In general the calculation methods of TEMA and ASME VIII Division 1 Part UHX will be considered unacceptable for this application.

3.2.5. Baffles and Support Plates shall be tied together with Rods and Spacers, and for Horizontal Exchangers they shall be provided with Notches at the Lowest Point to permit full drainage of the Shell and at highest point for Venting.

3.2.6. When the specified shell-side corrosion allowance exceeds 3 mm, the minimum baffle and support plate thickness specified in the TEMA standard shall be increased by the shell-side corrosion allowance in excess of 3 mm.

3.2.7. For exchangers which do not require baffles, support plates of 45% vertical cut shall generally be provided. Support plates need not be cut for Kettle Type Exchangers. To avoid flow-induced vibration problems, the

maximum unsupported tube span should not exceed 80% of the specified value in TEMA Standard.

3.2.8. When Longitudinal Baffles are welded to the Shell, the welding seams shall not be close to the longitudinal welded seams of the shell.

3.2.9. Clamp Bands shall be installed for Kettle Type Exchanger with a Shell Diameter of 400 mm and over, and the Tube Length 1500 mm and over.

3.2.10. Tubes shall be extended by 3 mm beyond the Channel Side Surface of each Tubesheet. For vertical exchangers, all Tubes shall be flush on to Tubesheet Surface.

3.2.11. For Heavy Expanded Joints, Tubesheet Holes shall be provided with two Square Grooves conforming to the TEMA Standard. For Clad Tubesheets, one Groove shall be in the Cladding and the Cladding shall extend 3 mm beyond the Groove.

3.2.12. The tube wall thickness reduction for Heavy Rolled Expanding shall be in accordance with the following,

1. Carbon steel, Low Alloy Steel (Max 9% Cr): Minimum 6% and Maximum 8%.
2. Stainless Steel and High Nickel Alloy: Minimum 4% and Maximum 6%.
3. Copper Alloy Steel: Minimum 4% and Maximum 8%.

3.2.13. The Intermediate Support Plates at the Inlet/Outlet Spacing or between the NTIW (no tubes in windows) Baffles shall be provided to keep the flow direction without Flow-Induced Vibration problem.

3.2.14. The Supplemental Requirements defined in API-660 Section 12 are applicable for the following conditions

1. Shell or Channels with a Cylinder thickness greater than 50 mm
2. For Hydrogen, Hydrogen Sulphide or other Lethal Services.

3.2.15. For Exchanger in H2 Service, the Floating Head Cover Flange shall be designed fully in accordance with API-660 Paragraph 7.5.4 Figs (b) or (c).

3.3. NOZZLES

3.3.1. Nozzle and manhole size shall not be changed without PURCHASER's approval. However, if nozzles, reinforcement pads, and main seams should interfere with each other, these dimensions may be changed upon PURCHASER's approval.

3.3.2. The Type, Rating and Facing of nozzle flanges shall conform to those specified in PURCHASER's Drawings and/or Data sheets.

3.3.3. Each Blind Cover with mass over 200N shall be supported by a Davit or Hinge. The details of davit or hinge shall be in accordance with Vessel Standard

3.3.4. Nozzle flange standard shall generally conform to Piping Material,
Nozzle flanges 24 inch and smaller shall be as per ASME B16.5. Nozzle flanges larger than 24 inch nominal shall be as per ASME B16.47 Series B or designed per ASME Sec. VIII Div.1 when ASME B16.47 Series B

is not applicable.

In the case a Non-Standard flange is designed, the companion flange with bolts, nuts and Gasket shall be supplied with it.

Non-Standard Flanges shall be designed to Code Rules and shall take into account external loads, flange deflection, initial bolt load and hydrotest conditions.

3.3.5. The nozzle neck thickness shall be selected in accordance with Vessel Standard for Materials, Nominal Size, Flange Rating and corrosion allowance. A code calculation is still required to be submitted for review to confirm wall thickness meets code requirements. The Pipe material for nozzle neck shall be Seamless, unless otherwise approved by PURCHASER.

3.3.6. When Male and Female (M&F) or Tongue and Groove (T&G) Type Flanges are specified, the Nozzle Flange Facing of the exchanger shall be of Female or Groove Type.

3.3.7. Drain, Vent and Process Nozzles shall be Trimmed flush with the inside surface of the exchanger. Other Nozzles may extend inward within the limits necessary for welding.

3.3.8. For nozzles that are to be connected to piping by Butt Welding, final weld bevel on the end shall be completed in shop before Pressure Testing. Pad Plate shall be furnished on the Nozzle Neck in order for the Temporary Cap / Closure can be attached by Fillet Welding. Detailed drawings shall be submitted for PURCHASER's review and approval.

3.3.9. The Highest and Lowest Points on Shell and Tube Sides, not otherwise vented or drained, shall be provided with 1 inch nominal size drain and vent in the following manner.

1. For General Service: 1" 6000# Coupling w/plug of 150mm length
2. For Hydrogen Service (partial H2 P ≥ 7kgf/cm2 abs.) and/or Wet H2S Service
   a. 600# & less: 1" Flange, SW Gasket W/Blind Flange
   b. 900# & higher: 1" Flange, RTJ Gasket W/Blind Flange".

Note. For heavier than VGO, drain shall be 1-1/2" flange.

3.3.10. The Nozzle facing of the Intermediate nozzles between the units which are to be stacked shall be raised face (RF) type unless Ring Type Joint (RTJ) is specifically specified.

3.3.11. Level Gauge Nozzles on Kettle Type Exchangers shall be supported from the shell.

3.3.12. Flanged nozzles larger than 2 inch nominal shall be provided with one instrument connection in the following manner.

1. For General Service: 3/4" 6000# Coupling w/plug of 150mm length
2. For Hydrogen Service (partial H2 P ≥ 7kgf/cm2 abs.) and/or Wet H2S Service
   a. 600# & less: 1" Flange, SW Gasket W/Blind Flange
   b. 900# & higher: 1" Flange, RTJ Gasket W/Blind Flange"

3.6.3. Threads of Bolts and Nuts shall be coated before Installation with Anti-Galling Agent.

3.6.4. All bolts 1½" and larger associated with Non Standard body flanges shall be fitted with washers.

3.6.5. All Bolts 1½" and larger on flanges shall require Hydraulic Bolt Tensioners. Bolt lengths shall be specified one nut thickness longer to accommodate the use of the Hydraulic Bolt Tensioning tool. The design of the flange shall provide enough clearance between bolt holes to allow fitting of the Tensioning Tool. Use of other methods shall be subject to PURCHASER's approval.

3.6.6. All Bolts 1⅜" and smaller on flanges shall require tightening by Torque Wrench. Use of other methods shall be subject to PURCHASER's approval.

3.7. SUPPORTS

3.7.1. Saddles or Lugs for Exchangers shall be as per the Tables in Vessel Standard,

. For exchangers which meet all the conditions stipulated in the Tables such as Maximum Weight or Saddle Height, Strength Calculations are still required to be submitted for PURCHASER's review / approval.

3.7.2. Units which are to be Stacked shall be provided with the Required Additional Intermediate Supports and Liners for elevation adjustment.

3.7.3. Supports for Low Temperature Horizontal Exchangers with the Operating Temperatures -20°C or below shall be provided with Wooden Pillows according to Vessel Standard,

3.7.4. 1.5 times load at Bundle Extraction shall be considered in Design of Saddle and Anchor Bolts in accordance with API-660. Loading Data at Bundle Extraction shall also be submitted.

3.7.5. Units which are to be stacked shall be designed so as to withstand the Load at Stacked condition. For nozzles connected to each other and intermediate saddles, thermal expansion shall also be considered in design.

3.8. MISCELLANEOUS

3.8.1. To facilitate breaking Gasketed Joint of Main Girth Flanges, Jack Screws or at the periphery of the Male Flange a cutback of 5 mm to a depth of approximately 30mm and width of 30mm shall be provided.

3.8.2. Guide Rails shall be provided for Kettle Type exchangers and the horizontal exchangers with the Removable Bundle weighing 100 kN and over.

3.8.3. Each Channel, Channel Cover and Shell Cover shall be provided with Plate Type Welded-On Lifting Lug with 25 mm Diameter Hole

3.8.4. Pulling Lugs or Tapped Holes for insertion of Eyebolts shall be provided on the Outer Face or Tubeside face respectively of Tubesheets for Pulling Bundles. Tapped Holes shall be Plugged for protection. Clad Tubesheets shall be the subject of special consideration and details shall be reviewed and accepted

4. FABRICATION

4.1. PLATE LAYOUT

4.1.1. Shell plates shall be laid out so that there will be a Minimum of Welded Seams.

4.1.2. Longitudinal and Circumferential welded seams shall not interfere with openings and / or cover any internal / external Attachments. They shall be arranged as far as possible to avoid any interference. If the seams are covered with reinforcement plates or saddle pads under PURCHASER's approval, the welds shall be ground flush with the Shell surface and Radiographically examined in the full length of the interference area plus 100mm.

4.1.3. Longitudinal Welded Seams on Adjacent Shell Segments shall be separated by at least 5 times the Wall Thickness of the thicker plate but not less than 100mm.

4.1.4. Longitudinal and Circumferential Welded Seams shall be kept out of the Internal Welds insofar as practical and shall be so located that they can be easily inspected with Internals in place.

4.2. FORMING

4.2.1. Selection of Hot or Cold Forming of Materials may be made by VENDOR, but Heat Treatment after Forming shall conform to the Requirements of Applicable Code.

4.2.2. Despite of Par. 4.2.1, Low Alloy Steel of 50mm and over in thickness shall be subjected to Hot Forming. Cold forming shall not be employed unless otherwise approved by PURCHASER.

4.2.3. Despite of Par. 4.2.1, Austenitic Stainless Steel including Clad Plate shall generally be subjected to Cold forming. Hot Forming shall not be employed unless otherwise approved by PURCHASER.

4.2.4. A Formed Head shall generally be made of Single Plate.

4.2.5. When Temporary Attachments are required during the forming work, they shall be welded to the Shell Plate using the same Welding Procedures as for the Main Seams. After removing these attachments, the Surface shall be Ground Flush and Examined by Magnetic Particle Method. In case of High Alloy Steel or Non-Ferrous materials, Liquid Penetrant Method can be substituted.

4.2.6. When forming of clad steel is required, the procedure shall be submitted for PURCHASER's approval prior to operation.

4.3. WELDING

4.3.1. As a rule, Pressure Retaining Parts of Pressure Vessels shall be welded by the Fusion Arc process but Flux Cored Arc Welding process for Pressure Retaining Parts is prohibited. Exceptional applications shall be as per , General Requirements for Weld Fabrication. The Electroslag

6. NAMEPLATE, PAINTING AND MARKING

6.1. NAMEPLATE

A Nameplate as shown in the Vessel Standard, shall be mounted on each Exchanger. Mounting on removable Parts is prohibited.

6.1.1. Fixed Tubesheet Heat Exchangers shall be equipped with Supplemental Nameplate in accordance with UHX-19 of ASME VIII Div.1.

6.1.2. Warning Plates are required for Differential Pressure or Temperature Designs, Low Temperature Operations, Hydrogen Service and any other special cases.

6.2. PAINTING

6.2.1. All exterior surfaces of Heat Exchangers shall be painted in accordance with Painting requirements in Appendix C and Painting Specification, Gasket Surface faces do not require painting.

6.2.2. All Flange Faces and other Machined Surfaces shall be coated with a readily removable rust preventive paint.

6.2.3. Weld Bevels on the ends of Carbon Steel and Low Alloy Steel Nozzles which are to be welded at site shall be coated on the inside and outside for a distance of 75 mm from the end of the nozzle with Deoxyaluminite, Taseto Silver or equivalent.

6.2.4. A detailed procedure of applicable Painting System (Painting Specification) shall be submitted for PURCHASER's approval.

6.3. MARKING

Each Heat Exchanger and its parts shall be marked in accordance with VS-55-0 of Vessel Standard, and Marking for Vessels and Heat Exchangers,

9. APPENDIX A BASIC DESIGN REQUIREMENTS

This Appendix describes the Basic Requirements of the Design of the Shell and Tube Heat Exchangers. For Shell and Heat Exchanger in Package Units, the requirements of this Appendix shall be followed in addition to the body of this Specification.

a. Type Selection
b. Basic Dimensions
c. Design Temperature (Minimum)
d. Corrosion Allowance
e. Material Selection
f. Gasket Selection
g. Minimum Shell Thickness
h. Pipe Shell
i. Minimum Nozzle Size
j. Nozzle Flange Design
k. Nozzle Protrusion
l. Girth Flange Design
m. Support Design of Vertical Heat Exchangers
n. Fire Proofing
o. Extent of Radiographic Examination

9.1. TYPE SELECTION

9.1.1. TEMA Standard type Shell and Tube Heat Exchangers shall be used except for High Pressure & Temperature or other Special Services.

9.1.2. Normally, Heat Exchangers shall be designed with Corrosive or Fouling Fluid in the Tube Side. Cooling water shall be serviced in the Tube Side to prevent C.W Corrosion. If Cooling Water should be serviced in Shell Side, approval of PURCHASER is needed.

9.1.3. Fixed Tubesheet Exchangers shall be used for Little fouling Service on the Shell Side, or when Chemical Cleaning Device is provided. Special considerations must be given to Fixed Tubesheet Exchangers that are in Dry-Out or Steam-Out conditions.

9.1.4. U-tube Exchangers shall be used for Little-Fouling Service (Fouling Factor is less than 0.00034 $m^2 \cdot °C/W$) on the Tube Side, or when Fixed Tubesheet or Floating Head Exchangers are not practicable.

9.1.5. In case of Cooling Water or Fouling Fluid (Fouling Factor is equal and larger than 0.00034 $m^2 \cdot °C/W$) on the Tube Side, Removable Flat Covers (TEMA Type A) shall be provided on the Channel.

9.1.6. "S" type of TEMA shall be limited to Design Pressure on Tubeside of 100 - (0.055 x Shell Diameter (mm))

barg, unless otherwise agreed with PURCHASER.

9.2. BASIC DIMENSIONS

9.2.1. Nominal Shell Inside Diameters shall be selected on every 50 mm, and limited, except for Kettle Type Exchangers, to the maximum of 1800 mm, as a rule.

9.2.2. Tube lengths will be selected from 3000, 5000 and 6000 mm.

9.2.3. Standard Tube Outside Diameters and Tube Pitches shall be as follows:

	Unit: mm
Tube Outside Diameter	Pitch
19.05	25.40
25.40	31.75

9.2.4. Standard Tube Patterns shall be of Triangular and Square. Square pattern shall be applied in case of Boiling service in Shell Side or Fouling Fluid (Fouling Factor is equal and larger than 0.00034 $m^2°C/W$) on the Shell Side.

9.2.5. Standard Tube Thickness shall be as follows:

Unit: mm			
Tube Outside Diameter	Tube Thickness		
	C.S. & Low Alloys (Minimum thickness)	High Alloys (Minimum thickness)	Copper & Copper Alloys (Minimum thickness)
19.05	2.11	1.65	1.65
25.40	2.77	2.11	2.11

Note:

1. 25.40 mm diameter tubes shall be applied when Fouling Factor on Tube Side is equal to and larger than 0.00034 $m^2°C/W$.
2. For Al brass, and Ti tubes, 19.05 mm Diameter Tubes with 1.65 mm average thickness may be used.

9.2.6. The Effective Heat Transfer Surface shall be defined as the outside surface of the Tubes between the Inner Faces of Tubesheets. Bent portions may be considered as the Heat Transfer Surfaces in U-Tube Exchangers.

9.2.7. Maximum Un-Supported Length shall be 0.8 times of TEMA specified values.

9.3. DESIGN PRESSURE AND TEMPERATURE

9.3.1. Internal Design Pressure shall be whichever greater from the following.

Calculation formula In case

1. Pmax.op. + 0.15 MPa Pmax.op. < 1.500

condition.

10.7. INSPECTION AND TEST RECORDS

10.7.1. Inspection and Test Records for each Heat Exchanger shall be supplied.

10.7.2. Inspection and Test Records shall include (where applicable);

1. Manufacturer’s Data Report
2. As-built Sketch or Tabulation for Identification of the Materials showing the location
3. Certified Material Test Report, including Data of Impact Tests and Records/Certificates of Non-Destructive Examination required for the Materials
4. Records of Production Weld Tests
5. Time-Temperature charts of Post Weld Heat Treatment, and Records of other Heat Treatments
6. Records/Certificates of Non-Destructive Examination, such as Radiographic, Ultrasonic, Magnetic-Particle and Liquid-Penetrant Examination
7. Data/Results of Dimensional Inspection
8. Certificates of Hydrostatic Test (including Certificate of the Test Water), Certificates of Pneumatic Test or other Pressure Tests
9. Rubbing of Nameplates