PART A - DESIGN PHILOSOPHY FOR PRESSURE VESSELS

1. GENERAL

1.1 Scope
This specification covers the minimum requirements for the design, materials, fabrication, and inspection of welded pressure vessels which are defined in U-I of ASME Code Section VIII, Division 1 Latest Edition and Addenda.

1.2 Regulations, Codes and Standards

1.2.1 Unless otherwise specified, the design, materials, fabrication and inspection of welded pressure vessels shall comply with ASME Code Section VIII, Division 1 latest edition.
Process licensors guidelines/standards may be adopted complying minimum requirements of this design philosophy of static equipment. Details of such selected guidelines/standards along with the list shall be furnished in the bid.
Unless specifically required, ASME Code stamp is not required.

1.2.2 CONTRACTOR shall follow all National Laws and regulations, together with the Local By-Laws of the State, including all statutory requirements as applicable. CONTRACTOR shall specifically note that any applicable local mandatory code / statutory requirement, if any, shall be informed later.

1.2.3 Apart from the ASME Code, other codes & standards, as listed in Section 6.1 of the ITB, shall form the basis of the design of the Pressure Vessels.

1.2.4 CONTRACTOR may select DIN, BS or any other well known international materials as substituted materials to ASTM/ASME materials, if they are equivalent or superior to ASTM/ASME ones. The chemical & mechanical properties of such equivalent or superior offered materials (preferably comparison with respect to ASTM materials shall be furnished along the bid. CONTRACTOR shall also submit the references of past supplies of similar type of equipment with respect to the proposed materials offered by them in their bid

1.2.5 SEISMIC & WIND LOADS

A) In addition to ASME Section VIII Div 1, columns shall be designed in accordance with following documents & standards for Seismic & Wind Loads:
- IS 1893 – 2002 Criteria for Earthquake Resistant Structure
- Report by University of Roorkee (Attached in Section – 6.2, Design Philosophy for Civil & Structures.)

B) For Strength Calculations of overturning moments due to seismic moment or wind loads, moment greater of Seismic Moment or Wind Moment shall be
considered as governing moment for design. Columns shall be evaluated for both: normal operation & during erection (No internal pressure nor fluids) condition in accordance with UG-23 (d) of ASME Section VIII Div I.

1.2.5.1 SEISMIC DESIGN


Horizontal Seismic Coefficient shall be higher of the following:
Calculated as per Clause 6.4 of IS 1893 – 2002
OR
0.1 as recommended by Roorkee Report.

Horizontal Seismic Forces & Moments shall be calculated considering the above Seismic Coefficient.

In general, all columns will be designed as “SELF SUPPORTED” with platforms & Cage Ladder Access to all Manholes, Instruments & piping nozzles. If the Columns are designed as Self Supported with swing stoppers at different elevations, as indicated on the data sheet, the horizontal deflection shall not exceed 1/325th of the Structure Height.

1.2.5.2 WIND LOAD DESIGN

Design of the Column for Wind Load shall be in accordance with IS 875 – 1987. The design should be carried out by Dynamic Wind Analysis. The Basic Wind Speed for the Plant Site, to be considered in design, shall be 44 Mtr/Sec (158 KMPH)

2. MATERIALS

2.1 Materials of Construction

2.1.1 Materials in contact with process fluids shall be as specified by the Process Licensor in Process Data sheets.

2.1.2 Materials for pressure parts and structural attachments directly welded to pressure parts shall be those permitted by ASME Code Section VIII.

2.1.3 All CS & LAS materials including forging used for pressure parts shall be procured in fully killed and normalized condition. CS & LAS materials above 50 mm thickness shall be vacuum degassed except for plate ring flanges.

2.1.4 All SS plates shall be hot rolled & solution annealed and pickled as per SA 480.

2.1.5 All plates above 50mm thickness shall be vacuum-degassed and examined by
Ultrasonic Testing (UT) at surfaces & edges as per SA-578 Level B and other equivalent applicable material specification code/standard. Pressure parts having thickness between 16 mm to 50 mm shall be ultrasonically tested as per SA - 435.

2.1.6 Material for Pressure Vessels shall be procured with following minimum requirement:

**CS and LTCS Material**
Carbon content shall not exceed 0.23%
Carbon equivalent shall be restricted to 0.40% max. ($\text{Ni} \leq 0.2\%$, $\text{Sulphur} \leq 0.002\%$ for plates and 0.01% for tubes, pipes and forgings)
Hardness for plates and pipes shall be $\leq 200$ BHN.
Hardness for forging shall be $\leq 187$ BHN.

**LAS Material**
Use of C-1/2 Mo is prohibited as per API-941 in hydrogen service.
LAS tubes hardness test shall performed on outside of tubes as per SA-450.

**SS and other High Alloy Material**
All SS material shall be fully annealed and pickled conditioned. All stabilized grades (SS 321, SS 347 etc.) shall be given stabilization heat treatment.
All SS (300 series) plates shall be hot rolled and shall have No. 1 finish on both side.

2.1.7 CLAD material

(a) Cladding shall be integrally and continuous bonded to the base metal. All clad plates shall be rolled or explosion bonded type.

(b) Clad plates shall be UT examined from the cladding in accordance with SA-578 level B. Scanning shall be 100% of the plate surface.

(c) Alloy clad steel plates shall be as per SA-264. Bond between cladding and base metal shall be checked for a minimum strength of 14 Kg/cm² in shear for alloy clad steel plate.

(d) During tension test of clad plates the bond between cladding shall be removed and the tensile properties of the base material shall meet the code material requirement.

(e) For austenitic SS clad plates the SS surface shall be acid pickled as per ASTM A-380.

(f) For all clad plates used in Hydrogen service with design temperature greater than 350 degree C, Hydrogen bonding test shall be carried out.

(g) Cladding shall be done either by integrally bonded cladding conforming to ASME SA-263, SA-264 or SA-265 or shall be weld overlay. Heat treatment for
clad plate shall conform to SA-263 and SA-264, Heat Treatment shall be done at the mill.

(h) The nominal thickness of mechanically bonded cladding shall be 7/64 inch (2.8 mm) except clad or weld overlay on tube sheets and gasket surfaces.

(i) The minimum thickness of weld overlay material shall be 1/8 inch (3 mm) except clad or weld overlay tube sheets and gasket surfaces.

(j) Tube sheets shall have a nominal clad or weld overlay thickness of 3/8 inch (10 mm) but not less than 5/16 inches (8 mm) regardless of shell side or tube side face. The minimum thickness of clad or weld overlay at a pass partition groove shall be 1/8 inch (3 mm) minimum.

(k) Weld overlayed nozzle and girth flange gasket faces shall have a minimum thickness of 3/16 inch (4.8 mm) after machining.

(l) Loose liners, strip liners or plug welded liners are not acceptable.

2.1.8 In order to minimize the effect of temper embrittlement for material to 2¼ Cr - 1 Mo specification in the temperature range of 375-575 degree C, the embrittlement factors ‘X’ & ‘J’ shall be limited to:

\[ X = \frac{(10P+5Sb+4Sn+AS)}{100} \leq 15 \]

The elements above are expressed as ppm

\[ J = (Si + Mn) (PHs) \times 10^4 \leq 160 \]

The elements above are expressed as percentages

A simulated PWHT followed by step cooling shall be performed on a sample of material. Acceptable toughness shall be demonstrated by means of a Charpy V Impact Test.

2.1.9 For SS 316 & 316L materials the requirements of ferrite content and inter granular corrosion test shall have to be complied with in conformity with Process Licensor’s standard. The inter granular corrosion test, weld & HAZ as per ASTM A 262 practice C & While for SS316L material ASTM A 262 practice E shall be applicable. The corrosion rate shall be as per the recommendations of Process Licensor.

2.1.10 For SS316 & 316L material Ferrite content for plate, pipe, and tubes a forging shall be max. 2%.

2.1.11 In case of equipment fabricated of materials of SS316L, low ferrite filler material shall be so selected that ferrite content in two subsequent pass in contact with process fuel shall be max. 2%. The welding not in contact with process fluid may have ferrite content limited to 6%.

2.1.12 Steel for Hydrogen service at elevated Temperature & pressure shall be selected as per API 941. The following special requirements shall be met with
for Hydrogen/Sour gas as per NACE standard.
   a) All pressure parts shall be post weld heat treated.
   b) All pressure retaining welds shall be 100% radiographed.
   c) Hardness of base metals, weld and HAZ shall not exceed 22 HRC.

2.1.13 Unless otherwise specified Copper & Copper alloys shall not be used. Copper content as impurities up to 0.4% are acceptable in carbon steel & 0.6% in stainless steel.

2.1.14 For high pressure equipments, in shell & heads, the impurity limit shall be Copper ≤ 0.20% & Nickel ≤ 0.30% for Mo & Cr - Mo low alloy steels while Copper shall be ≤ 0.20% & Vanadium ≤ 0.15% for carbon steels.

2.2 Bolting

2.2.1 All bolting for shell flanges, manholes, and hand holes, except for ANSI Standard flanges, shall be stud bolts and nuts, and conform to the requirements of ASME Code Section VIII, Division 1.

2.2.2 Unless otherwise specified, threads on bolting shall be Unified Inch Screw Threads. When bolt size is 1 inch and over, Unified Inch Screw Threads, 8 UN (8 thread per inch) shall be used.

2.2.3 Nuts shall be heavy-duty hexagonal nuts except for piping connections.

2.2.4 Bolting materials for connection of internal parts shall be minimum SS 304.

2.3 Non pressure Parts

2.3.1 Materials for external parts directly welded to high-alloy steel vessels shall be as follows:
   1) External parts which are strength welded to shell, for example, clips for platform or pipe supports, pads for vessel supports or lifting lugs, etc., shall be of similar composition to the shell. For austenitic stainless steel vessels, materials for such external parts shall be selected in accordance with Table 2.3.1.

<table>
<thead>
<tr>
<th>Shell Material</th>
<th>Attachment Material</th>
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<tbody>
<tr>
<td>SS 304</td>
<td>SS 304</td>
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<tr>
<td>SS 304 L</td>
<td>SS 304 L</td>
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<tr>
<td>SS 316</td>
<td>SS 316 OR SS 304</td>
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<tr>
<td>SS 316 L</td>
<td>SS 316 L OR SS 304 L</td>
</tr>
</tbody>
</table>

2) External parts which are not strength welded to the shell, such as clips for insulation support rings, may be of carbon steel, provided if SS 304 stainless steel pads are furnished between shell & external parts.
3) At least, the top 500 mm of vessel skirts shall be of similar composition to the vessel shell. The remainder of the skirt may be of carbon steel.

2.3.2 Materials for all non pressure parts directly welded to low-alloy vessels and low-temperature service carbon steel vessels shall be as follows:
1) Internal and external parts shall be of similar composition to the vessel shell.
2) At least the top 500 mm of vessel skirts shall be of similar composition to the vessel shell. The remainder of the skirt may be of structural quality carbon steel.

2.3.3 Materials of heavy-duty lifting lugs for vessels shall be of killed steel.

3. DESIGN

3.1 Design Pressure and Design Temperature

3.1.1 Design pressure and design temperature for strength calculation shall be determined considering the following:
1) Design pressure and design temperature shall be as specified in the data sheets.
2) Specified design pressure shows a pressure at the highest point of a vessel.
3) Static liquid head shall be added to the specified design pressure to determine the thickness of any specific part of the vessel.

3.1.2 For jacketed vessels, internal shell shall be designed for both internal pressure and external pressure (equal to internal pressure of jacket).

3.1.3 Design based on differential pressure shall not be used except where vacuum design is specified for internal shell or jacket.

3.2 Loading and Stability

3.2.1 Vessels and vessel Supports including anchor bolts shall be designed to support combinations of loads and forces to which the vessels may be subjected.

3.2.2 The following combinations of loads and forces shall be considered as a minimum for the design of vessels and supports including anchor bolts, and stability against overturning.

1) Erection period - new and ambient temperature conditions:
   a) Deadweight of the vessel, less all removable internals, insulation, fireproofing, piping and platforms supported from the vessel.
   b) Wind or earthquake load, whichever is greater

2) Field testing or flushing period in operating position - new and ambient temperature conditions:
   a) Deadweight of the vessel, including all internals, fireproofing, piping and platforms supported from the vessel (except insulation)
   b) Weight of water for testing or flushing
   c) Pressure applied for testing
   d) Water static head
   e) Wind load equivalent to a 44 m/s wind velocity for this calculation (No earthquake
3) Normal operation period - corroded and design temperature conditions:
   a) Deadweight of the vessel, including all internals, insulation, fireproofing, piping and platforms supported from the vessel
   b) Operating weight of fluids, including fluids on trays or packing.
   c) Design pressure plus static liquid head for calculating tensile stress of the shell. For calculation of compressive stress, minimum operating pressure, or design vacuum pressure if specified, plus static liquid head
   d) External pressure or full vacuum condition when specified
   e) Eccentric load and additional load
   f) Wind or earthquake load, whichever is greater

4) Plant shutdown period - corroded and ambient temperature conditions:
   a) Deadweight of vessel, including all internals, insulation, fireproofing, piping and platforms supported from the vessel
   b) Weight of liquid, if liquid remains in the vessel
   c) Eccentric load and additional load
   d) Wind or earthquake load, whichever is greater

3.3.3 Wind Force

1) For Columns.

Columns shall be designed in accordance to Para 1.2.3 above.

2) For vessels excluding columns.

Wind force shall be calculated by the following formula:

\[ F_w = q \times c \times A \]

where

- \( F_w \) = Wind force (N)
- \( q \) = Velocity pressure (as per IS 875 latest)
- \( c \) = Shape factor
  - = 0.7 for cylindrical vessels
- \( A = \text{Effective area (m}^2)\)
- \( = \text{De} \times H \)
- \( \text{De} = \text{Equivalent diameter (m)} \)
  - = \( \text{Do} + 0.5(m) \), for erection condition
  - = 1.2 \( \text{Do} \), or \( \text{Do} + 0.6(m) \), whichever is greater for operation condition
- \( \text{Do} = \text{Vessel outside diameter including insulation (m)} \)
- \( H = \text{Vessel height from ground level to the top of head (m)} \)

3.4 Earthquake Force

1) For Columns

Columns shall be designed in accordance to para 1.2.3 above.
2) For vessels excluding columns. Earthquake force shall be calculated by the following formula:

\[ F_e = K_i \times W_i \times g \]

where

- \( F_e \) = Earthquake force (N)
- \( K_i \) = Seismic coefficient
- \( W_i \) = Weight of parts under consideration (kg)
- \( g \) = 9.8 m/s²

3.5 Allowable Stress

3.5.1 Vessel stresses during hydrostatic tests shall not exceed 90% of the minimum yield strength of the material.

3.5.2 Vessels to be hydrostatically shop tested in the horizontal position shall be supported adequately to keep local stresses in the shell not exceeding 90% of the yield strength of the material.

3.6 Stress and Deflection Analyses

3.6.1 Stress Analyses

The following stress analysis reports shall be submitted to the Owner for review, if applicable.

1) Where cyclic operation data are specified in data sheets, vessels shall be designed to prevent fatigue failure caused by cyclic thermal, mechanical or pressure stress.

2) Horizontal vessels of large size and thin wall shell on saddle supports shall be investigated for buckling, local circumferential bending and shear stress. The method of L. P. Zick (Supplement to Welding Research, 1971) may be used for this investigation.

3) Vibration due to wind load (Karman vortex) shall be analyzed under the following conditions for columns higher than 30 m with a height to diameter ratio over 20.
   a) Erection period
      Refer to paragraph 3.2.2,1).
   b) Testing or flushing period
      Refer to paragraph 3.2.2,2), except for subparagraph e), and no piping and platform condition.

4) Where external forces for nozzles or supports are specified in data sheets, local loads due to external forces shall be analyzed according to Welding Research Council (WRC) Bulletin 107, WRC 297. Where necessary, reinforcing pads of compatible material to shell shall be provided to reduce stresses to an acceptable level.

3.6.2 Deflection of Columns

Unless otherwise specified, the deflection of vessels under normal operating conditions with the design wind load or wind load equivalent to a 50 m/s wind velocity, whichever is smaller, shall not exceed \( H/200 \), where \( H \) is the total height. Earthquake load shall not be taken into consideration in this calculation.
3.7 Corrosion Allowances

3.7.1 Corrosion allowances specified by the process licensor shall be added to the calculated thicknesses of the pressure parts.

If corrosion allowances are not specified in the data sheets, the following corrosion allowances shall be applied:
- for carbon and low-alloy steel 3.0 mm
- for high-alloy steel 1.0 mm
- for nonferrous materials 0.0 mm

3.7.2 For the inside of shells, heads, nozzles and manholes, the specified corrosion allowances shall be added.

3.7.3 For non removable internal parts, the specified corrosion allowances shall be added to both sides.

3.7.4 For removable internal parts, the specified corrosion allowances shall be added to one side only.

3.7.5 Corrosion allowances for trays shall be in accordance with "General Specification for Trays".

3.7.6 No corrosion allowance shall be required on gasket surface of flanges, anchor bolts, vessel skirts and other supports.

3.7.7 For an intermediate head, corrosion allowances shall be added to both sides.

3.8 Minimum Thickness

3.8.1 The nominal thickness of shells and heads, exclusive of corrosion allowances, shall not be less than the following:

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>THK (mm)</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>2.5</td>
<td>for carbon and low-alloy steel</td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td>for high-alloy and austenitic steel</td>
</tr>
</tbody>
</table>

3.8.2 Notwithstanding the above 3.8.1, the minimum thickness of vessel heads of 2:1 ellipsoidal or tori-spherical type shall not be less than 0.002 x D (nominal vessel diameter), exclusive of corrosion allowance, to avoid the possible buckling of the knuckle region under internal pressure.

3.9 Heads

3.9.1 Tori spherical heads shall be used for Pressures up to 6.86 bar (g). For tori spherical heads, ratio of Knuckle to Inside Crown Radius shall not be less than 6%.
3.9.2 Beyond 6.86 bar g, heads shall be of ellipsoidal type having a ratio of major axis to minor axis 2:1 or hemispherical type. Alternatively, Hemispherical Heads with minimum weld joints may also be used.

3.10 Supports

3.10.1 Horizontal vessels shall be supported on steel saddles fully welded to the vessel and covering at least 120 degrees of the vessel circumference.

3.10.2 Where saddle pads are provided, the pads shall be continuously welded to the vessel. The pad shall be vented with a NPT 1/8 hole. Each hole shall be plugged with plastic sealant or hard grease prior to shipment.

3.10.3 Where vessels are supported on concrete saddles, corrosion plates shall be provided between the saddle and the vessel. The plates shall be minimum 6 mm thick, shall extend 50 mm beyond the periphery of the bearing area of the concrete saddle, and shall be continuously welded to the vessel. A NPT 1/8 vent hole shall be provided in each plate. Each hole shall be plugged with plastic sealant or hard grease prior to shipment.

3.10.4 Where vessels are installed on concrete foundation, sliding plates shall be furnished for installation under saddle, where slotted holes for anchor bolts have been furnished, to provide for shell expansion. For heavy equipment special consideration is required to reduce the friction.

3.10.5 Horizontal vessels on saddle supports subject to vacuum shall be investigated for buckling and circumferential bending. If necessary, one continuous stiffening ring shall be placed in plane of each saddle to resist circumferential bending. The sizing of this stiffener shall be sufficient to satisfy the combined effects of vacuum and circumferential bending and shall meet the requirements of both ASME Code Section VIII, Division 1 and the method of L. P. Zick.

3.10.6 Vessel supports shall be designed to support full water or full liquid loads, unless otherwise specified. For skirts of columns with trays, full water loads shall be considered only when hydrostatic testing at site in operating position is specified.

3.11 Flanges

3.11.1 Flanges of nozzles and manholes shall conform to ANSI standards.

3.11.2 Shell flanges shall be designed in accordance with ASME Code Section VIII, Division 1.

3.11.3 The type of nozzle flanges shall be of welding neck type. Long Welding Neck flanges can be used for sizes 2" and below. Slip-on flanges may be used for ratings of 300 LBS and lower when the design temperature is less than 260°C, except for vessels in hydrogen, lethal, or low-temperature service.

3.11.4 All flanges, including Manhole Flanges, Girth Flanges, etc. shall be of the same
material as that of the Pressure Vessel. Lined flanges or nozzles with stub-end / lap joint flanges shall not be considered in design.

3.11.5 Nozzles and manholes located in lined portion of vessels shall be solid having material of construction same as that of lining.

3.11.6 Flange ratings of 600 LBS and higher shall be of welding neck, including built-up welding neck construction, or stud-pad type construction. Flanges of 600 # Rating and Higher will have “Ring Joint Gaskets” only.

3.11.7 All bolt holes for flanges shall straddle the centerlines of the vessels.

3.11.8 Vent holes shall be provided to the enclosed space of slip-on flanges when vessel is subject to post weld heat treatment.

3.11.9 The finish of contact faces of flanges shall be according to the followings:
   - Sheet Gasket: Stock finish (125 to 500 AARH)
   - Spiral wound Gasket: Smooth finish (125 to 250 AARH).
   - Ring Joint Gasket Surface: 63 micro inch

3.12 Nozzles and Connections

3.12.1 The minimum size of nozzles and connections shall be 3/4", except for instrument connections.

3.12.2 In general, nozzles shall be of flanged type.

3.12.3 Nozzles of 1" and smaller shall be reinforced with couplings and bracing by ribs, except self-reinforcing integral type.

3.12.4 Threaded 3/4" and 1" diameter couplings may be used for drain, vent, thermocouple and piping connections.

3.12.5 Vent connections shall be of 3/4" minimum should be provided with Valve & Blinds.

3.12.6 Drain connections shall be of 3/4" minimum should be provided with Valve & Blinds.

3.12.7 Nozzle connections inside skirts shall be provided with 90° long radius elbows for projection outside the skirt.

3.12.8 Reinforcing pads shall not be fitted to shells exceeding 50 mm thickness nor where thermal gradient between pad and shell is severe.

3.12.9 Nozzle connections for vessels greater than 50 mm thick shall be of self-reinforcing integral type.

3.12.10 All nozzles shall be designed to withstand all expected external loads.
3.12.11 Reinforcing pads for nozzles and manholes shall be tapped with at least one
telltale hole of NPT 1/8” with steel or plastic plugs.

3.12.12 Gaskets used for high pressure shall be of the following type:
   - Ring Joint
   - Double conical with graphite tape
   - Diaphragm gasket
   - Lip seal Gasket

3.13 Manholes

3.13.1 Nominal diameter of manholes shall not be smaller than 20”.

3.13.2 The maximum spacing of manholes in columns with trays shall be smaller of 13
m or 20 trays.

   Horizontal vessels shall have at least one manhole on the head or the top
   longitudinal line of the vessel. Where two manholes are provided, one manhole
   shall normally be located above normal working liquid level.

3.13.4 Manhole covers shall be equipped with davits or hinges to facilitate handling.

3.14 Internal Parts

3.14.1 Internal support rings and gratings for packed columns shall be designed to
support load equal to the weight of the dry packing plus the weight of 75% of full
water of the void space of packing.

3.14.2 The material for support rings, clips, and brackets shall be minimum SS 304.

3.14.3 Removable internal parts shall be so designed as to be installed through
manholes or shell flanges.

3.14.4 Internal distribution pipes shall have flanged connections with gaskets unless
otherwise specified. Internal pipes shall be divided into suitable lengths to pass
freely through the vessel manholes and internal man ways, and shall be suitably
supported from shells or tray decks.

3.14.5 All nozzles connected to a pump inlet, except for heavy slurry service, shall be
equipped with vortex breakers.

3.14.6 Bolt/studs of manhole should be so designed to accommodate normal Heavy
duty spanners (i.e. bolt/stud center to center distance between outer edge of
nuts and piping/nozzle flange OD should be able to accommodate normal width
H.D. spanners).

3.14.7 Bolts of size M52 and above shall be designed and spaced so as to permit
tightening with a hydraulic stud-tensioners. The bolts shall have an extra
threaded length at one end of approximately 1 bolt diameter and shall be provided with threaded protection caps. Hex nuts shall have suitable holes for manual tightening. Equipment having bolt size above M52 shall be supplied with hydraulic bolt tensioning device along with recommended spares and operating manual indicating tightening torque. For bolts size above M52 the following information are required to be furnished along with offer:

i) Size of bolt indicating pitch of thread.

ii) P.C.D. of bolt holes

iii) Required tightening torque.

iv) Dimension of the nut (across flat & across corner)

v) Catalogue indicating range of operation etc.

3.15 Cladding and Lining

3.15.1 Cladding & lining is not allowed. If it is allowed in special case after taking permission of OWNER than Integrally clad metal and weld overlays shall not be considered as contributing to the strength of the vessel wall thickness of the Equipment. It should not be considered in the minimum thickness calculation.

3.15.2 Strip liners shall not be used in vessel shell for hydrogen service.

3.15.3 Cladded plates shall be supplied as per ASTM A 264 material specification. All clad plate shall be UT examined at the steel works in accordance with ASTM A 578 level S8.

3.16 Accessories

3.16.1 Clips for platforms, ladders and piping supports shall be furnished and attached to the vessel by the vessel manufacturer.

3.16.2 Top davits of vertical vessels shall be so designed and fabricated so that heavy valves around the vessels and internal parts of vessels can be removed and grounded without being interrupted by piping and steel structures.

3.16.3 Insulation Support Rings

1) Insulation support rings shall be suitable provided as per the specified insulation thickness.

2) Maximum longitudinal interval of insulation support rings shall be 3600 mm when preformed insulating material are used.

3) Stiffening rings may be used as insulation support rings.

3.16.5 Lifting lugs of appropriate size shall be provided to ensure complete safety during erection of the Vessel.

3.16.6 Grounding lugs shall be attached to the vessel support for the ground connection.

3.16.7 Anchor bolts shall not be smaller than 5/8-11 UNC. At least , 80 % of the length of the Anchor bolt is to be casted.
3.16.8 Templates

Templates for vertical vessels with skirts shall be provided for laying out of anchor bolts at site. The template shall have adequate strength against deformation. Template shall be identical to the Vessel Base Frame having double ring. Template should be of chair type only.

2) It shall be confirmed that markings of the bolt hole orientation on the templates coincides with those shown on the approved drawings.

4. FABRICATION

4.1 Welding

4.1.1 Welding procedure, and welders and welding operators shall be qualified in accordance with ASME Code Section IX, Welding and Brazing Qualifications.

4.1.2 Weld joints included in Categories A and B of UW-3 of ASME Code Section VIII, Division 1, shall be double-welded butt joints with full penetration. When double weld is not practicable, TIG weld or consumable backing strips may be used. Backing strips shall be removed.

4.1.3 Pipes and plates may be cut, shaped, and beveled for welding by mechanical means. Edges may also be prepared by oxygen cutting or plasma cutting after which the edges shall be ground back to bright metal. The edges to be welded shall be uniform and smooth. All foreign materials such as oil, grease, cutting lubricant, paint, and layout marking shall be removed from the areas subject to heating. Solvents used for cleaning shall be sulfur-free.

4.1.4 Each completed bead shall be thoroughly cleaned of all slag and weld spatter before proceeding with the next bead. For double butt welds, the root area of the weld from the first side shall be thoroughly cleaned by chipping prior to welding from the second side. Weld spatter shall also be cleaned from areas adjacent to the weld. Weld deposits shall not be used to extend edges of plates or to fill cavities resulting from poor fit up without written approval of the purchaser. All defects that appear on the surface of any deposited bead shall be removed by chipping, grinding, or flare gouging before depositing the next bead. Weld repairs shall be completed before equipment is heat treated.

4.1.5 Oxyacetylene welding is not permitted.

4.1.6 Attachments of parts, such as nozzles, pads, and clips by welds which cross or for which the minimum distance between the edge of the attachment weld and the edge of the existing main welds or nozzle welds is less than the smaller of twice the thickness of the pressure part or 40 mm should be avoided, as far as possible. Where this is not possible, such welds should cross the main weld completely rather than stop abruptly near it in order to avoid stress concentration.

4.1.7 When openings occur in welded seams or within 12 mm of any main seams, or
attachments cover any main seams, the soundness of all welds shall be demonstrated on completion by appropriate radiographic or ultrasonic inspection.

4.1.8 Full penetration butt welds shall be used for any radial joints in stiffening rings and for any similar joints in other members used for stiffening or support purposes where such a member is welded across the joint to the pressure part. The soundness of all such welds shall be demonstrated on completion by appropriate radiographic or ultrasonic inspection.

4.1.9 All filler metal shall have the same quality as, or higher quality than the base metal.

4.1.10 For welds between dissimilar metals, welding electrodes, or filler metals shall be selected to obtain deposited weld metal of the same quality as the higher grade material.

4.1.11 Welding and welding repair procedures shall be submitted to the purchaser for review prior to start of fabrication.

4.1.12 Repair welding of defects in material shall be performed using a qualified procedure after approval by the purchaser.

4.1.13 All nozzle welds shall be fully penetrated except for pad type nozzles. Full penetration type shall be used for pad type nozzles for hydrogen service, and set-in type defined by ASME Code Section VIII, Division 1 may be used.

4.1.14 Tray support rings shall be attached to the shell by continuous fillet weld. However, the underside for carbon steel vessels may be attached by intermittent fillet weld.

4.1.15 All clips and brackets on internal or external surface of vessels shall be attached by continuous fillet weld.

4.1.16 For vessels in hydrogen or lethal service, all clips and brackets for internals or externals of vessels shall be attached by full penetration weld.

4.1.17 Alignment of sections of edges to be butt welded shall be such that maximum offset is not greater than the value specified in ASME Code Section VIII.

4.2 Forming of Shells and Heads

4.2.1 When a difference in thickness exists between shell plate and heads, the inside surface shall be kept flush.

4.2.2 Where thickness between adjacent plates differs by more than 3 mm, the thicker plate shall be tapered maximum 3:1 to give smooth transition over joint.

4.2.3 Carbon and low-alloy steel cold formed dished ends shall be normalized.

4.2.4 Carbon and low-alloy steel plates may be formed by blows at a forging
temperature provided the blows do not objectionably deform the plate and it is subsequently post weld heat treated.

4.2.5 Vessel shell sections, heads, and other pressure boundary parts of all carbon and low-alloy steels fabricated by cold forming, shall be heat treated subsequently when the resulting extreme fiber elongation is more than 5% from the as-rolled condition and any of the following conditions exist.

1) The vessel will contain lethal substances either liquid or gaseous.
2) The material requires impact testing.
3) The thickness of the part before cold forming exceeds 16 mm.
4) The reduction by cold forming from the as-rolled thickness is more than 10%.
5) The temperature of the material during forming is in the range of 120 °C to 480°C.

For P-Number 1, Group Numbers 1 and 2 materials, the extreme fiber elongation may be as great as 40% when none of the conditions listed above in (1) through (5) exist.

The extreme fiber elongation shall be determined by the formulas in UCS-79 of ASME Code Section VIII.

4.2.6 Plate Layout
1) Shell plate shall be laid out so that there will be minimum of welded seams.
2) Longitudinal and circumferential welded seams shall not interfere with nozzle openings, reinforcement plates, saddle pads, and other attachments as far as possible.
3) Longitudinal welded seams on adjacent shell segments shall be separated by at least 4 times the wall thickness of the thicker plate but not less than 100 mm.
4) Longitudinal weld seams in heads shall be arranged near to the head axis but not covered by a reinforcing pad. If the above is impractical or good seam location is not obtained, longitudinal weld seams in heads shall be arranged to pass through head axis, provided that any portion of the welded seam covered by a reinforcing pad is radiographed.
5) Weld seams in hemispherical heads formed from more than one plate shall be arranged in ‘crown & petal’ fashion with single crown plate.
6) Circumferential weld seams of shell shall be located at least 50mm apart from tray support rings.
7) Longitudinal weld seams shall not be located behind down comer.

4.3 Connections

4.3.1 Unless shown in data sheets, nozzles, manholes, and hand holes shall be ground flush and smooth inside the vessel. The edges of internal projections for both nozzles and manholes shall be rounded to a radius of 2 mm minimum. Reinforcement pads shall be external.

4.3.2 Main vessel seams shall not pass through openings for connections as far as possible. When unavoidable, the portion of the weld seam covered by a reinforcing pad shall be ground flush with the parent metal and 100% radiographed prior to attachment of the pad.
4.3.3 All reinforcing pads shall be provided with at least one telltale hole of NPT 1/8".

4.4 Heat Treatment

4.4.1 Fabricated vessels shall be post weld heat treated in accordance with ASME Code Section VIII, Division 1, and requirements specified in the data sheets.

4.4.2 The complete post weld heat treatment procedure including temperature and holding time shall be submitted to the purchaser for review.

All machined surfaces shall be protected against scaling during post weld heat treatment.

4.4.4 All internal and external attachments, clips, insulation studs, name plate bracket, and the like shall be welded to the vessel before post weld heat treatment.

4.4.5 No welding, hammering or deforming is permitted on the pressure retaining parts after post weld heat treatment except as permitted by the codes or standards and when approved by the purchaser.

4.4.6 Simulation Heat Treatment for the Alloy Steel Material shall be carried out as per the CODE Requirement.

4.5 Pickling

When specified, all internal / external surfaces of stainless steel shall be cleaned by pickling before hydrostatic test.

1) Care shall be taken so that stainless steel surfaces shall not be subject to any scratch or damage during pickling.

2) Weld scale and other foreign material deposited on the surfaces shall be removed.

3) Pickled surfaces shall be completely neutralized, and washed by freshwater.

4.6 Fabrication Tolerance

Dimensional tolerances shall be in accordance with the design codes or standards, and as specified in "Inspection Philosophy Section", whichever is more stringent.

5. INSPECTION AND TESTING

Inspection & Testing shall be carried out as per “INSPECTION PHILOSOPHY” section of the ITB.

6. PAINTING

Upon completion of all testing and inspection and before shipment, exterior surface of carbon and low-alloy steel vessels except machined surfaces shall be primed.

7. PREPARATION FOR SHIPMENT
7.1 All vessels shall be drained, clean, and free of grease, oil, scale, weld spatter, and any other foreign substance.

7.2 All flange faces and other exposed machined surfaces shall be properly protected with substantial metal shields or covering against damage during shipment.

7.3 All inside surfaces and internal parts of carbon steel shall be coated with a suitable rust preventive before shipment.

7.4 All openings shall be provided with metal closures.

7.5 Test holes of reinforcing pads for nozzles and manholes shall be plugged with steel or plastic plugs.

7.6 Vent holes of saddle pads shall be plugged with plastic sealant or hard grease prior to shipment.

7.7 All threaded connections shall be plugged with threaded round bars or covered with standard pipe caps of the same material as the equipment. Covers, flanges, gaskets, bolts, and nuts furnished by the fabricator shall be shipped in place.

Internals shall be tied or braced as necessary to avoid damage or dislodgment during Shipping and installation.

Baselines indicating four directions with figures of 0°, 90°, 180° and 270° shall be marked by paint on the shell. The paint color shall be white for carbon steel and black for stainless Steel.

PART B - DESIGN PHILOSOPHY FOR HEAT EXCHANGERS

1. GENERAL

1.1 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication and inspection of shell and tube type heat exchangers.

1.2 The Design Philosophy for the Shell & Tube Heat Exchangers shall be read in conjunction with the Design Philosophy for Pressure Vessels, as per Section – A above.

1.2.1 Unless otherwise specified, the design, materials, fabrication and inspection of heat exchangers shall comply with Standards of Tubular Exchanger Manufacturers Association (TEMA) 1999 Eighth edition and ASME Code Section VIII, Division 1 2004 edition. TEMA – R shall be used for design. Unless specifically required by OWNER / LICENSOR, ASME Code stamp is not required.

1.2.2 Tubular heat exchangers of auxiliary component for machine units such as lube
oil coolers is to be designed, fabricated, inspected and tested in accordance with the manufacturer's standards and ASME Code Section VIII, Division 1, provided written approval is obtained from the purchaser.

1.2.3 Double pipe exchangers may be designed, fabricated, inspected and tested in accordance with the manufacturer's standards and the ASME Code Section VIII, Division 1.

1.2.4 Steam surface condensers shall be designed, fabricated, inspected and tested in accordance with Heat Exchanger Institute Standards and ASME Code Section VIII, Division 1.

Process licensors guidelines/standards may be adopted complying minimum requirements of this design philosophy of static equipment. Details of such selected guidelines/standards along with the list shall be furnished in the bid.

1.2.5 CONTRACTOR shall follow all National Laws and regulations, together with the Local By-Laws of the State, including all statutory requirements as applicable. CONTRACTOR shall specifically note that any applicable local mandatory code / statutory requirement, if any, shall be informed later.

1.2.6 Apart from the ASME Code, other codes & standards, as listed in Section 6.1 of the ITB, shall form the basis of the design of the Pressure Vessels.

1.2.7 CONTRACTOR may select DIN, BS or any other well known international materials as substituted materials to ASTM/ASME materials, if they are equivalent or superior to ASTM/ASME ones. The chemical & mechanical properties of such equivalent or superior offered materials (preferably comparison with respect to ASTM materials shall be furnished along the bid. CONTRACTOR shall also submit the references of past supplies of similar type of equipment with respect to the proposed materials offered by them in their bid.

1.3 Priority
Any conflicts between documents, including regulations and codes, shall be brought to the purchaser's attention for resolution.

2. MATERIALS

2.1 General

2.1.1 Materials of major parts in contact with the process fluids shall be specified in the data sheets.

2.1.3 Castings shall not be used for pressure parts and pass partitions of channels and floating heads.

2.2 Tube sheets

2.2.1 Tube sheets and Girth Flanges shall be shall be of Forged Quality & Ultrasonically tested. It shall not have any segmental joint.
2.2.2 Tube Sheets from Plates shall not be used.

2.2.3 Stainless steel clad tube sheet.
   1) Cladding shall be integral and continuously explosion bonded to the base metal.
   2) Clad plates shall have minimum shear strength of 1.45 N/mm².
   3) Clad plates shall be ultrasonically examined for bond before commencement of any Fabrication with ASME SA-578 level B. 1992 edition with the following modifications and Requirements:
      - Scanning shall be continuous over 100% of the plate surface.
      - Acceptance criteria shall be in accordance with S7 for stainless steel clad.
      - All weld repair shall be obtained prior approval from the purchaser.

      The vendor shall submit weld-repair procedure, and sketch showing the extent and location of weld-repair required. The purchaser will decide the acceptability of the weld-repair proposed by the vendor, based on the above documents.

      For clad plates, Clauses 2.1.7 of Section – A, shall also apply.

2.3 Tubes

2.3.1 Minimum SS 304 as MOC for tubes shall be used for Heat Exchangers having Cooling Water service. All tubes shall be seamless only.

2.3.2 All heat Exchanger Tubes shall be Eddy Current Tested in addition to Hydro testing.

2.3.3 MOC for Tubes shall be as specified in the Process Data Sheet of the Exchangers.

2.3.4 Copper & Copper Alloy tubes shall not be used for any Exchangers.

2.4 Bolts and Nuts

Bolting shall be as per Clause no 2.2 of Section A above.

3. DESIGN

3.1 General

Design of the Shell & Tube Heat Exchangers shall be as per TEMA – R only.

3.1.1 All tubular heat exchangers shall be of the type specified and shall be designed for the service and performance conditions given in the specification or data sheets.

The specified heat transfer surface shall be taken as the minimum required surface area. For U-tubes, the exposed surface at U-bend portion shall not be considered as effective surface, unless otherwise specified in the data sheets.

Unless otherwise specified, parts subject to both shell and tube side fluids shall be designed for the pressure on one side that requires the maximum material
thickness for the parts. When design pressure of either side is vacuum, the pressures of both sides shall be taken into consideration.

3.1.4 Tube Sheets will be designed as per “ASME Section VIII Division 1 Clause UHX” as per the notification issued by TEMA.

3.1.5 Gaskets for Synthesis Gas, Hydrogen & other lethal services shall be of “LIP SEAL GASKET” Design.

3.2 Design Pressures and Design Temperatures

3.2.1 Design pressures and design temperatures used for strength calculation shall be as specified in the data sheets.

3.2.2 The following vacuum condition shall also be considered.
   1) Steam side of steam heated exchangers shall be designed for full vacuum.
   2) Cooling water side of coolers installed on structure above 10 m from ground line shall also be designed for evacuation vacuum.

3.3 Allowable Stresses

3.3.1 The basic allowable stress values for pressure parts shall be those established by the applicable codes and standards.

3.3.2 Stresses for all parts during hydrostatic tests shall not exceed 90% of the minimum yield strength of the material.

3.4 Corrosion Allowance

3.4.1 Unless otherwise specified in the data sheets, the corrosion allowance specified by the TEMA standard shall be added to the calculated thickness of carbon and low-alloy steel pressure parts.

3.4.2 Unless otherwise specified in the data sheets, no corrosion allowance shall be added to all tubes.

3.4.3 For the inside of shells, heads and nozzle and manhole necks, the specified corrosion allowance shall be added.

3.4.4 Non pressure parts such as tie rods, spacers, baffles, and support plates shall have no corrosion allowance.

3.4.5 Internal covers shall have the corrosion allowance on each side.

3.4.6 Tube sheets shall have the corrosion allowance on each side. The depth of the pass partition groove may be considered as available for corrosion allowance.
3.4.7 Where flat external covers are grooved, the depth of the groove may be considered as available for corrosion allowance.

3.4.8 Corrosion allowance shall be added to the inside diameter of flanges. Gasket surfaces of flange shall have no corrosion allowance.

3.4.9 Floating head backing devices and internal bolting shall have no corrosion allowance.

3.5 Minimum Thickness

3.5.1 Unless otherwise specified, the minimum thickness of heat exchanger parts, including corrosion allowance, shall be in accordance with applicable codes and standards & specified elsewhere in the bid

3.6 Expansion Joints

3.6.1 Where fixed tube sheet heat exchangers are specified, thermal stress shall be checked in accordance with the TEMA standard to determine if an expansion joint is necessary.

3.6.2 Expansion joints shall be designed for the most severe conditions of differential expansion that can occur during normal operations, startup, shutdown, or upset conditions.

3.6.3 Expansion joints shall be bellows type and rated for 7000 cycles at full design movement, unless otherwise specified.

3.6.4 Expansion joints shall be of the single layer standard one-piece construction unless otherwise approved by purchaser. Length of the bellow and preset shall be specified on the manufacturer's drawings.

3.6.5 When thin wall multi convolution type bellows are used, the bellows shall be fitted with restraining bars so that, under operating conditions, thermal expansion causes the bellows to be in equilibrium.

3.6.6 For floating head type exchangers with single pass which are provided with bellows, permanent restraining bars or other means shall be fitted to allow the tube side of the exchanger to be pressure tested with the shell cover removed.

3.7 Channels and Heads

Heads for the Channels shall be as per Clause No 3.9 of section – A above.

3.7.1 Lifting lugs shall be provided to channels, channel covers and bonnets, when the weight is 30 kg and over.

3.7.2 Stacked shells shall be designed to accommodate local load imposed on bottom shell by top shell.

3.8 Girth Flanges
3.8.1 All girth flanges joining two parts with different design conditions shall be
designed for the severer condition.

3.8.2 All girth flanges for carbon and low-alloy steel exchangers shall be integrally
forged welding necks, unless otherwise specified in the data sheets. i.e Girth
Flanges shall be WNRF / WNRTJ type only. Bodies threaded in the Flanges are
Not Acceptable. D-type construction of any Heat Exchanger is Not Allowed.

3.8.3 Lined Flanges shall not be used.

3.8.4 Slip-on flanges are not permitted for exchangers in hydrogen service, lethal
service or low-temperature services below -29°C.

3.8.5 The minimum bolt size permitted for girth flanges shall be 5/8-11 UNC.

3.8.6 All flanges designed with bolts greater than M 52 & above shall have
sufficient clearance to permit the use of hydraulic bolt tensioning instrument.
Bidder has to supply such hydraulic bolt tensioning instrument along with the
supply of exchangers & its spares.

3.8.7 The Contractor shall guarantee tightness compatibility of closure designs. The
differential thermal growth of gasketed joints of dissimilar materials (including
gaskets) shall be considered.

3.8.8 All girth flanges shall be provided with jack screws to facilitate dismounting.

3.9 Pass Partitions

3.9.1 All pass partitions shall have a gasket contact surface of 9 mm width minimum,
and shall be machined to a common plane at the gasket face.

3.9.2 The depth of pass partition grooves in tube sheets and flat cover plates shall be a
minimum of 5 mm. For alloy cladding or facing, there shall be at least 3 mm of
alloy after machining beneath the pass partition groove or gasket face.

3.9.3 When space permits, pass partitions shall be continuously welded from both
sides. In cases where space is too small for both side welding, weld shall be
continuous on one side in so far as possible.

3.9.4 Pass partitions shall be provided with a weep hole of about 6 to 12 mm in
diameter at low points of pass partitions.

3.10 Tubes

3.10.1 Unless otherwise specified, the standard tube length shall be in
accordance with the TEMA - R standard.

3.10.2 Unless otherwise specified, the tube outside diameter and gages for bare tubes
shall be as follows:
Table 3.10.2

<table>
<thead>
<tr>
<th>Tube Material</th>
<th>Tube Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel and B.W.G. 14</td>
<td>B.W.G.14</td>
</tr>
<tr>
<td>Low-alloy steel (2.11 mm)</td>
<td>(2.11 mm)</td>
</tr>
<tr>
<td>Stainless steel B.W.G. 16</td>
<td>B.W.G. 16</td>
</tr>
<tr>
<td></td>
<td>(1.65 mm)</td>
</tr>
</tbody>
</table>

3.10.3 The minimum radius of U-tubes shall be 3.0 times the outside tube diameter.

3.10.4 U-tubes shall be of one-piece construction & tube shall be seamless.

3.11 Tube Bundle

3.11.1 If tube sheet layout permits, tube bundles shall be designed to be rotated 180°.

3.11.2 Unless specified in the data sheets, heat exchangers for non boiling or non condensing service shall be provided with sealing strips when the radial clearance between outermost tubes and shell inside exceeds 38 mm.

3.11.3 Dummy tubes shall be provided when bypass area of bend portion for U-tube exchangers is parallel to flow direction as specified on data sheet.

3.11.4 Tube bundles shall be designed to permit lateral movement of at least 25 mm due to thermal expansion.

3.11.5 Tube bundles shall be designed to prevent tube vibration.

3.12 Tube sheets

3.12.1 Unless otherwise specified, design based on differential pressure for tube sheets shall not be used.

3.12.2 Dowels or match marks shall be provided to prevent misassembly of floating head covers and channels with pass partitions, channel covers with grooves, and stationary tube sheets to shell flange.

3.12.3 Tube to tubesheet joint shall be designed in accordance with TEMA – R.

3.13 Flanges, Nozzles and Connections

Nozzles and connections for heat exchangers shall be as per Clause 3.11 & 3.12 of Section – A above.

3.15 Baffles and Support Plates
3.15.1 Weld seams for longitudinal baffles shall not be located adjacent to longitudinal seams of the shell.

3.15.2 Removable longitudinal baffles shall be sealed to reduce by passing to minimum.

3.15.3 Cross baffles and support plates shall be provided with notches for draining and venting.

3.16 Impingement Baffles

3.16.1 Tube impingement protection shall be provided for all shell and tube type exchangers. Perforated plates and "increaser" type nozzles are unacceptable for impingement protection.

3.16.2 Impingement plates shall be supported by a minimum of two tie rods or equivalent.

3.16.3 Impingement baffles shall extend at least 1.1 times of the inside diameter of nozzles, or nozzle inside diameter plus 50 mm, whichever is the larger.

3.17 Chemical Cleaning Connections
   If chemical cleaning is required, cleaning pipe connection shall be installed on heat exchanger or connecting pipes.

3.18 Stacked Exchangers

3.18.1 When two or more heat exchangers are to be stacked, they shall be assembled in stack in the shop.

3.18.2 Bolts for connecting nozzles of stacked exchangers shall be removable without moving exchangers.

3.18.3 Supports for the upper exchanger shall be furnished on the lower exchanger.

3.19 Cladding and Lining
   Clad material shall be as per clause No 2.1.7 and 3.15 of Section – A above.

3.20 Accessories
   Accessories for heat exchangers shall meet the requirements of paragraph 3.16 of Section – A above.

3.21 Test Rings
   Floating head type heat exchangers as well as U-tube type without full diameter stationary tube sheets shall be provided with test rings and test gland so that the exchanger shells may be pressure tested with the channels removed. Drawing and calculations for test rings and test gland shall be provided by vendor for all exchangers of applicable type.

4. FABRICATION
4.1 General
Fabrication shall meet the requirements of applicable codes and standards, and specifications listed in paragraph 4.0 of section A above, unless otherwise specified in the following paragraphs.

4.2 Heat Treatment

4.2.1 The bent portion of U-tubes having the bending radius smaller than 5 times the tube outside diameter shall be heat treated for either of the following cases:
1) When stress corrosion cracking is expected for carbon steel
2) When tubes are Al-killed steel, 3-1/2 Ni steel or Cr-Mo Steel

4.2.2 All channels and floating heads having six or more tube side passes shall be post weld heat treated. Solid austenitic stainless steel shall not be post weld heat treated.

4.2.3 Unless otherwise specified, all expansion joints made of carbon and low-alloy steel shall be stress relieved and austenitic stainless steel shall be solution heat treated after forming.

4.3 Pickling
Pickling, when specified, shall be carried out as per Clause 4.5 of Section – a above.

4.4 Fabrication Tolerance
Dimensional tolerances for all heat exchangers shall be in accordance with applicable codes and standards, and the specifications listed in this ITB.

5. INSPECTION AND TESTING

5.1 General
Heat exchangers shall be inspected in accordance with:
1. Applicable codes and standards, and specifications listed in section 6.1 of this ITB,
2. Section A of Inspection Philosophy as per Section 6.4.9 of this ITB
3. As specified in the following paragraphs.

5.2 Hydro Testing

5.2.1 Each heat exchanger shall be hydro tested in accordance with
1. Applicable codes and standards.
2. Clause 5.8 of Section A above.
3. Inspection Philosophy – Section 6.4.9 of this ITB.

5.2.2 The shell side test shall be performed in such a manner that the Tube–to-tubesheet joints can be adequately inspected during testing.

5.2.3 Hydro Testing sequence & procedure for testing Exchangers having Lip Seal Gasket shall be approved by the Purchaser.
5.2.4 Stacked units shall be hydraulically tested in the fully assembled condition.

5.2.5 Water to hydro test austenitic stainless steel heat exchangers or their parts shall be potable water containing not more than 50 ppm of chlorides.

5.2.6 Each heat exchanger shall be air leak tested & helium leak tested at the pressure specified in the data sheet.

5.2.7 After testing, all exchangers shall be completely dried.

5.2.8 Service bolts shall be used in all shop hydrostatic tests.

5.2.9 Test gasket shall meet the requirements of Clause 5.8 of section – A above.

6. PAINTING
Upon completion of all inspection and testing, and before shipment, exchangers except machined surfaces shall be primed in accordance with the applicable specifications.

7. PREPARATION FOR SHIPMENT

7.1 All exchangers shall be dried, thoroughly cleaned, and free of grease, oil, scale, weld spatter, and any other foreign materials.

7.2 All flange faces and other machined surfaces shall be properly protected against damage during shipment.

7.3 All inside surfaces and internal parts of heat exchangers shall be coated with a suitable rust preventive prior to shipment, if required.

7.4 All openings shall be provided with metal closures.

7.5 Threaded openings shall be protected by steel or plastic plugs.

7.6 Equipment item No., weight, center of gravity, and base lines indicating four directions with figures of 0°, 90°, 180° and 270° for vertical exchangers shall be marked with paint on the shell. The paint color shall be white for carbon steel and black for stainless steel.

PART C - DESIGN PHILOSOPHY FOR COLUMN TRAYS

1. GENERAL

1.1 Scope
1.1.1 This specification covers the minimum requirements for the design, materials, fabrication, inspection and testing of proprietary and nonproprietary trays.

1.1.2 The trays shall be complete with all components of trays such as floors, weirs, down comers, seal pans, draw off pans, baffles, risers, valves, caps, beams, clamps, bolts, nuts, washers, gaskets and other special parts. In addition to the quantity for normal installation, 5% of clamps, bolts, nuts, washers and gaskets shall be supplied as excess materials during assembly of trays at site. Materials of the Column Trays (all part), support grid etc shall be minimum 304L or higher as specified on the Data sheet.

1.2 References

1.2.1 This specification shall be used in conjunction with the following specifications:

- Process & Mechanical data sheets of the Process Licensor.
- Section 6.4.1 of ITB – Design Philosophy for Static Equipment
- Section 6.4.9 of ITB – Inspection Philosophy.

1.3 Priority

Any conflicts between documents shall be brought to the purchaser's attention for resolution.

2. MATERIALS

2.1 General

2.1.1 All materials shall be in accordance with ASTM specification and with those specified in the data sheets.

2.1.2 Vendor's proposal to use other materials or thickness shall be submitted to the purchaser for approval.

2.2 Fittings

2.2.1 Fittings such as clamps, bolts and nuts for connecting internal parts liable to disassemble be Minimum SS 304L

2.2.2 Unless otherwise specified, thread on bolting shall be Unified Inch Screw Threads & connection of Trays with support ring shall be with D-type clamps only.

2.3 Gaskets and Packing

2.3.1 In general, gaskets or tapes between tray sections or between tray peripheries and tray support rings are not required.

2.3.2 Gaskets or tapes will be accepted only when necessary to meet purchaser's leakage requirements, or to insure tray performance under required conditions.

2.3.3 Gaskets or tapes of down comer sections and between down comer ends and clamping bars are required.
2.3.4 Design of bolted or clamped joints of tray sections shall be such that gaskets cannot be dislodged during normal operation. When used, unless otherwise specified on the data sheets, gaskets or tapes material shall be 2.0 mm thick P.T.F.E..

3. DESIGN

3.1 Loads

3.1.1 Trays, support beams, pans, draw off pans, or similar internals in the corroded condition shall be capable of supporting their own weight plus the following live loads at design temperatures.

3.1.2 Design live loads shall be:

1) For fractioned trays shall be the greater of 100 Kg / M^2 or the weight of water 50 mm over the highest weir setting.
2) For areas under down comers shall be the greater of 300 kg/m or a head of water equal to one-half the height of the down comer.
3) For pans, e.g., draw off or accumulator, shall be the greater of 700 kg/m or the weight of water at the maximum operating level of the pan.

3.1.3 Hiccups load in vapor flow up the column shall be taken into account in the tray design.

3.1.4 Maintenance loads for trays and pans together with their support members shall be a concentrated live load of 135 kg at any point plus self weight, independent of other design live loads. The design shall be based on the allowable stress at 35°C and the corroded thickness of support members.

3.2 Deflections

3.2.1 Maximum deviation from the horizontal at the design live loads shall not exceed 1/900 of each span or 3.2 mm, whichever is smaller. For large diameter vessels, an initial camber shall be made in the principal support members of the tray assemblies to compensate for the deflection due to dead load.

3.2.2 Modulus of elasticity shall be as specified in ASME Section VIII Division 2.

3.3 Allowable stresses

3.3.1 Allowable tensile, compressive and bending stresses of structural materials shall be 1.3 times the allowable stress values in tension given in ASME Sect. VIII Div. 1, but not exceed 90 % of the minimum specified yield or 0.2 % proof stresses of the materials. Allowable stress values for short time loads, such as maintenance loads, may be increased up to 90 % of the minimum specified yield or 0.2 % proof stresses of the materials.

3.4 Dimensional Requirements
3.4.1 All tray parts shall be accessible for inspection, cleaning and repair through internal man ways without removing an excessive member of tray components.

3.4.2 Tray parts shall be interchangeable where practical.

3.4.3 All tray parts shall be designed to pass through vessel manholes with a minimum clearance of 13 mm.

3.4.4 All parts except tray man ways shall be designed to permit installation and removal from the upper side without help from the lower level.

3.4.5 The nominal tray diameter shall be determined by the following formula: 
   \[ \text{Tray diameter} = \text{Vessel ID} - (1\% \text{Vessel ID} + 20 \text{ mm}) \]
   A minimum of 20 mm overlap shall be provided between tray floor sections and support ring or members, pans and similar items.

3.4.6 Spacing of bolts or clamps shall be close enough to insure optimum liquid tight construction. Bolt hole spacing around the edge of tray sections shall not exceed 175 mm. Bolt hole spacing in down comers, pans or bubble cap trays shall not exceed 100 mm.

3.4.7 Standard width of tray support rings and down comer bars shall be as follows:

<table>
<thead>
<tr>
<th>Vessel Diameter (MM)</th>
<th>Width Support Ring</th>
<th>Width Side Downcomer Bar</th>
<th>Width Center Downcomer Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1000</td>
<td>40</td>
<td>100</td>
<td>_</td>
</tr>
<tr>
<td>1001 to 3000</td>
<td>50</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>3001 to 5000</td>
<td>65</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>5001 to 7000</td>
<td>75</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>7000 over</td>
<td>90</td>
<td>125</td>
<td>165</td>
</tr>
</tbody>
</table>

3.5. Corrosion Allowance

Unless otherwise specified, corrosion allowances shall be considered on every process fluid contacting surfaces. The corrosion allowances in Table 3.5.1 show the total corrosion allowance (TCA).

<table>
<thead>
<tr>
<th>Vessel Shell Interior Surface</th>
<th>Total Corrosion Allowances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internals</td>
<td>Removable Parts (Note 1, 3)</td>
</tr>
</tbody>
</table>
### Design Philosophy for Static Equipment

#### Notes
1. Parts seal welded to a support ring or bar shall be considered as removable.
2. Parts directly welded to the pressure parts of a vessel.
3. Corrosion allowance of tray elements not welded to tray floor such as valves and caps need not be considered.

#### 3.6 Minimum Thickness

**3.6.1** The following minimum thickness shows nominal plate thickness including a tolerance on the minus sides specified in material specification.

**3.6.2** The minimum thickness excluding corrosion allowance for tray decks, downcomers, weirs or pans shall be:

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>3 mm</td>
</tr>
<tr>
<td>Low-alloy steel</td>
<td>3 mm</td>
</tr>
<tr>
<td>High-alloy steel</td>
<td>2 mm</td>
</tr>
<tr>
<td>Nonferrous Metals</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

**3.6.3** The minimum thickness for caps and risers or bubble caps shall be:

<table>
<thead>
<tr>
<th>Material</th>
<th>Minimum Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Steel</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Low-alloy steel</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>High-alloy steel</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Nonferrous Metals</td>
<td>1.5 mm</td>
</tr>
</tbody>
</table>

**3.6.4** The minimum thickness for valves or similar parts of proprietary trays shall be in accordance with the manufacturer's standard.

**3.6.5** The minimum thickness of support rings and downcomer bars to be provided by vessel fabricators shall be:

<table>
<thead>
<tr>
<th>Vessel Diameter (MM)</th>
<th>Vessel Corrosion Allowance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Up to 1000</td>
<td>4</td>
</tr>
<tr>
<td>1001 to 3000</td>
<td>5</td>
</tr>
<tr>
<td>3001 to 5000</td>
<td>6</td>
</tr>
</tbody>
</table>

#### 3.7 Trays

**3.7.1** Tray sections shall be divided perpendicular to liquid flow. If it is impossible,
means to prevent short cut of liquid flow shall be considered.

3.7.2 Cartridge type trays may be used for vessels of 800 mm inside diameters or less.

3.7.3 Cartridge type trays shall be designed to minimize leakage from the periphery and to remove from the vessel top only.

3.8 Down comers

3.8.1 Bolted joints of down comers shall be sealed with P.T.F.E. gaskets, unless other materials are specified.

3.8.2 Stiffeners shall be provided to limit horizontal movement of the bottom edge of the down comer at any point within 6 mm under liquid head pressure.

3.8.3 All openings for support beams passing through down comers shall be sealed to prevent vapor bypassing.

3.9 Seal Pans. Draw off Pans and Risers

3.9.1 All joints in draw off pans shall be of liquid tight construction by using gaskets or seal welds, unless otherwise specified.

3.9.2 Chimney risers on trays shall be seal welded to the trays.

3.9.3 All joints in the risers shall be seal welded.

3.10 Tray Man ways

3.10.1 Access through trays shall be provided as follows:
1) All trays of 1500 mm and larger in diameter shall be equipped with man ways.
2) All trays smaller than 1500 mm in diameter shall be either split or equipped with man ways.

3.10.2 Tray man ways shall be provided in each flow pass.

3.10.3 When major support beams hinder passage of a man from one side of a tray to the other, each side shall be provided with a man way.

3.10.4 Tray man ways shall be rectangular opening of a minimum 350 mm x 450 mm.

3.10.5 Tray man ways shall not form a part of the down comer seal area.

3.10.6 Tray man ways shall be located in vertical alignment, and located to permit access to every area of the tray.

3.10.7 Tray man ways or tray sections used in lieu of man ways shall be removable from both above and below the trays.
3.11 Support Beams

3.11.1 All stiffeners and support members shall be located on the underside of tray floor.

3.11.2 Stiffeners and support members in bubbling areas shall not exceed 75 mm in width and shall be designed so as not to impede or channel the liquid flow on the tray.

3.11.3 The depth of stiffeners and support members shall not exceed 75 mm or 5 percent of the column diameter, whichever is greater.

3.11.4 Depth of stiffeners and support members transverse to the liquid flow direction shall not exceed 20 percent of the tray spacing.

3.11.5 Major beams shall be installed to transverse the liquid flow.

3.11.6 Slotted holes with sufficient clearance for thermal expansion shall be used where support beams are bolted.

3.12 Tray Bolting

3.12.1 Tray sections shall be fastened to the support rings and support beams with frictional type tray clamps or bolts.

3.12.2 Clamping shall be used except where bolting is necessary for load support capabilities.

3.12.3 The size of alloy steel bolts shall be 3/8 - 16 UNC minimum.

3.13 Drain Holes

3.13.1 Trays and seal pans not specified to be liquid tight and of a design which would not easily drain shall be provided with one or more 6 to 12 mm diameter drain holes to permit draining.

3.13.2 Drain holes in recessed seal pans shall be located downstream or on the tray side of the down comer so that any vapor passing through the holes will not bypass the tray above.

3.13.3 Inlet weirs shall have a 6 to 12 mm hole at the base to drain into the tray.

3.13.4 All boxes and pans from which liquid is normally withdrawn shall be equipped with nozzle that will insure complete drainage of the box and pan. Drain holes shall not be provided in the water draw off boxes.

4. FABRICATION

4.1 Forming
4.1.1 Bending shall be by cold press-bending.

4.1.2 Press-forming shall be made in such a manner that wrinkling and roughening may not be caused.

4.1.4 Holes on tray floors shall be punched from upper side. Burring shall be minimized.

4.1.5 Hole area per tray shall be within 2% of the area specified in the data sheets, except as otherwise specifically approved by the purchaser.

4.2 Surface Finishing

4.2.1 Surfaces of fabricated parts shall be smooth and free from dents, hammer marks, kinks or other defects which will prevent close metal-to-metal fit.

4.2.2 All perforated areas and edges shall be free from burrs.

4.2.3 Welds shall be smooth and free from slag and spatter.

4.2.4 Welded portion of stainless steel shall be pickled.

4.3 Welding

4.3.1 Welding shall be done by a metal arc weld, TIG weld or flux cored arc weld for stainless steel.

4.3.2 Gas or carbon-arc welding shall not be done.

4.3.3 Resistance welding will be permitted for minor details on approval of the purchaser.

4.3.4 Welding electrodes shall be in accordance with ASTM / ASME.

4.3.5 Welding electrodes of a composition similar to tray material shall be used, except austenitic electrodes of higher chromium and nickel content may be used for 13 Cr and type 304 stainless steel.

4.3.6 Tray support rings shall be attached to the vessel by continuous fillet weld from both sides. However, the underside fillet weld seams for carbon steel may be intermittent.

4.3.7 Parts to be welded shall be thoroughly cleaned free from moisture, oil, grease, paint, scale and other foreign materials before welding.

4.3.8 When trays and beams are welded, jigs and other positioning devices shall be used to minimize deformation.

4.3.9 All joints and seams of trays specified to be liquid tight shall be seal welded in
4.4 Fabrication Tolerance

4.4.1 Unless otherwise specified, tolerances shall be in accordance with "Inspection Philosophy section 6.4.9 of the ITB.

4.4.3 Clearances between the bottom edge of down comer and tray floors shall be within ± 3 mm of the specified dimensions.

4.4.4 Dimensions from weirs to shell plate shall be within ± 9 mm of the specified dimensions.

4.4.6 Dimensional tolerances of proprietary trays shall be in accordance with the tray manufacturer's standard.

4.4.7 All other parts shall be fabricated in accordance with good shop practice and all corresponding parts shall be interchangeable.

5. INSPECTION AND TESTING

5.1 General

Trays shall be inspected in accordance with the specifications listed in Paragraph 1.2 of this specification and manufacturer's inspection specification for proprietary trays. Also, Inspection Philosophy as per Section 6.4.9 shall be followed.

5.2 Inspection of Materials

5.2.1 All materials rejected by the purchaser, because of defects or incorrect material shall be promptly replaced by the vendor.

5.2.2 Mill sheets for all alloy steels and nonferrous metals shall be submitted.

5.3 Visual Inspection

Each tray part shall be visually inspected for the following items:

1) Surface finish
2) Surface cleaning (Pickling)
3) Appearance
4) Burring of punched holes
5) Harmful deformations

5.4 Dimensional Inspection

Dimensional inspection shall be made for items specified in paragraph 4.4 above.

5.5 Trial Assembly

At least one tray of each type shall be trial assembled at the manufacturer's shop.
using parts selected at random. The trial assembly shall be supported in a manner comparable to the final installation.

5.6 Leakage Tests

5.6.1 When liquid tightness test is required in the data sheet, this shall be made in the following way:
These trays to be assembled with all holes closed and the man ways placed in position and bolted-on, then the tray deck shall be flooded with water. In this condition the level drop shall not be more than 25 mm in 3 minutes, unless otherwise specified in the tray drawings.
The initial water level shall be equal to the maximum weir height.

5.6.2 Leakage tests are not performed on sieve, valve or cartridge trays.

6. PREPARATION FOR SHIPMENT

6.1 General
All carbon steel surfaces of trays shall be coated with a suitable rust preventive before shipment. Rust preventive material shall be submitted to the purchaser. All internal parts including trays shall be clearly identified with corresponding marks provided on the assembly drawings to permit rapid assembly. No paint shall be used for marking.

6.2 Packing
6.2.1 For shipment, tray parts shall be properly protected to prevent deformation, damage and rusting.
6.2.2 Tray parts for different vessels shall not be intermixed.
6.2.3 Small items shall be properly packed to prevent loss in transit and detailed packing lists shall be attached to each package.

PART D - DESIGN PHILOSOPHY FOR PLATE TYPE EXCHANGERS

1.0 The plate type exchanger shall be designed in accordance with" API 662"

2.0 All plates shall be pressed from a homogeneous single metal sheet in one placing and normal thickness of plate being pressed shall not be less than 0.5 mm. Material shall be minimum SS 304 L.

3.0 Nozzle neck attachments shall be with full penetration weld. Set on nozzles are not permitted -

4.0 Lock washers shall be provided for all rotated nuts.

5.0 Inspection of these Exchangers will be carried out in accordance with the relevant
PART E - DESIGN PHILOSOPHY FOR AIR COOLED EXCHANGERS

1.0 Detailed design calculations of all pressure parts shall be made. Design calculations of air cooler structure shall be performed by CONTRACTOR considering local wind & seismic requirements.

2.0 Air cooled Heat Exchangers shall have spiralled fins mechanically embedded type (G-type). L-type fins are not acceptable. Material of tubes with fin shall be minimum SS 304 L.

3.0 Fans having pneumatic actuator shall be supplied with positioned.

4.0 Tube to tube sheet joints shall be seal welded and expanded. Air/soap bubble test shall be carried out after welding prior to expansion.

5.0 The following painting specifications shall be followed:

   a) All surfaces shall be sand blasted to SA 2.5

   b) All structure including bundle frame shall be hot dip galvanized in accordance with ASTM Specn. referred in API 661.

   c) Components like plenum chamber, fan deck/guard fan cylinder etc. shall be zinc sprayed. Minimum and average thickness of zinc layer shall be 450 & 500 gm/M2 respectively.

6.0 Air side performance for air flow rate, static pressure drop, power consumption, noise level etc. shall be guaranteed. All mechanical guarantees as required for complete Air cooler assembly shall also be met with by CONTRACTOR.

7.0 Inspection of these Exchangers will be carried out in accordance with the relevant standards & QA Plan, as approved by TPIA / GNFC.

PART F - DESIGN PHILOSOPHY FOR TANKS

1.0 The following design codes shall be adopted for tank design in addition to other codes as applicable:

   - API 620 Design and Construction of Large Welded Low Pressure Storage Tanks
   - API 650 Welded Steel Storage Tanks for Oil Storage

2.0 For Storage tanks the minimum thickness shall be based on stability considerations. Minimum thickness for any Material (CS / SS / etc ) for roof & shell shall be 5 mm, and bottom plate 6 mm, excluding corrosion allowance.
3.0 Storage tanks up to 4m. in diameter shall be shop fabricated items. Tanks with diameters greater than 4m shall be field erected.

4.0 Inspection of these tanks will be carried out in accordance with the relevant standards & QA Plan, as approved by TPIA / GNFC.

**PART G - DESIGN FOR GLASS LINED VESSELS/Reactor /Agitator**

1.0 The design codes for the Glass Lined Vessels / Reactors shall be as mentioned in the Part – A of this section. Vessels have to be designed as per the Pressure Vessels only. Agitator shall be fitted with the Mechanical Seal Only.

2.0 Vessel shall be designed as per the ASME Sev VIII Div. I. only.

3.0 All welds shall be ground flush with surrounding surfaces. All corners shall be rounded off and contour changes shall be smooth and generously dimensioned to minimize stressing of the glass lining.

4.0 Steels having tensile strength more than 480MPa shall not be glass lined due to increased risk of stress induced failure of glass lining in highly stressed areas.

5.0 Welded equipments shall be fully normalized before glass lining process in order to remove stresses that may cause deformation during high temperature firing cycles of glass lining process. Normal post weld heat treatment (Stress relieving) may not be enough.

6.0 On flat and convex surfaces, there may be a local increase in the maximum thickness of up to 0.2mm. On flat and concave surfaces, there may be local decrease in the minimum thickness of up to 0.2mm. Such variations shall be gradual, without abrupt steps.

7.0 On flange faces the thickness shall not vary by more than 0.2mm per 10mm measured length.

8.0 Thickness measurements shall be performed according to ISO2808 with an apparatus with 5% accuracy or better.

9.0 Agitator shall be designed, manufactured & supply shall be as per API standard only.

10.0 Mechanical seal shall be Designed , manufactured & supplied as per API 682 latest edition only. (Present it is fourth edition)

11.0 Capacity of each reactor shall be 8 KL (Maximum). All reactors shall be identical.

12.0 Thickness of the Glass lines shall be minimum 1.5 to 2.2 mm. Glass Lining as per DIN 28063.
13.0 All gaskets used for the Glass lined vessels / Reactors shall be 25% Glass Filled TEFLON (Du-Pont Make).

14.0 Inspection of these vessels / Reactor / Agitator shall be carried out as per the relevant standard & QA Plan, approved by GNFC / TPIA.

15.0 Spark test of the Glass lining shall be carried out at 20KV.

16.0 Vessels & jackets shall be designed for the full vacuum also.

17.0 Radiography shall be 100 %. Joint efficiency shall be 1.0

18.0 Corrosion on the inner vessels & jackets shall be minimum 3.00 MM.

19.0 Vessels / Reactor shall be plug free. i.e any repair is not allowed.

20.0 Glass lining testing shall be as per DIN 28063

21.0 All nozzles flanges, clamps shall be as per ANSI B 16.5 only (Nozzles to have loose backing flanges).

22.0 Vessels should be provided with minimum 2 nos. Of sight glass.

23.0 Reactors should be provided with the centre top opening of the Agitator.

24.0 Along with the supply, Vendor shall provide 10 Plug of tantalum per reactor to attend the repair at site.

25.0 Minimum thickness shall be based on stability considerations. Minimum thickness for any Material (CS / SS / etc ) for roof & shell shall be 5 mm, and bottom plate 6 mm, excluding corrosion allowance.

26.0 **Tests and Inspection:**

The seller will allow the buyer or consulting company indicated by Buyer to check advancement of design and construction inside seller’s premises.

Mechanical tests: The equipment will be dimensionally checked and a blank test will be carried with a procedure agreed by Buyer and seller.

Acid Resistance
- Representative samples of the glass lining shall be tested in accordance with ISO 28706-2.

Base Resistance
- Representative samples of the glass lining shall be tested in accordance with ISO 28706-4.
Resistance to thermal shock
  o Representative samples of the glass lining shall be tested in accordance with EN ISO 13807.

Resistance to mechanical shock
  o Representative samples of the glass lining shall be tested in accordance with DIN ISO 4532.

Freedom from pores
  o Representative samples of the glass lining shall be tested in accordance with ISO 2746 or ASTM C537.

Lining thickness
  o Representative samples of the glass lining shall be tested in accordance with ISO 2808.

The whole glass lined surface shall be inspected for defects with a high voltage direct current (20 KV) spark tester according to ISO 2746.

Test and inspection will include also:
  - Eye test
  - Statiflux (Magnetic powders)

Vendor to provide details of the complete Reactor, Agitator with capacity, details of each equipment (rotating plus stationary), Materials of Construction, size, area etc in the offer.

All individual equipment shall be inspected as per the inspection philosophy given separately for type of equipment. Agitator shall be inspected in line with the rotating equipment (like Pumps, blowers etc.)

PART H - DESIGN FOR SPRAY DRIER SYSTEM

1 The SPRAY DRIER system should consist of the co-current drying system with Atomisation with High Pressure Nozzles (50 % spares installed nozzles are required) with Feed system by High Pressure pumps

2 Heating medium shall be with direct gas fired heater.

3 Drying chamber should be vertical & also product recovery should be with Cyclone & wet scrubber.

4 In the product discharge, double point discharge under chamber & cyclone plus vibro feeder for after drying & de-dusting shall be provided.
5. All equipment required for the conveying PAC powder to silo & bagging system shall be provided. In this system 100 % spare installed stream has to be provided.

6. All materials in the spray drier including scrubber, ducting, blowers, high speed pumps, chutes etc shall be of SS 316 L only.

7. Vendor to provide details of the complete system with capacity, details of each equipments (rotating plus stationary), Materials of Construction, size, area etc in the offer.

8. All individual equipment shall be inspected as per the inspection philosophy given separately for type of equipment. Agitator shall be inspected in line with the rotating equipment (like Pumps, blowers etc.)

PART I- DESIGN FOR ACID TANKS / VESSELS.

1. All tanks / vessels and any equipment of all sizes shall be made from the PP + FRP only. Only PP make equipment is not acceptable.
2. Materials shall be as per relevant ASTM class only.
3. Design shall be as per the relevant ASTM code only.