

हीट एक्सचेन्जर्स के लिए सामान्य विनिर्देश

GENERAL SPECIFICATION FOR HEAT EXCHANGERS

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Abbreviations:

ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BHN	Brinell Hardness Number
BTB	Bolt Tensioning Device
BV	Bureau Veritas
CIB	Chief Inspector of Boilers
CS	Carbon Steel
DIA	Designated Inspection Agency
DNV	Det Norske Veritas
DP	Dye Penetrant
EIL	Engineers India Limited
FPW	Full Penetration Weld
GPC	General Purchase Condition
HAZ	Heat Affected Zone
HIC	Hydrogen Induced Cracking
IBR	Indian Boiler Regulation
ID	Inside Diameter
IGC	Inter Granular Cracking
IS	Indian Standards
LAS	Low Alloy Steel
LTCS	Low Temperature Carbon Steel
MDMT	Minimum Design Metal Temperature
MP	Magnetic Particle
NB	Nominal Bore
NDT	Non Destructive Testing
PO	Purchase Order
ppm	parts per million
PTC	Production Test Coupons
PWHT	Post Weld Heat Treatment
QAP	Quality Assurance Plan
SS	Stainless Steel
TEMA	Tubular Exchangers Manufacturers' Association
UT	Ultrasonically Tested
UTS	Ultimate Tensile Strength

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1.0 GENERAL

1.1 Scope

This specification covers the requirements for residual design, engineering, materials, fabrication, workmanship, inspection and testing of shell and tube heat exchangers and is intended to supplement the requirements of the applicable Codes. EIL specifications and standards wherever indicated in the requisition shall be followed unless stated otherwise.

This specification shall not be considered limiting and it shall be Supplier's responsibility to comply with all requirements of requisition or bid documents to which it is annexed.

1.2 References

1.2.1 CODES AND REGULATIONS

The following Codes in their edition referenced in drawings or data sheets or design basis along with the other specifications enclosed with the requisition shall form the basis for design, materials, fabrication, inspection, testing and acceptance of the equipment:

- (a) ASME Boiler and Pressure Vessel Code Section VIII Division 1 (Code), ASME Section II Part A, B, C and D, ASME Section V, ASME Section IX.
- (b) TEMA (Class as specified on the drawings or data sheets or design basis).
- (c) IBR, if applicable (latest edition with amendments up to date).
- (d) National and local laws or regulations, as applicable.

1.2.2 FOR HEAT EXCHANGERS UNDER THE PURVIEW OF IBR:

- (a) Supplier shall carry out design calculations as per IBR and only in case of any doubt refer the same to Owner and EIL for clarifications. All materials, fabrication, welding, testing etc. shall meet the requirements of IBR.
- (b) In case the equipment is manufactured in India, the design calculations and fabrication drawings after preliminary review of Owner and EIL shall be got approved by Supplier from CIB of the State where Supplier's shop is located, prior to start of fabrication. Supplier shall also provide the necessary assistance to Owner for obtaining approval from CIB of State of installation, such as providing additional copies of calculations and drawings etc. as required by CIB of that State.
- (c) In case the equipment is manufactured outside India, the design calculations and fabrication drawings after preliminary review by Owner and EIL shall be got approved by Supplier from the agency authorised by IBR in the country of fabrication and the CIB of the State where the equipment is to be installed, before the start of fabrication.
- (d) It shall be the responsibility of Supplier to incorporate modifications or additions required by CIB or its authorised agency and obtain the final approval. Owner and EIL shall be kept informed about these. All costs towards approval from CIB shall be borne by Supplier. All IBR approved design calculations and drawings shall be furnished to EIL for final review of fabrication drawings and in equipment dossier.

1.3 Deviations

In general, no deviations from datasheets, drawings, standards, specifications and requisition shall be permitted. This does not preclude possible innovations or improvements by the Supplier based on available facilities. Such deviations must be clearly listed in the format "SCHEDULE OF DEVIATIONS" in the Supplier's offer, so as to avoid any confusion and ambiguity and to facilitate analysis of offer in minimum possible time. It shall be taken for granted that except for the deviations listed under the "SCHEDULE OF DEVIATIONS" in the Supplier's offer, all other technical requirements shall be adhered to by the Supplier.

Generally no deviations shall be entertained after the Supplier has accepted the order unless it is to comply with statutory or Code requirements. All waivers and deviations after order shall be routed through the Regional Procurement or Inspection Office In charge in the prescribed format. Delay in supply of the equipment because of such deviations being not entertained or approved by Owner or EIL or any delay in processing the same by Owner or EIL shall be to Supplier's account. Any additional design work in support of such a deviation shall be performed by the Supplier and submitted along with the deviation.

1.4 Contradictory requirements

In case of any contradiction between the requirements of the requisition, drawings and other documents forming part of the requisition, Supplier shall resolve the matter in consultation with Owner or EIL. Decision of Owner or EIL shall be binding and without any implication of cost and time, if not resolved at bidding stage.

2.0 MATERIAL SPECIFICATION

2.1 General

2.1.1 All materials used for fabrication shall be new and of first quality. All materials and accessories required for the fabrication, inspection, testing etc. of the heat exchanger shall be supplied by the Supplier unless otherwise stated. Whenever some material is to be supplied by the Owner, this shall be so indicated as Free Issue Material and the supplementary specifications in this regard shall be complied with.

2.1.2 In addition to the requirements of materials as per material specifications, materials shall also meet the requirements mentioned in this specification and other specifications enclosed with the requisition. All materials shall be certified for compliance with IBR requirements for the item(s) so specified. While procuring materials, Supplier shall stipulate additional requirements such as limits on hardness, UTS, yield strength, chemical composition, heat treatment and any other specific requirements to ensure that final requirement as per specification and Code are met with.

All materials for pressure parts and parts welded to pressure parts including materials in the scope of sub-suppliers, shall be accompanied with mill test certificates duly certified by a reputed third party inspection agency. In the absence of mill test certificate the material shall be got tested from a reputed third party inspection agency like CEIL, Lloyds, BV, DNV etc. and test results shall be submitted in lieu of mill test certificate. All cost towards such testing and inspection shall be borne by the Supplier. All materials shall be inspected at Supplier and sub-supplier's shop for verification prior to use on the job. The decision of DIA to accept or reject materials on the basis of such testing shall be final.

2.1.3 Wherever simulated heat treatment of test specimens is required as per Code or specification, the simulation cycle shall include one extra cycle of stress relieving for any eventuality of repair at site by Owner during the life of the equipment.

2.1.4 MDMT shall be taken as 0°C or the design temperature specified in drawing or datasheet whichever is lower, unless specified otherwise in design basis or datasheets or drawings. For low temperature service, all CS and LTCS materials for pressure parts and attachments to pressure parts shall be charpy V-notch impact tested. All LAS materials for pressure parts and attachments to pressure parts shall be charpy V-notch impact tested irrespective of the design temperature. Impact test temperature shall be lowest of minimum ambient temperature, design temperature and MDMT. Low temperature service shall be specified in datasheets or drawings.

2.1.5 PLATES

2.1.5.1 Pressure parts having thickness 16 to 50 mm (both inclusive) shall be UT as per SA-435.

2.1.5.2 Pressure parts having thickness >50 mm shall be UT as per ASME SA-578 Level B.

2.1.6 TUBES

- 2.1.6.1 All the tubes shall be seamless and cold drawn.
- 2.1.6.2 Product analysis of tubes shall be carried out and reported in the material test certificates.
- 2.1.6.3 Tubes shall be in fully heat-treated condition as received from the mill. CS tubes shall be in annealed condition and copper alloy tubes shall be in annealed temper condition. LAS tubes shall be supplied in normalised and tempered condition.
- 2.1.6.4 All unstabilised SS tubes shall be supplied in the solution annealed condition and all stabilised grades of SS such as SS 321 and SS 347 shall be supplied in stabilization heat treated condition, in addition to solution annealing.
- 2.1.6.5 It is preferable while ordering tubes the maximum yield strength and hardness of tubes are specified such as to be lower than those of tube sheet, in order to achieve a sound expanded tube to tube sheet joint, complying with Code requirements.
- 2.1.6.6 "Air under water" testing shall be carried out for all tubes except non-ferrous tubes. As an alternative, tubes can be hydro tested. In case the tubes are hydro tested, hydro test pressure of tubes shall be higher of tube side test pressure or as required by Code. Water quality shall be as per Para 7.2.1 of this specification.
- 2.1.6.7 For requirements of U tubes refer EIL specification 6-15-0006.

2.1.7 FORGINGS

Forgings manufactured to SA-105 and SA-266 above 75 mm thickness (thickness as defined in para AM 200.2 of ASME Sec. VIII Division 2), all tube sheet forgings and all forgings of other materials, except for the standard nozzle flanges up to 8" NB and small forgings (of couplings, plugs and eye bolts) shall be 100% UT as per SA-388. Acceptance criteria shall be as per para AM 203.2 of ASME Section VIII Division 2.

2.1.8 PIPES

Pipes shall be seamless and sizes above 1½" NB shall be hot finished. Dimensions and tolerances shall be in accordance with ASME 36.10 or ASME 36.19, as applicable, as per material specification.

2.2 Specific material requirements (Pressure parts and parts welded to pressure parts)

2.2.1 CS AND LTCS MATERIALS

- (a) Carbon content shall not exceed 0.23%.
- (b) All plates shall be in normalised condition.
- (c) Use of SA 515 of any grade is not permitted.
- (d) Plates > 50mm thickness shall meet following additional requirements of SA-20:
- (i) Vacuum treatment as per the supplementary requirement S1. If vacuum degassing is not reported in the test certificates, then through thickness tests as per SA 770 shall be conducted and minimum reduction in area of 35% shall be ensured.
- (ii) Charpy V-notch test as per supplementary requirement S5. Test temperature shall be lowest of minimum ambient temperature, design temperature, MDMT and Minus 29 °C for MDMT > or equal to 0°C. For MDMT less than 0°C refer clause 2.1.5. Impact energy values shall be as per para UG-84 of Code or applicable material specification, whichever is higher. Orientation of test bar shall be transverse to rolling direction.
- (iii) Bend test as per supplementary requirement S14.

- e) Unless specified otherwise in requisition or bid document, all CS materials specified as HIC tested shall meet the following requirements.
 - i) Carbon equivalent shall be $< 0.40\%$. Nickel content shall be $< 0.2\%$.
 - ii) Sulphur content shall be $< 0.002\%$ for plates and $< 0.01\%$ for tubes, pipes and forgings.
 - iii) Hardness of plates and pipes shall not exceed 200 BHN, and that of forgings shall not exceed 187 BHN.
 - iv) Plates shall conform to SA 516 Gr 60 only (higher grades like SA 516 Gr.65 and 70 are not acceptable). The plates shall be treated with calcium or other rare earth elements to create spherical inclusions instead of stringers. The plates shall be tested in accordance with NACE TM-02-84 using the test solution 'A' of NACE TM-01-77. The acceptance criteria shall be crack length ratio 10 % maximum.
- (f) All LTCS and CS charpy plate material shall be made to fine grain practice and the primary austenitic grain size shall be measured and reported in mill test certificates.
- (g) CS pipes shall be SA-106 Gr. B. LTCS pipes shall be SA 333 Gr. 1 or 6.
- (h) Non-standard forgings (SA 266, SA 350 etc.) shall be normalised and tempered.

2.2.2 LAS MATERIALS

- a) All LAS plates, pipes, forgings and fittings shall be in normalised and tempered condition. Use of C- $\frac{1}{2}$ Mo material is prohibited. All LAS materials shall be charpy V-notch impact tested. Test temperatures shall be lowest of minimum ambient temperature, design temperature, MDMT and -18°C (0°C instead of -18°C for 5Cr-1/2Mo materials). Impact energy values as per UG-84 or applicable specification, which ever is higher.
- b) In the case of $1\frac{1}{4}$ Cr- $\frac{1}{2}$ Mo materials and weldments, the maximum room temperature tensile strength for all pressure containing components, materials and welds shall be 100000 psi.
- c) For LAS tubes (SA-199, 209 and 213) hardness test shall be performed on outside of the tubes as per SA-450.
- d) For LAS plates > 50 mm thickness, following supplementary requirements of SA-20 shall also apply:
 - i) Vacuum treatment as per supplementary requirement S1. If vacuum degassing is not reported in the test certificates, then through thickness tests as per SA 770 shall be conducted and minimum reduction in area of 35% shall be ensured.
 - ii) Bend Test as per supplementary requirement S14.

2.2.3 SS AND OTHER HIGH ALLOY MATERIAL

- a) All SS material (300 series) shall be in the solution heat-treated (fully annealed) and pickled condition. All stabilised grades of SS (SS 321, SS 347 etc.) shall be given stabilisation heat treatment, in addition to solution annealing.
- b) SS (300 series) plates shall be hot rolled and shall have No.1 finish on both sides.
- c) SS (300 series) materials for all components including non-pressure parts like baffles, tie rods, etc. shall be procured with the IGC test as per ASTM A-262 (test shall be carried out, after the specified heat treatment and sensitisation per specification) with acceptable corrosion rate and practices as under:
 - i) For all services except nitric acid service, Practice E shall be followed. Specimen after exposure shall be bent as per requirements mentioned in

A262 Practice E and shall be inspected under magnification of 200X. The bent specimen shall be free of any cracks or grain dropping. The microstructure shall be submitted to DIA for approval.

- ii) Nitric acid service: Practice C with corrosion rate not > 25 mils per year.
- (d) For straight chrome (13% Cr.) material, maximum carbon content shall be < 0.06%. Hardness of UNS no. S41000 and S40500 shall be < 85 RB.

2.2.4 NON-FERROUS MATERIALS

- (a) All copper based non-ferrous plates shall be procured in annealed condition.
- (b) Plates for pressure parts shall be 100% UT. Supplier shall submit the procedure for UT to DIA for approval.
- (c) In addition to hydro test, all tubes shall be eddy current tested in their final annealed condition.
- (d) All pipe bends shall be stress relief annealed after bending.
- (e) The paragraphs NF7 and NF14 in part UNF of Code are mandatory. This applies to non-ferrous cladding and weld overlay also.

2.2.5 CLAD MATERIALS

- (a) Cladding shall be integrally and continuously bonded to the base metal. All clad plates shall be rolled-on or explosion bonded type.
- (b) Clad plates shall be UT from the cladding surface as per SA-578. Scanning shall be 100% of the plate surface. Acceptance standard shall be level B. Clad plates shall meet the supplementary requirements of S7 of SA-578. All UT shall be undertaken after specified heat treatment of clad plates.
- (c) Both base material and clad material shall meet the specification of the respective materials as stipulated in this specification.
- (d) Alloy clad steel plates shall be as per SA 263 or SA 264 or SA 265. Bond between cladding and the base metal shall be checked for a minimum strength of 14 kg/mm² in shear for alloy clad steel plates, by conducting shear test as per applicable material specification.
- (e) For copper alloy clad plates, the bond between cladding and base metal shall be checked for a minimum strength of 10 kg/mm² in shear by conducting shear test.
- (f) During tension test of clad plates the cladding shall be removed and the tensile properties of the base material shall meet the Code material requirements.
- (g) For austenitic SS clad plates the SS surface shall be acid pickled as per ASTM A-380. For chromium steel clad surfaces the pickling shall be as per Supplier's established procedure. The same shall be submitted to Owner or EIL for approval.
- (h) For clad components, Supplier to ensure that plate thickness after bonding and machining shall not be less than the thickness specified in drawings. Supplier to consider sufficient margin on clad and base materials so that thickness after machining and complete fabrication shall be as per the drawings. For nozzle necks with weld deposit, sufficient margin on ID shall be taken to allow for shrinkage

2.3 Non pressure parts

- 2.3.1 CS plates shall be minimum IS-2062 or SA 283 Gr. C or equivalent. Pipes shall be to IS 1239 or SA 53 or equivalent.
- 2.3.2 Saddle material shall be same as that of shell for shell design temperature > 350 °C.

2.4 Equivalent materials

The materials for various components in a heat exchanger shall be as per Owner or EIL's requirement. This does not preclude use of equivalent or better materials. However, these deviations should be clearly indicated in the prescribed format. If an equivalent material sought by the Supplier is to a specification, other than IS or ASTM or ASME, it is necessary for the Supplier to submit the specifications of the equivalent material with complete details in English for approval.

3.0 SUPPLY

Supply shall be in accordance with requisition or bid document to which this specification is attached. It shall, however, include the following also:

3.1 Test ring assembly, dummy shell and test flange

- a. Test ring assemblies, dummy shells and test flanges wherever required shall be designed and supplied by the Supplier. The stresses shall not exceed 90% of the minimum yield stress of the material as stipulated in material specification. Material used for fabricating these shall be of tested quality. For removable bundle with tube side test pressure higher than shell side, the bundle shall be tested outside the shell, with tube side pressurised for tube side test pressure to check tube to tube sheet joint leakage from the back of tube sheet. Test flange shall be designed accordingly.
- b. Test ring assembly construction shall be stuffing box type as per fig. E-4.13.2 of TEMA. It is preferred that the test ring flange thickness not exceed the shell cover flange thickness. Otherwise, Supplier to provide separate bolting for assembling test ring flange to shell. Similarly, Supplier to check that the studs for stationary tube sheet bolting can be used with test flange. Else separate bolting shall be provided for assembling test flange.
- c. For "T" type of floating head exchanger necessary washers, bolts and nuts for sealing of bolt holes in tube sheet to be provided during hydro test.

3.2 Accessories for testing

All necessary accessories such as supports, blind flanges, test gaskets, bolts, nuts etc. shall be provided and supplied by the Supplier for testing of heat exchangers, in Supplier's shop and for subsequent testing by Owner at site, whenever required.

3.3 Other accessories

- 3.3.1 Supplier shall also supply tie bolts, leveling shims or intermediate supports for stacked units. Gaskets, nuts and bolts for interconnecting nozzles (both tube and shell side) along with spares shall be supplied by Supplier. All these components shall be despatched separately with due care having been taken regarding identification of these for ease of installation.
- 3.3.2 Earthing lugs shall be provided on each heat exchanger and shall be located in such a way as to avoid any fouling with the exchanger foundation bolts at site.
- 3.3.3 Supplier to supply one set of torque wrenches for bolt size M45 (1 3/4") to M56 (2 1/4") and one BTD for bolt sizes greater than M56 (2 1/4"), in case these bolt sizes are being used in exchangers covered in the requisition. BTD capacity shall be 40% more than the maximum load required for hydro test condition. BTD pump shall be pneumatically and manually driven. Supplier shall supply one pump unit, required load cells and 4 heads of each size. Torque values for tightening the bolts shall be mentioned in the fabrication drawings.
- 3.3.4 Davits, if required as per design basis or drawings, shall be provided.
- 3.3.5 Additions like cleats for piping, ladder, platform, insulation etc. that may be required at a later stage shall be provided.

3.4 Cathodic protection

Whenever cathodic protection is specified both sacrificial anodes and internal painting shall be provided. Separate specifications shall be provided in the requisition.

3.5 Spares to be supplied by Supplier

3.5.1 BOLTING: 20% studs and nuts but not less than 4 studs with 8 nuts for each joint.

3.5.2 GASKET: 400% gaskets other than those used for hydro testing and despatch for each joint.

3.5.3 Spare bolting and gaskets shall be provided for all joints of girth flanges, floating head, channel cover, tube sheet, interconnecting nozzles, nozzles with blind flange etc.

4.0 FABRICATION

4.1 Edge preparation

4.1.1 For CS, the edges for welding shall be made by machining, chipping, cold shearing, oxy-acetylene flame cutting or a combination of these. Chipping or cold shearing shall be followed by grinding to a smooth and regular surface. Oxy-acetylene flame cutting shall be followed by machining or grinding to eliminate any discoloration of material affected.

4.1.2 For LAS, the edges for welding shall be made by oxy-acetylene flame cutting or by machining. Cold shearing may be used for cutting thickness up to 10 mm. Oxy-acetylene flame cutting shall be used with preheat and shall be followed by machining or grinding to eliminate any discoloration of material affected.

4.1.3 For austenitic SS, the edges for welding shall be made by plasma arc, however, cold shearing may be adopted for thickness up to 15 mm. In all cases the cut edges shall be ground back or machined back by 2 to 3 mm.

4.1.4 All welding edges after cutting shall be DP or MP examined for laminations, cracks or segregation. Additionally UT shall be carried out within five times the material thickness of edge for LAS materials or when the service is low temperature or hydrogen or HIC.

4.1.5 The paragraphs NF7 and NF14 in part UNF of Code are mandatory. This applies to non-ferrous cladding and weld overlay also.

4.2 Rolling and dishing of plates

4.2.1 ROLLING

Rolling for bending and forming of plates shall be in the longitudinal direction of the plates. This direction shall be clearly marked on the plates.

Rerolling after welding is not normally recommended. However, if for large diameter shells, rerolling of welded shell course is inevitable, procedure for rerolling along with extent of NDT shall be submitted for approval of the DIA. All welds on the section to be rerolled must be ground flush. After rerolling all the welds on the re-rolled section must be DP checked. Such welds shall then be subjected to radiography as required by drawings and Code.

4.2.2 DISHING

All dished heads shall preferably be of single piece construction. However dished ends with one chordal seam are acceptable for shells with diameter greater than 1 m. In such cases, the chordal seam shall preferably be in the middle one-third of the blank. Dished ends shall be torispherical (knuckle radius 15% of outside diameter and crown radius 80% of outside diameter) or 2:1 ellipsoidal. Dished heads shall be subjected to DP test on knuckle portions (both inside and outside) and weld edges after heat treatment. Supplier to ensure adequacy of indicated thinning allowance for dished head. If nominal thickness indicated is not adequate then the nominal thickness should be increased accordingly, keeping minimum thickness as per item drawing. A straight face of 38 mm or 3 times the nominal thickness of dished head, whichever is more, shall be provided, but maximum straight face shall be limited to 50 mm.

4.3 Welding

- 4.3.1 All welding and weld overlays shall be done with electrodes, fillers and fluxes of reputed make with proven reproducibility of results. DIA shall specifically approve brand names. For CS pressure parts, the electrodes shall be of low hydrogen type. IGC test as per ASTM A262 Practice E shall be done for austenitic SS consumables, which are to be used in application involving solution annealing. Austenitic SS consumables of low carbon and stabilised grade shall also be IGC tested as per ASTM A262 Practice E. Straight chrome materials shall be welded with electrode that produces an austenitic chromium nickel weld deposit or a non air hardening nickel-chromium-iron weld deposit.
- 4.3.2 All welding procedures shall be submitted for approval by DIA giving all relevant details. Welding qualification records shall indicate hardness values of weld metal, HAZ and parent metal and also results of impact tests when design temperature are below 0 C or when specifically indicated for materials being welded. No welding shall be undertaken until DIA has approved the welding procedure and welder's qualification. All welding procedures and welders shall be qualified for the particular type of welding and material in accordance with the ASME Section IX. Supplier shall be responsible for the quality of the welds performed.
- 4.3.3 Pressure holding joints shall be FPW. Root pass of single side welded joints shall be done with GTAW process. Backing strip for single side welded joints is not permitted. For LTCS materials, both inside and outside of welds shall be ground flush or dressed smooth. All internal welds in the shell shall be ground flush in order to insert and remove tube bundle. Also all internal welds shall be ground flush to the extent of facilitating draining of complete equipment. All other weld may be left in the descaled condition only.
- 4.3.4 Longitudinal seams shall be staggered with the circumferential distance between the centres of welds being at least 5 times the thickness of the thicker-plate. Weld seams shall be located so as to avoid interference with weld seam of nozzles and external attachments.
- 4.3.5 Attachment to pressure part shall be of same quality as the pressure part. All LAS weld attachments to pressure retaining component shall be FPW and ground to a smooth concave contour. External attachments like lugs, supports etc. of CS shall not be welded directly to high alloy or austenitic SS heat exchanger components. These attachments should be of the same material as the heat exchanger component. If this is not so, intermediate pad plate of the same material type as the heat exchanger component may be used. These pads shall be at least 100mm wider and longer than the attachment and shall be at least 5 mm thick. Welding of CS or LAS to austenitic SS shall be done with austenitic SS electrodes or filler wire (AWS-ASTM-E 309L or E-309 Mo L only).
- Wrapper plates, reinforcing pads, saddle plates or stiffeners of higher thickness than specified can be used provided there is no change in basic dimensions and with the approval from DIA. No separate deviation permit is required for the same.
- 4.3.6 Partition plates of CS and 300 series SS except for low temperature service, shall be welded to channels etc. by continuous fillet welds with minimum size of 6 mm on both sides. For all other materials and for hydrogen and low temperature services, all welds involving partition plates shall be FPW. However all pass partition plates shall be FPW up to a distance of 2"(50mm) from the gasket contact surface. Partition plates thicker than 10 mm shall be tapered to 10 mm at partition groove end except when mentioned otherwise on drawings. One weep hole of 6 mm diameter shall be provided at the center of each horizontal pass partition plate and a 5 mm radius notch on top and bottom point of each vertical pass partition plate for all multipass exchangers for effective venting and draining.
- 4.3.7 Welding of shell to unhubbed tube sheet shall meet the requirements of Code considering that the tube sheet is unsupported.
- 4.3.8 When impact tests are required on material as per Code or specification the welds shall also be qualified for impact test. In such case following special requirement shall apply to the welding procedure qualification:

- i) Qualification tests shall be made on plates of the ASME specification as specified for the exchanger using welding electrodes of AWS or SFA specification and wire & flux of the specification and brand as are to be used on the job.
- ii) Welding current and travel speed shall be considered essential variables in order to ensure that production welding is substantially equivalent to the procedure qualification.
- iii) Welded test plates shall be subjected to a total thermal cycle sequence similar to the finished equipment. Specifically, test plates shall be held at intermediate and final stress relief temperatures for approximately the same length of time as the finished exchanger. Final cooling rate shall be approximate to that expected for the finished exchanger.
- iv) Charpy V-notch impact tests shall be made on the weld and HAZ of the test plate for each welding procedure to be qualified. Test procedure shall be as per UG 84 of Code. Test temperature shall not be higher than MDMT. Impact energy requirements shall be as per Table 2.15 of SA 20 of ASME Section II Part A or UG 84 of Code whichever is higher.

4.3.9 WELD OVERLAY

- 4.3.9.1 Wherever cladding is specified in datasheets or drawings, weld overlays are not acceptable.
- 4.3.9.2 Weld deposit overlay shall be done by a qualified welding procedure and surface shall be properly machined or ground flush after overlay. Minimum thickness of finished weld deposit shall be as indicated in the drawings or specifications. In case a higher deposition thickness and multiple weld layers are required to achieve the minimum specified undiluted deposit metal, the same shall be done only after taking prior approval from EIL. Minimum thickness of undiluted finished weld overlay from top shall be 2 mm or as specified in the drawings. For non-ferrous weld deposit, the iron dilution should be restricted to 2.5% (maximum) in the finished undiluted layer (thickness defined above).
- 4.3.9.3 The weld overlay procedure shall be qualified on base metal of the same composition as the exchanger component and meeting the requirements of ASME Section IX.
- 4.3.9.4 The weld overlay shall be relatively smooth with no notches and undercuts that would act as stress raisers. All cracks, fissures and circular defects greater than 1/16 inch diameter shall be removed. Repaired areas shall be DP checked. Weld overlay shall be applied to base metal, which has been grit blasted and is smooth and clean so as to ensure full bonding. Welding overlay cladding shall be applied after any normalising but before PWHT. The weld overlay shall consist of at least 2 layers.
- 4.3.9.5 The alloy cladding shall be cut back at all seams to permit back welding of the base metal. Weld metal shall be ground flush and fully covered with the applicable weld deposit. The weld joint in base plate shall be 100% DP tested for detection of cracks and flaws before welding from clad side. The weld deposit shall be at least as thick as the cladding.
- 4.3.9.6 Shells, cones, dished heads and nozzles formed from clad plates shall be subject to UT after forming, for a minimum of 10% of the clad surface, but no less than one square feet in each 10 square feet or fraction thereof. Unbonded areas that cannot be encompassed by a 3 inch diameter circle shall be repaired by weld overlay. When repairs in excess of 5 % of the total examined area are required, the complete component shall be subject to 100% UT. Repaired areas and weld deposit overlay at weld seams shall be DP examined. UT shall be repeated for dished heads after heat treatment. UT procedures shall be in accordance with SA 578 S6 for spot examination and SA 578 S7 for 100% examination.
- 4.3.9.7 All weld overlays shall be 100% DP examined in accordance with the method described in ASTM-E-165. The barrier layer shall be 100% examined. When the overlay involves multiple passes (layers) and the procedure uses an intermediate heat treatment with cooling to room temperature prior to applying the subsequent layer, each layer shall be examined by DP. Where overlay is to be machined such as for flange facing, machined surface shall be

100 % examined after final PWHT. If 100% of overlay is examined prior to the final PWHT, overlay shall be spot examined (not less than 10% of the surface) after heat treatment.

- 4.3.9.8 Samples of the weld overlay shall be taken to perform chemical analysis to the specified depth. The number and location of samples and method of taking samples shall be approved by DIA. However, they shall be representative of each exchanger component for each type of welding process. Report of chemical analysis shall be submitted to DIA for approval.
- 4.3.9.9 For all weld overlays used in hydrogen or H₂S service with design temperature greater than 350°C, Hydrogen disbonding test shall be carried out. The test condition shall be representative of the actual design conditions and the procedure shall be submitted to DIA for approval. Rate of cooling shall be 100°C/hr (min.) unless specified otherwise in datasheets. Holding time shall be 48 hours unless specified otherwise in datasheets
- 4.3.9.10 PTCs are required for CS welds above 50 mm thickness and for LAS welds above 25 mm or when required by the Code or when specified in the requisition. The following shall apply: -
- a) Two PTCs representative of one longitudinal and another circumferential seam shall be provided for each procedure, position and thickness.
 - b) PTC shall be from material of the same heat and thickness as that of parent metal. During and after production welding PTC shall be subjected to same heat treatment as and together with the course they represent. Extra PTC shall be preserved to take care of eventuality of retests.
 - c) The tests mentioned below shall be carried out as per methods of testing in Code:
 - i) One transverse tension test.
 - ii) Two side bend tests with weld located in the center of bend.
 - iii) One hardness test on PTC weld and HAZ. The acceptable limits are 200 BHN for CS, 225 BHN for P3 and P4 materials and 235 BHN for P5 as per EIL specification no. 6-15-0091.
 - iv) Micro and macro structural examination of welds.
 - v) For CS, charpy V notch tests on weld and HAZ shall be carried out. For MDMT < 0°C, impact test temperature shall be MDMT. For MDMT > or equal to 0°C, the test temperature shall be 0°C. The acceptance criteria for impact energy shall be as per table a 2.15 of SA 20 of ASME Section II part A or UG-84 of Code whichever is higher.
 - vi) For LAS, charpy V notch test on weld and HAZ shall be carried out. Test temperature and acceptance criteria shall be as per clause 2.2.2 (d) (ii).

4.4 Tube to tube sheet joints

Requirements of EIL specification no. 6-15-0003 shall be complied with for welded tube-to-tube sheet joints and that of EIL specification no. 6-15-0004 shall be complied with for expanded tube-to-tube sheet joints.

4.5 Hardness limitations

Hardness limitation for CS materials, welds and HAZ wherever specified on drawings or datasheets shall be ensured as per Specification 6-15-0091. Hardness limitation for LAS materials, welds and HAZ shall always be ensured as per Specification 6-15-0091. Hardness limitation compliance for tube-to-tube sheet welded joints shall be established/verified on a mock-up with simulation heat treatment

4.6 Nozzle flanges, nozzles and reinforcing pads

4.6.1 FLANGES

Unless otherwise indicated, dimensions, drilling, facing and tolerances for nozzle flanges (and blind covers if required) shall be as per ASME B 16.5 (for size up to 24" NB) and

ASME B 16.47 series B (for sizes above 24" NB) for the respective class. Weld overlays, wherever specified or required, shall be in addition to the thickness as per these standards. Boltholes on these nozzle flanges shall straddle principal vertical and horizontal centerlines of equipment. If the component to which nozzles are attached is subsequently stress relieved, it shall be Supplier's responsibility to maintain true gasket faces by machining or otherwise. If distortion is expected, final machining operation should be done after stress relieving; sufficient machining allowance for this purpose should be available. Gaskets, for flanges to ASME B 16.5 and B16.47, shall be as per ASME B16.20.

4.6.2 NOZZLES

4.6.2.1 Nozzle pipes shall be attached to the heat exchanger components by FPW. Attachment welds using only inner and outer fillet welds are not permitted. Unless otherwise indicated on the datasheets or drawings, necks of all nozzles shall be flush with the inside of the heat exchanger component. Inside corners of nozzle pipes at shell and channel inside diameter shall be radiused. All nozzles 2" NB and below, except long weld neck, shall have two stiffeners (30 mm x 6 mm) at right angles.

4.6.2.2 Whenever nozzle inside is required to be overlaid, these shall be done by weld overlay or cladding. Minimum nozzle ID before weld depositing to be 50 mm in such cases. Liners are not acceptable.

4.6.3 REINFORCING PADS AND TESTING

Reinforcing pads whenever required as per drawings or Code shall be of the same material or equivalent as the heat exchanger component to which it is welded. All reinforcing pads shall be provided with two 1/8" (3 mm) NPT tapped holes located 180 apart for air soap solution test with a pressure of 1.25 kg/cm² (g). This test shall also be required to be carried out for slip on flanges. Higher test pressures are not recommended because of accompanying risks and also because the soap bubbles have a chance to blow off. Tell-tale holes in the reinforcing pads shall be plugged with hard grease unless otherwise indicated after the hydro test of the exchanger.

4.7 Bolts, studs etc. and tapped holes

4.7.1 All inch bolting and threading shall conform to ASME B 1.1 except for size 1" and above where it shall be 8 threads per inch. Metric bolting and threading shall conform to ISO-R261 except for size M24 and above, where it shall have 3 mm pitch.

4.7.2 Studs shall extend beyond the nut by about 10 mm and shall be threaded full length except when square ends are required for use with BTJ, in which case the extension shall be as per BTJ manufacturer's recommendation. The studs for extended tube sheets and the studs for use with connecting piece shall also have square ends.

4.7.3 All nuts shall be of heavy series only and nut seating faces shall be machined or spot faced.

4.7.4 Threads on external bolting, plugs etc. shall be lubricated with graphite grease for working temperature up to 200°C and with Molybdenum Disulphide for higher temperatures.

4.7.5 Tapped holes on the channel side face of clad tube sheet for removable bundles shall be fitted with plugs of a material similar to channel side material in contact with tube side fluid.

4.7.6 For extended tube sheets, tapped holes shall be provided for girth bolting.

4.7.7 All floating head bolting to have 2 mm wide and 0.5 mm deep groove at both ends to prevent mix up with other bolts.

4.7.8 In addition to stamping, the specifications and manufacturers symbol as specified in ASME material specifications, on one of the ends the size of the studs shall be clearly punch marked. Similarly the nuts shall have the size punch marked on one of the faces. In case of tapped hole the size shall be punch marked near the hole without disturbing the gasket seating area. Further for all alloy/SS metallurgy bolts & nuts shall also be identified by distinct colour marking at the stud end/bolt side face

4.8 Assembly and handling

- 4.8.1 Supplier shall be responsible for taking adequate preventive measures to ensure the quality and finish of materials and to avoid any rusting.
- 4.8.2 Suitable method of alignment like dowels etc. shall be provided for proper assembly of channel, channel covers, stationary tube sheet etc.
- 4.8.3 Stacked exchangers shall be assembled in the shop for a trial fit. Special care shall be exercised in truing up connecting nozzle flanges.
- 4.8.4 'T' wherever indicated on drawings, denotes match mark for assembly and shall be punched on all mating parts.
- 4.8.5 Lifting lugs shall be provided as per standard for lifting of channels, channel covers, floating heads, shell covers, test rings, test flanges etc.
- 4.8.6 In case of removable bundles the following are required: -
 - (a) Stationary tube sheets shall be drilled and tapped at vertical (0°) position for attaching eyebolts; or a lifting lug of adequate thickness shall be welded with 25 mm (minimum) diameter hole.
 - (b) Drilling and tapping as above shall be carried out on floating tube sheet.
 - (c) Last support plate shall be drilled (25 mm diameter hole) for lifting the assembled bundle. Local stiffening may be necessary to withstand the bundle load., which shall be designed by the Supplier.
- 4.8.7 Pulling eyebolts made from forged CS shall be provided for all removable bundles. These shall be sent loose along with the spares. Insert piece shall be provided for all clad tube sheets. Material of insert piece shall be same as that of cladding material.
- 4.8.8 Stationary tube sheet shall be drilled and tapped for tie rods. Care should be taken to ensure that holes are not drilled through.
- 4.8.9 Interchangeable and 180° rotatable bundles shall have common pass-partition groove arrangement in the respective tube sheet. For exchangers where bundles are specified to be interchangeable, the same shall be ensured at the Supplier's shop by actually inserting the bundles or using a template consisting of 4 full diameter baffles, each spaced at a distance equal to the baffle pitch.
- 4.8.10 Jackscrews shall be provided on all girth flanges.
- 4.9 Descaling, pickling and passivation shall be done for all SS parts in accordance with ASTM A-380. The Supplier shall furnish details of the procedure for approval to DIA.
- 4.10 No distortion whatsoever shall be permitted on the gasket seating surfaces due to tube to tube sheet welding, shell to tube sheet welding, PWHT etc. If distorted, the same shall be machined subsequently.
- 4.11 **Fabrication tolerances and finish**
 - 4.11.1 The dimensional tolerances shall be within the limits indicated on EIL drawings and standards. Where tolerances are not specified, these shall be in accordance with the requirements of TEMA and Code.
 - 4.11.2 All edges and corners including baffle holes shall be deburred (or rounded, if shown).
 - 4.11.3 Finish of all machined components shall be minimum 12 microns (500 RMS) unless otherwise indicated. Parts subjected to UT shall have minimum finish of 6 microns.
 - 4.11.4 Tube sheet face shall be flat within +/- 1.5 mm (camber).

5.0 NON DESTRUCTIVE TESTS

- 5.1 All the NDT procedures shall be submitted to DIA for approval. For all NDT activities, only qualified NDT technicians shall be deployed with the approval of DIA.
- 5.2 The extent of radiography shall be as specified in datasheets or drawings or job specification. Radiography shall be performed after PWHT. In case radiography is carried out before PWHT, then UT shall be carried out on the welds after PWHT.
- 5.3 Minimum extent of radiography shall be spot, unless full radiography is specified in the drawings or required as per specification or Code. Spot radiography shall mean that at least 5% of the total welded length must be radiographed. Further, all 'T' joints must be radiographed and at least one shot must be taken on each longitudinal and circumferential seam. This requirement shall supplement the ones specified in Code. DIA shall be consulted in marking the areas to be radiographed.
- 5.4 Full radiography when specified shall imply 100% radiography of all butt welds including nozzle flange to nozzle neck, pipe to pipe and pipe to fitting.
- 5.5 All welds of nozzle necks fabricated from plate, irrespective of diameter, thickness of plate and radiography specified, shall be 100% radiographed.
- 5.6 Weld seams of formed heads shall be 100% radiographed after forming and heat treatment.
- 5.7 All nozzle to shell welds and unhubbed tube sheet to shell welds shall be DP or MP checked at the root run and final weld.
- 5.8 All welds, which cannot be fully radiographed such as nozzle to shell, shell to unhubbed tube sheet, unhubbed floating head to cover etc., shall be 100% UT after final PWHT. Fillet welds and welds which cannot be radiographed or UT (i.e. pass partition plate to channel and floating head etc.), the root run shall be DP checked and the welds shall be finally MP checked after PWHT.
- 5.9 All attachment welds shall be either DP or MP tested.
- 5.10 If radiography is being substituted by UT for the final closing seam as permitted by Code, MP shall be carried out in addition to UT

6.0 HEAT TREATMENT

- 6.1 PWHT shall be done if required by datasheets, drawings, specifications, Code etc. PWHT when mentioned on the drawings shall be over and above the requirements of specifications or Code. No welding or heating is permitted after PWHT. All machining operations shall preferably be carried out after PWHT (also refer clause 4.6.1). It shall be the responsibility of the Supplier to leave sufficient allowance for this purpose. Supplier shall submit all the procedures for PWHT to DIA for review.
- 6.2 During PWHT of assemblies of fixed tube sheet exchangers, care shall be taken to ensure that differential stresses are not caused between tubes, shell and tube sheet. The temperature differential between shell and tubes during PWHT to be minimised (not to exceed 25°C) and the rate of heating and cooling shall not exceed 25-30°C per hour. For this purpose, thermocouples shall be installed on various components and compliance assured.
- 6.3 Heat treatment of SS clad assemblies shall be at reduced temperature to avoid sensitisation of SS materials. The soaking time shall be increased accordingly as per Code.
- 6.4 Heat treatment of non-ferrous clad assemblies, if required, shall be performed with extra care, at reduced temperatures to avoid differential thermal expansion. The soaking time in such a case shall be increased accordingly as per Code.
- 6.5 Heat treatment of CS and LAS dished heads shall be as follows:
 - a) Stress Relieving for:
 - (i) Cold formed dish heads up to 16 mm thick.

- (ii) Cold formed floating head cover up to 16 mm thick if fibre stretch exceeds 5%.
- b) Normalising for CS and normalising and tempering for LAS:
 - (i) Hot formed dish head and floating head dish if not formed in normalising range.
 - (ii) Cold formed dish heads for thickness greater than 16 mm.
 - (iii) Cold formed floating head dish above 16 mm thick.

This heat treatment need not be given if same heat treatment is given subsequently on sub-assembly. Thicknesses specified above are nominal.

6.6 SS components shall be solution annealed in the following cases.

- i) Cold formed dished heads with nominal thickness of 16 mm or above.
- ii) Hardness value of dished heads after cold forming exceeds 235 BHN.
- iii) Hot formed shells, cones, dished heads.

After any heat treatment on austenitic SS, IGC test shall be carried out as per clause 2.2.3 (c)

6.7 All LAS welds shall be PWHT.

6.8 If stress relieving is indicated on shell side or tube side and the service on either side is lethal or low temperature or if specifically indicated in the datasheet or drawings, the welded tube-to-tube sheet joints of CS or LTCS material shall be stress relieved.

6.9 For LAS materials, preheating procedure shall be established in the welding procedure and got approved by DIA. Preheating by resistance or induction-heating method is preferred. Preheating shall extend uniformly to at least three times the thickness of joint but not less than 50 mm on both sides of the weld. Temperature indicating crayons shall be used for assessment of correct pre heat temperature.

7.0 INSPECTION AND TESTING

7.1 Inspection

7.1.1 The inspection shall be carried out by DIA. The materials, fabrication and testing of exchangers shall be open to inspection by DIA in addition to any inspection required by the specified Code or local authorities having jurisdiction over the installation.

7.1.2 Inspection shall be carried out both during fabrication and before delivery and also for sub ordered materials. In addition to final inspection and certification by DIA during the course of manufacture, DIA's written approval shall be obtained by the Supplier at various stages of fabrication. For this purpose, Supplier shall prepare his QAP, defining the stages of fabrication, hold points for his own inspection and that by the DIA or Code or Statutory Authorities etc. The QAP shall be discussed with DIA before start of job and mutually agreed. The various stages of fabrication to be inspected (either by Supplier or DIA or both) shall include but not limited to the following:

- (a) raw material identification and verification of mill test certificate.
- (b) edge preparation for welding, including visual check for laminations.
- (c) alignment of longitudinal and circumferential seams.
- (d) rolling tolerances on individual section.
- (e) alignment and fit up of sections and components.
- (f) root pass clearance before further welding and cleaning.
- (g) profile and thinning of dished ends and toriconical pieces after forming.
- (h) checking of tube sheet after drilling including checking of tube layout patterns, tube holes, pass partition locations, visual check for laminations.
- (i) tube sheet to shell set up for fixed tube sheet exchangers, prior to welding.

- (j) tube to tube sheet joint expansion or welding.
 - (k) visual check of shell inside and tube bundle insertion.
 - (l) welding of expansion bellows or joints, if required.
 - (m) review of NDT reports and heat treatment charts.
 - (o) final visual and dimensional inspection.
 - (p) witnessing of hydro test.
- 7.1.3 The presence of DIA shall not modify or reduce the obligation of the Supplier to carry out his own tests and control. If any material and/or equipment are not found in compliance with the specified requirements, DIA or his delegate shall be entitled to irrevocably reject them, even if such non-compliance has not been evidenced in the course of inspection and/or tests.
- 7.1.4 DIA will, at the time of his initial visit, set up with the Supplier actual details of inspection stages to be witnessed or carried out; the schedule of future visits and subsequent inspection notices can be arranged between DIA and the Supplier.
- 7.1.5 The Supplier shall notify DIA sufficiently in advance of any fabrication operations to permit arrival at the Supplier's shop in time to witness these.
- 7.1.6 The Supplier shall provide to DIA, free access to his shops at all times. He shall also supply all tools and tackles to DIA for carrying out the inspection. The Supplier shall also arrange for similar facilities at his sub-contractor's shops.
- 7.1.7 The Supplier must satisfy DIA that the welding procedures, welders, electrodes, fluxes, welding wires etc. are in accordance with the requirements of the Code and specifications. Further the welder's qualification test must be carried out in the presence of DIA.
- 7.1.8 Prior to final inspection, all slag, weld spatter loose scale, dirt, grit, paint, grease, oil and other foreign matter shall be removed in order to facilitate inspection. All reinforcing pads and slip on type flange welds shall be pressure tested with air and soap solution before and after heat treatment (if any) and before final hydrostatic test.
- 7.1.9 A dimensional check of equipment shall be carried out taking into account the tolerances shown on drawings, standards, specifications or Code, the more stringent values shall govern. Dimensional checks are to be taken of the internal measurements of equipment together with external ones and these are to be recorded on the drawings as being the "As Built" dimensions.
- 7.2 **Hydrostatic tests**
- 7.2.1 Hydrostatic tests shall be witnessed by DIA. When hydrostatic tests are performed the indicating gauge shall be connected to the upper most part of the equipment. Testing water shall be clean potable water. Seawater shall not be used. For SS equipment, water used for these tests shall not contain more than 25 ppm chlorides. Minimum metal temperature during hydrostatic tests shall be 20 C. Test pressures shall be maintained for at least one hour. Shell and tube sides shall be tested separately, unless otherwise mentioned on the drawing. For tube sheets designed for differential pressure, special care shall be taken during testing. Equipment drawings shall clearly indicate if tube sheets have been designed for differential pressure. Drying out as per clause 9.1 shall be carried out immediately after hydro test.
- 7.2.2 All vertical exchangers shall be tested in vertical position. Alternatively, exchanger may be tested in horizontal position with test pressure modified with prior approval of Designer.
- 7.2.3 Stacked exchangers with nozzles interconnected shall be hydro tested in stacked condition except when the hydro test pressure of the individual exchanger is different.
- 8.0 **STAMPING, NAME PLATES AND WARNING PLATES**
- 8.1 Each exchanger shell shall be fitted with an SS nameplate.

8.2 Warning plates, if required, shall be provided.

8.3 The following exchanger parts shall have the item number stamped except for heat exchangers in low temperature service in which case the item number shall be marked with non-removable ink:

Shell girth flanges, shell cover flange, channel girth flanges, flat channel cover, stationary and floating tube sheets, floating head cover flange, floating head backing ring, connecting pieces, test rings, test flanges and other main removable parts.

9.0 PROTECTION AND DESPATCH

9.1 After completion of all testing and inspection, the inside of complete equipment shall be thoroughly drained and dried out. Equipment shall be completely dried by passing hot air for sufficient time until no further increase in relative humidity of outgoing air is observed. Dry out shall be done simultaneously on both shell and tube sides. After drying, the equipment shall be purged and filled with dry N_2 at 0.25 kg/cm^2 . The equipment shall be provided with pressure gauge to monitor N_2 pressure, and $\frac{1}{2}$ " non-return valve. All threaded holes, other than tell tale holes for testing, shall be suitably protected with steel bar plugs. All nozzles not provided with blind flange shall be provided with steel covers, temporary gaskets and bolts.

9.2 Shop painting

All CS and LAS external surfaces, except gasket faces and machined surfaces, shall be primer painted. Surfaces to be painted shall be prepared for painting by removing loose mill scale, rust, oil, grease and other films or substances harmful to the adhesion of paint by an approved method such as shot blast cleaning. The surface shall be prepared to near white finish as per SSPC-SP-10 [SA 2 $\frac{1}{2}$ Swedish standard (SIS-05-5900)]. The primer shall be inorganic zinc silicate (65-75 microns dry film thickness), unless stated otherwise.

9.3 The equipment item number, PO number and Owner name and address shall be painted in bold white paint letters written with stencil, on the heat exchanger.

Sliding end of exchangers shall be painted as "CAUTION-SLIDING END" in black on the primer coating in the shop.

9.4 Despatch of equipment

No heat exchanger shall be released for shipment until it has been approved by DIA. Heat exchangers shall be despatched after the operations as required by clauses 9.1, 9.2 and 9.3 have been carried out and shall be despatched in as-tested condition. In case stacked exchanger shells are despatched separately the Supplier shall provide additional set of gaskets for interconnected nozzles other than the gaskets included in spares. Heat exchangers shall be securely anchored for despatch in order to prevent any shifting and damage during transportation. Expansion joints and bellows shall be suitably protected against any possible damage by providing tie bars before boxing up. Packaging shall be suitable for rail or road transport and also sea worthy if transported by sea. Spares shall be despatched separately in a box and marked with PO number, item number and Owner's name and address.

Supplier shall provide sling mark identification on all heat exchangers with respect to center of gravity of the equipment.

No equipment shall be despatched until a written clearance is obtained from Owner or EIL regarding Piping Clips and Structural Cleats on individual equipment.

10.0 SUPPLIER'S GUARANTEES

The Supplier shall be completely responsible for the compliance to Code requirements, residual design, detailing, fabrication, materials and workmanship of the exchangers as per the stipulations of the requisition and its attachments. In this regard, it may be noted that review by Owner or EIL shall not relieve the Supplier of his responsibility of meeting all requirements and ensuring satisfactory performance of the equipment. Guarantee period shall be as per GPC of Owner