



NATIONAL PETROCHEMICAL COMPANY
STANDARDS

MATERIAL STANDARD
FOR
SHELL & TUBE HEAT EXCHANGERS

NPCS-MS-HM-01

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1 GENERAL

1.1 SCOPE

- 1.1.1 This standard covers the minimum requirements for mechanical design & guarantee, materials, fabrication, workmanship, inspection, testing and supply of unfired shell and tube type heat exchangers.
- 1.1.2 The intent of this standard is to supplement, amend or limit the reference codes and standards mentioned below.
- 1.1.3 Exceptions or variations shown in the material/purchase requisition take precedence over requirements shown herein.
- 1.1.4 No variations from the material/purchase requisition, data sheets and this standard are permitted unless approved in writing by purchaser.
- 1.1.5 In case of any conflict between the various standard and codes, the matter shall be referred to purchaser for clarifications and the clarifications provided by purchaser shall be final and binding on vendor.
- 1.1.6 The compliance with this standard and accompanying data does not relieve the vendor from his own responsibilities and guarantees nor from any further contract obligations.
- 1.1.7 The approval of the work by the purchaser's inspector and/or his release of the equipment for shipment shall in no way release the manufacturer from or relieve the manufacturer of any- responsibility for carrying out all of the provisions of this standard and/or the fulfillment of the guarantee, nor does the purchaser by such approval and/or release assume any responsibility whatever for such provisions and/or guarantee.
- 1.1.8 In case of conflict in various documentation, the following order of priority shall apply :
- a) Equipment data sheet
 - b) Material/purchase requisition
 - c) This standard
 - d) Licensors standard specifications and drawings



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1.2 REFERENCES (LATEST EDITIONS)

- 1.2.1 TEMA Standards of Tubular Exchanger Manufacturers Association, Class 'R'.
- 1.2.2 ASME Boiler and Pressure Vessel Code Section VIII! Division 1, Unfired Pressure Vessels.
- 1.2.3 ASME Boiler and Pressure Vessel Code Section II, Material Specification.
- 1.2.4 ASME Boiler and Pressure Vessel Code Section IX, Welding Qualification.
- 1.2.5 ASME Boiler and Pressure Vessel Code Section V, Non Destructive Examination.
- 1.2.6 ASTM Specification
- 1.2.7 AWS-ASME Specification for Welding Electrodes.
- 1.2.8 ANSI American National Standards Institute, INC., B16.5, steel pipe flanges and flanged fittings and 816.11 forged steel fittings, socket-welding and threaded, (latest editions approved by ASME).
- 1.2.9 API 605 Large Diameter Carbon Steel Flanges.
- 1.2.10 EJMA Standards of the Expansion Joint Manufacturers Association INC.
- 1.2.11 All exchangers shall be designed and fabricated in accordance with TEMA Standard, latest edition, class 'R' and sections II, V, VIII and IX of the ASME boiler and pressure vessel code, and ASTM Codes, latest edition.
- 1.2.12 Nozzles, flanges, tapered pipe threads, pipe fittings, bolts, nuts and gaskets shall be in accordance with appropriate ANSI, ASTM and TEMA Codes, and welding electrodes to AWS Specifications.
- 1.2.13 The design, fabrication and testing of pressure vessels shall also comply with all the specifications, standards, drawings, provisions and codes indicated on drawings provided by the purchaser. Unless otherwise specified in the order the latest editions of codes and specifications in force at the date of the contract shall be used.
- ASME Code stamp is not required, unless otherwise specified on heat exchanger Data sheet.



2 DESIGN

2.1 GENERAL

2.1.1 All exchangers of the same size type and material shall maximize interchangeability of parts where practical. The highest practical number of exchangers shall have interchangeable tube bundles.

Whenever possible tube bundles shall be **designed to** permit rotation through 180°.

2.1.2 Where equipment is mounted on concrete foundations, the anchor bolts shall be designed with the following allowable anchor bolt stresses :

TENSION:	110 N/mm ²
SHEAR:	69 N/mm ²
Allowable bearing stress on concrete :	7.5 N/mm ²

2.1.3 The use of stay bolts as a means to stiffen tube sheets, channel covers and flange heads is not permitted.

2.1.4 In addition to normal design loads, exchangers shall be designed to withstand a horizontal bundle pulling force "H" of :

<u>Bundle Weight (BW)</u>	<u>Horizontal Effort</u>
BW < 50 KN	H = BW
50 KN ≤ BW ≤ 100 KN	H = 50 KN
BW > 100 KN	H = 0.5 BW

Only one effort shall be considered, when several exchangers are stacked.

The assumed bundle pulling force, "H" shall be checked against vendors recommendations and adjust, if required.

2.1.5 All combinations of loads shall be considered to determine the maximum design stress conditions for design except for maintenance loads combined with wind and earthquake loads. Erection loads shall also be taken into consideration.

2.1.6 When U-tube bundle or kettle type reboiler shell (TEMA "K") is **used**, the shell cover shall be integral with shell.

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- 2.1.7 When removable longitudinal baffle shall be used, the seal strips shall be the replaceable type and be securely attached to longitudinal sides of baffle plate adjacent to shell wall. They shall be Multitlex of an alloy appropriate for the service, or Neoprene rubber or equal, subject to design temperature limit recommended for the material being used. When metal seals are used, fabricator shall provide copies of instructions to purchaser that outlines proper steps for folding seal strips inward so edges do not rub unduly against inside of flange when tube bundle is inserted into shell.
- 2.1.8 Impact baffles shall be no closer to the inlet nozzle than is required for escape height and flow area.
- They shall be of sufficient size so that the distance from the projected 'inside of the nozzle to the edge of the plate, in any direction, is at least equal to the distance of the plate from the nozzle opening.
- 2.1.9 Perforated baffles are not permitted.
- 2.1.10 Shells shall be of one piece construction whenever practical and shall be fabricated of seamless pipe or rolled plate.
- 2.1.11 All shells on floating head units, except kettle type reboilers, shall be removable with through bolting.
- 2.1.12 Shell and channel girth flanges shall be of forged steel, hub type and designed for thru-bolt joint construction.
- 2.1.13 Pulling lugs or tapped holes for insertion of eye bolts shall be provided on the outer face of the stationary tube sheet to permit removal of the tube bundle from the shell.
- 2.1.14 Jack screws shall be provided to aid in loosening all heads, channels, and channel covers.
- 2.1.15 When one unit is composed of two or more shells in series it shall be assumed, unless otherwise specified, that the shells will be stacked and the manufacturer shall design the shell and supports to eliminate the possibility of the lower shells distorting and binding the tube bundle. The corrosion allowance shall be deducted from the unit before investigating such external loading.



- 2.1.16 When two or more exchangers are stacked, intermediate supports shall be installed during fabrication and the entire stack shall be erected at the manufactures works and checked for accuracy of nozzle location and alignment.
- 2.1.17 Stacked large exchangers shall be limited to 2 shells high. Stacked small exchangers shall be limited to a centre line elevation of 3.5 m (12 ft) at the top exchanger.
- 2.1.18 Expansion Joints
- 2.1.18.1 Single pass tube bundle exchangers, having a bellows type expansion joint between floating head and shell covers, are permitted. Such designs shall include provisions (guide device) that allows quick and easy mating of expansion joint end flange to its companion flange on the inside face of shell cover. Expansion joint shall be the hydraulically formed type and it shall also permit replacement in the field. It shall be constructed of Inconel 600, Incoloy 800, or Incoloy 825, listed in preferential order unless otherwise specified.
- 2.1.18.2 Stresses due to thermal expansion shall be analysed in both clean and fouled condition, to determine the necessity of using expansion joints. **Stress conditions** due to start-up, shutdown, steam cleaning, etc., shall also be investigated.
- 2.1.18.3 The type of expansion joint recommended by the vendor shall require the approval of the purchaser.
- 2.1.19 Designer of exchanger unit shall be responsible for furnishing equipment that is free of over stressing for any loading within the specified maximum loading.
- 2.1.20 During the design of fixed tubesheet heat exchangers, consideration must be given to the stresses induced at operating, alternate operating, start-up, shutdown and other upset conditions. Where necessary, expansion **joints** shall be provided.
- 2.1.21 Where stated tube bundles may be designed for the differential pressure given in job specification. Vendor shall provide visible warning plate adjacent to, or part of, name plate outlining test regulations, when differential design is used.



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2.1.22 Alloy Protective Lining

2.1.22.1 When the process data sheet indicates materials other than carbon steel for tube sheets without specifying "solid", vendor may quote the more economical alternative between "solid" and "cladded" material.

2.1.22.2 Pass partition grooves in lined tube sheets and channel covers shall have the specified minimum lining thickness on all surfaces.

2.1.22.3 Applied alloy liners shall be considered as corrosion allowance only, not as part of the base metal, when calculating the thickness of pressure parts.

2.1.22.4 If the base metal is carbon steel, then if other carbon steel components in contact with the same process flow are specified to be of fully killed carbon steel, the base metal of the cladding shall also be of the same material.

2.1.22.5 Thickness requirements of lining are in TEMA "R" .

2.1.22.6 Silver soldered or brazed bonded liners shall not be used.

2.1.23 Deviations

In general no deviations from purchaser Standards and specifications shall be permitted. This does not preclude possible innovations or improvements on the part of the supplier, based on available facilities. Such deviations must be clearly pointed out as a separate paragraph entitled "DEVIATIONS" in the supplier's documents, so as to avoid any confusion and ambiguity and to facilitate analysis of quotation in minimum possible time. It shall be taken for granted that except for the deviations pointed out under the "DEVIATIONS" paragraph, all other technical requirements shall be adhered to, by the supplier. No deviation shall be incorporated, unless it has been approved in writing by purchaser. It is in supplier's own interest to get the written approval of purchaser for all deviations before accepting the purchase order. No deviations shall be entertained or approved after the order has been accepted by the supplier. Delay in supply of the equipment, on account of such deviations being not entertained or approved by purchaser shall be contractor's liability.



In case there are no deviations required by the supplier quotation under the "DEVIATIONS" paragraph shall read as "EQUIPMENTS SHALL BE SUPPLIED AS PER PURCHASER'S SPECIFICATIONS, CODES, ETC., IN ALL RESPECTS". It shall be presumed that supplier has understood very clearly the job requirements and shall fully comply with them.

2.1.24 Material Supply

- 2.1.24.1 All materials and accessories required for the fabrication of the heat exchangers shall be supplied by the vendor unless otherwise stated.
- 2.1.24.2 Stainless steel name plate shall be provided on each heat exchanger shell.
- 2.1.24.3 Test rings, dummy shell and test flanges wherever required shall be designed and supplied by the supplier. Drawings for these shall need prior approval of purchaser. Material used for fabricating these shall be of tested quality. The number of test ring/test flange assemblies shall be equal to the number of shells stacked.
- 2.1.24.4 All necessary arrangements such as supports, blind flanges, test gaskets, bolts, nuts and other accessories shall be provided by the supplier for testing of heat exchangers.
- 2.1.24.5 Supplier shall include in his quotation supply of tie bolts, leveling shims or intermediats supports for stacked units, gaskets, nuts and bolts relating to interconnecting nozzles (tube and shell side). All these components shall be despatched separately with due care having been taken regarding identification of these for case of installation.
- 2.1.24.6 It is deemed that supplier shall supply the equipment strictly as per the requirements of the codes, specifications, etc., as such it is presumed that unless indicated under the "DEVIATIONS" paragraph of the quotation, the dimensions and materials for various components in a heat exchanger are as per purchaser requirements. This does not preclude use of equivalent or better materials. However, these deviations should be clearly indicated in the quotation. If an equivalent material sought by the supplier is to a specification, other than ASTM/ASME, it might be necessary for the supplier to submit the specifications of the equivalent material (translated in English language, if the original is not in English).

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2.2 CORROSION ALLOWANCE AND MINIMUM WALL THICKNESS

- 2.2.1 Corrosion allowances shall be per TEMA Standard. For materials other than carbon steel corrosion allowance shall be specified on the data sheet. corrosion allowances as specified on the data sheet shall be adhered to if more stringent.
- 2.2.2 No corrosion allowance shall be added to tubes.
- 2.2.3 Minimum admissible wall thickness shall be per TEMA and ASME Codes.
- 2.2.4 For U-tubes the wall thickness specified applies to the tubing before bending except as noted in paragraph 2.2.5 below. All U-tubes shall be formed from a continuous length of tubing, free of girth welds.
- 2.2.5 The minimum mean radius of U-bends shall be 1 1/2 times the O.D. of the tube. Flattening at the bends shall not exceed 10% nominal O.D. of straight portion tube. Proposal may be based on the use of heavier wall tubing for short radius U-bends when design pressure demands thicker tube walls.

2.3 TUBES, TUBE BUNDLES AND TUBESHEETS

- 2.3.1 Tubesheets shall be fabricated from forged materials when integral with shell and/or channel.
- 2.3.2 On vertical exchangers installed with the channel at the bottom at least 4 collar bolts shall be provided to support the tube bundle when the channel is removed. Alternative means shall be approved by the Purchaser.
- 2.3.3 When gasket grooves are required in tubesheets the minimum distance between the edge of the tube hole and the edge of the gasket groove shall be 1.5mm.
- 2.3.4 A minimum of one dowel or some equivalent method of alignment shall be provided to prevent misassembly of floating head cover, channel, channel cover having grooved partitions and stationary tube sheet to shell flange.
- 2.3.5 Guide pins shall be placed in tube sheets to facilitate assembly and to keep tube sheets with integral tube sheets from dropping out of position when the bundle is to be withdrawn from the shell.



Note: Provide three guide pins approximately 120" apart with one located on top of vertical centerline of a horizontal unit, the outside edges are to be 1mm clear of the shell I.D. and are to be the same material as the tie rods.

2.3.6 Guide pins are not required when the tube sheets are held in position by:

- a) Tube sheets with tapped holes for stud bolts, nuts at both ends.
- b) Tube sheets having drilled holes when adjoining flanges are tapped for studs.
- c) When the distance from the tube sheet to the second segment cut baffle is 450mm or less, or when the tube bundle is made up of baffles spaced 225mm center to center or less, regardless of the distance from the tube sheet to the first baffle.

2.3.7 Support plates shall be provided on units without transverse baffles. In case of floating head exchangers a suitable support plate shall support the floating head of each bundle. Baffles shall be of the cross flow segmental type, and shall be tied together with rods and spacers and shall be provided with notches, only when necessary, to permit drainage of the shell.

2.3.8 Baffle clearances between design I.D. of shell and baffle O.D. shall be as shown in TEMA. These maximum clearances may be increased to twice the tabulated values only when isothermal vaporization or isothermal condensing occurs on the shell side of an exchanger.

2.3.9 Impingement baffles are not required for non abrasive liquids, gases or superheated vapors when, at the smallest cross sectional area of the nozzle, the value of $(\text{density}) \cdot (\text{velocity})^2$ is less than that stipulated in the TEMA. For all other conditions impingement protection is required.

2.3.10 Impingement protection shall be provided by a plate baffle, a distributing belt or by an enlarged inlet nozzle with an internal distributor plate, of minimum 6mm thickness;



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2.3.11 Plate baffles shall extend beyond the projection of the nozzle bore. This baffle shall be located at a distance from the nozzle to provide a minimum free cylindrical entrance area at the projected nozzle bore equal to the nozzle bore area.

2.3.12 Where enlarged inlet nozzles, containing internal distribution plates, are used, the actual entrance area into the shell must be at least equal to the line bore. The maximum fluid velocity at the cross-sectional area of the enlarged nozzle shall be limited by :

$$(\text{density in kg/m}^3) \times (\text{velocity in m/s})^2 = 1040$$

Enlarged inlet nozzles shall not be used for mixed phase liquids.

2.3.13 A minimum of two longitudinal replaceable long life sealing strips of approved design shall be provided for cross-baffled exchangers between the outer row of tubes and the inside of the shell as follows:

<u>Radial Clearance</u>	<u>Shell Diameter</u>
over 18mm	to 630mm
over 25mm	710mm & over

2.3.14 Where U-tube construction is utilized, each U-tube shall be formed from a single length of tubing.

2.3.15 Where U-tube construction is utilized, Stress investigations shall be conducted whenever temperature of 95°C or greater, are assigned over both legs of any U-tube. When steam is in U-tubes and process is controlled by low control of condensate, U-tubes shall be in a horizontal plane.

2.3.16 Each U-tube shall be formed from a single length. The length specified shall be the straight length measured from end to return bend tangent.

2.3.17 In general, tube to tubesheet joints shall be expanded. All tubesheet holes and the grooving in them shall conform to TEMA and the following supplements. Grooves shall be square edged and concentric. When heat treatment of tubesheet is required, final tube hole sizing shall be attained by reaming after heat treatment.



- 2.3.18 The tube-to tubesheet joint shall be welded if:
- a) The design temperature is $< -10^{\circ} \text{C}$ or $> 300^{\circ} \text{C}$.
 - b) For U-tube type with design pressure $> 150 (\text{kg}/\text{cm}^2) \text{g}$.
 - c) For floating head types and fixed tube-sheet type with design pressure $> 40 (\text{Kg}/\text{cm}^2) \text{g}$
 - d) With cladding on the tubeside face of the tubesheet (channel side, floating head side)
 - e) Where the high reliability of the joint is required because of lethal substance, product quality, hazards of inter-mixing etc.
- 2.3.19 When welding of tube to tubesheet is required, after welding, the tubes shall be light expanded into the tube holes. The light expansion shall imply minimum 5% tube thinning. The procedure and details of welding shall be submitted to the purchaser for approval .
- 2.3.20 Tubes shall be expanded into the tubesheet for a length equal to four tube outside diameters or the tubesheet thickness minus 3mm whichever is smaller. In addition for tubesheets with thickness in excess of four tube diameters expand one diameter at the shell side face of the tube sheet minus 3mm . In no case shall the expanded portion extend beyond the shell side face of the tubesheet . The expanding procedure shall provide substantially uniform expansion throughout the expanded portion of the tube without a sharp transition to the unexpanded portion.
- 2.3.21 Adequate lifting and handling lugs, etc., shall be provided by the fabricator to ease handling, lifting, erection etc., of the complete equipment .
- 2.3.22 Davits shall be provided for removal of channel, channel cover, shell cover and floating head assembly unless specified on drawing.
- 2.3.23 Vibration
- For exchanger unit subject to vibration, the tube bundle shall be designed as per TEMA, 7th edition, SEC.6, para. V, and the following fabrication clearances shall also be satisfied .



- a) For baffles spaced less than 300mm apart, tube hole diameter shall not exceed the O.D of the tube plus 0.5mm. For baffles spaced 300mm or more apart or for tube support plates the tube hole diameter shall not exceed the O.D of the tube plus 0.25mm.
- b) Minimum baffle thickness shall be 10mm Otherwise follow TEMA "R" .
- c) Deburr and ream all tube holes in baffles and support plates, to eliminate all sharp edges of these parts. Also deburr edges on cut for baffle window.

2.4 NOZZLES, MANWAYS AND OTHER CONNECTIONS

- 2.4.1 The 150 lb, series nozzles are not permitted for design temperatures over 370°C or for pressure relief valve connections; the 300 lb series shall be used as a minimum instead.
- 2.4.2 All flanges intended for use with spiral wound metal gaskets shall be designed using the manufacturers minimum gasket seating stress or the ASME Code values, whichever is greater.
- 2.4.3 All flanges designed as special shall account for external loads imposed by piping reactions and consideration givent to differential thermal expansion for dissimilar joints.
- 2.4.4 The inlet and outlet stream connections shall be flanged, faced and drilled to the specified rating .All other nozzles 2" and larger shall be flanged.
- 2.4.5 Nozzle sizes shall be as indicated on he data sheet. The vendor shall not alter these nozzle sizes without specific approval by the Purchaser.
- 2.4.6 Flanged nozzles shall be one of the following types:
 - a) Integrally flanged forged (long welding necks) are preferred
 - b) Seamless pipe neck or plate rolled and longitudinally welded, full penetration, with a full penetration welded attachment to forged welding neck flange.
 - c) Block forged nozzles welded to a forged welding neck flange.



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- d) Nozzles of alloy material may be fabricated from seamless alloy pipe with forged carbon steel slip-on flange faced with alloy on gasket seat except in H₂ service.
- e) Lap joint flanges shall not be used.
- 2.4.7 Integral reinforced nozzles are required if any of the following conditions is applicable:
- a) **The design pressure** exceeds 40 (kg/cm²)g.
- b) The design temperature is <-10°C or >350°C.
- c) Plate thickness exceeds 50 mm.
- 2.4.8 The minimum permissible thickness of flanged steel nozzle necks shall be Schedule 80 of size 8" and smaller. Necks of nozzle sizes 10" and above shall be 12.7mm minimum wall thickness.
- 2.4.9 Nozzles flanges bolt hole shall straddle principal vertical and horizontal center line of equipment .
- 2.4.10 All nozzles 2" and below, shall have two stiffeners 30mm wide x 6mm thk. at right angles
- 2.4.11 Each exchanger for use in fully condensing service shall have a 1" flanged vent, of the same rating as the other shell nozzles, provided at the top of the end opposite to the shell inlet. For stacked units provide a vent nozzle *in each shell*.
- 2.4.12 Flanges for connection to external piping 24" and smaller shall be per ANSI B16.5. For larger size flanges shall be according to API 605 unless otherwise specified on the data sheets.
- 2.4.13 Where exchangers are connected in series; process data sheet indicates ratings of inlet nozzle on first unit and outlet nozzle on last unit .Intermediate flanges of stacked exchangers shall always be "RF" type irrespective of the requirements for other flanges. Gaskets and bolting are to be supplied for intermediate flanges by the vendor.
- 2.4.14 Connections below 3/4" will not be permitted.
- 2.4.15 A 3mm (1/8") radius shall be provided on the inside edges of flush trimmed openings and on both exposed edges on internally projecting nozzles.



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- 2.4.16 Neutralizing facilities shall be provided on exchangers having austenitic stainless steel bundles. Chemical cleaning connection shall be provided on condensers where process conditions will make this necessity, and these shall be specified on the process data sheet. Minimum connection size is 1 1/2".
- 2.4.17 Minimum Nozzle length
- 2.4.17.1 The length taken from the outside of the insulated barrel or head to the back of the flange shall exceed the bolt length.
- 2.4.17.2 Minimum length of nozzles in noninsulated exchangers shall be 150mm for 4" and smaller and 250mm for large nozzle sizes.
- 2.4.17.3 Bolts between connecting nozzles of stacked exchangers shall be supplied and shall be removable without moving the exchangers.
- 2.4.18 When tube side fluid is steam, a 3/4"-6000 lb threaded coupling operating vent connections shall be provided in the channel cover or bonnet head at high point of second pass.
- 2.4.19 When shell side fluid is steam, a 3/4"-6000 lb threaded coupling shell side operating vent connections shall be provided as follows:
- a) For horizontal units one vent located below centerline at the end opposite the inlet.
 - b) For vertical units two vents required one below horizontal centerline at end of steam travel and one near the top.
- 2.4.20 Provide one 1 1/2" flanged connections and one 3/4"-6000 lb coupling in all main shell and tube side nozzles of exchangers nominal size 4" and above and 3/4"-6000 lb coupling on nozzles size 2" NB to below 4" NB. Except on long forged weld neck or block forged nozzles or when data sheet prohibits use of these connections.