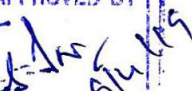
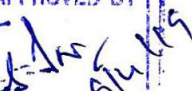
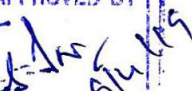
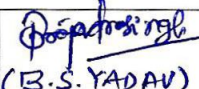
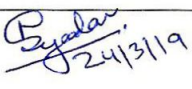
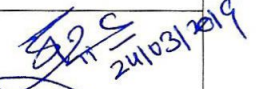
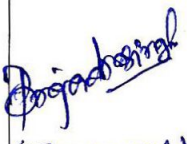
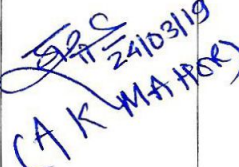


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| <b>MAIN SUPPLIER'S NAME:</b><br><b>BHARAT HEAVY ELECTRICALS LIMITED, BHOPAL</b><br>(A GOVERNMENT OF INDIA UNDERTAKING) <div style="float: right; text-align: right;">  </div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>NAME OF SUB-VENDOR: N/A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>NPCIL PO NO.: CMM/FTP/10-33-1-1149/e-PO/30599, DTD: 25.01.19</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>QA REF. NO.: 2190190</b><br><b>MAIN VENDOR: QAX-TH-1483, QAX-TH-1484, QAX-TH-1485, QAX-TH-1486 &amp; QAX-TH-1487</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>SUB VENDOR: N/A</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>CUSTOMER:</b><br><b>NUCLEAR POWER CORPORATION OF INDIA LIMITED</b><br>(A GOVERNMENT OF INDIA ENTERPRISE) <div style="float: right; text-align: right;">  </div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>PROJECT:</b><br><b>2x700MW GORAKHPUR HARYANA ANU VIDYUT PARIYOJANA</b><br><b>( UNIT 1&amp;2)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>EQUIPMENT: D2O HEAT EXCHANGERS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>DOCUMENT NO.: BHEL/NPCIL/30599/INCOLOY-800 TUBES/CDE-19-3410</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <b>TITLE:</b><br><b>TECHNICAL SPECIFICATION FOR SEAMLESS ANNEALED NICKEL- IRON-CHROMIUM ALLOY (INCOLOY-800) TUBES</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
| <div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;">  <b>न्यूक्लियर पावर कॉर्पोरेशन ऑफ इंडिया लिमिटेड</b><br/> <b>NUCLEAR POWER CORPORATION OF INDIA LTD.</b><br/> <input checked="" type="checkbox"/> अनुमोदित / <b>APPROVED with minor comments</b><br/> <input type="checkbox"/> टिप्पणी के अनुसार अनुमोदित / <b>APPROVED AS NOTED</b><br/> <input type="checkbox"/> संशोधन का आगे बढ़ाएं / <b>रोकें !</b><br/> <b>PROCEED WITH / HOLD FABRICATION</b><br/> <input type="checkbox"/> अंतिम ट्रांसपैरेन्सी एवं प्रतियाँ भेजें ।<br/> <b>SEND FINAL TRANSPARENCIES &amp; PRINTS</b><br/> <input type="checkbox"/> संशोधन करें एवं अनुमोदन के लिए पुनः प्रस्तुत करें।<br/> <b>REVISE AND RESUBMIT FOR APPROVAL</b><br/> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="width: 33%; text-align: center;"> <b>जाँचकर्ता</b><br/> <b>CHECKED BY</b><br/> <br/> <b>9-4-19</b> </td> <td style="width: 33%; text-align: center;"> <b>समीक्षकर्ता</b><br/> <b>REVIEWED BY</b><br/> <br/> <b>9/4/19</b> </td> <td style="width: 33%; text-align: center;"> <b>अनुमोदन कर्ता</b><br/> <b>APPROVED BY</b><br/> <br/> <b>9/4/19</b> </td> </tr> </table> <p style="font-size: small; margin-top: 5px;">             किए जानेवाले कार्य का अनुमोदन आपूर्तिकर्ता को विनिर्देशनों के अनुसार आपूर्ति के उत्तरदायित्व से मुक्त नहीं करता ।<br/>             The Approval of the work to be done does not relieve the supplier of responsibility of supply according to specifications.           </p> </div> |                                                                                                                                                   |                                                                                                                                                      |                                                                                                            |                                                                                                       |                                                                                                            | <b>जाँचकर्ता</b><br><b>CHECKED BY</b><br><br><b>9-4-19</b> | <b>समीक्षकर्ता</b><br><b>REVIEWED BY</b><br><br><b>9/4/19</b> | <b>अनुमोदन कर्ता</b><br><b>APPROVED BY</b><br><br><b>9/4/19</b> |
| <b>जाँचकर्ता</b><br><b>CHECKED BY</b><br><br><b>9-4-19</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <b>समीक्षकर्ता</b><br><b>REVIEWED BY</b><br><br><b>9/4/19</b> | <b>अनुमोदन कर्ता</b><br><b>APPROVED BY</b><br><br><b>9/4/19</b> |                                                                                                            |                                                                                                       |                                                                                                            |                                                                                                                                               |                                                                                                                                                   |                                                                                                                                                      |
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|                    | <b>CONDENSER &amp; HEAT EXCHANGER ENGG. DIVISION</b><br><b>BHEL BHOPAL</b> | <b>Document No.</b><br>BHEL/NPCIL/30599/INCOLOY-800 TUBES/CDE-19-3410 |
| <b>TECHNICAL SPECIFICATION FOR SEAMLESS ANNEALED NICKEL-IRON-CHROMIUM ALLOY (INCOLOY-800) TUBES</b> |                                                                            |                                                                       |

*Control*  
**REVISION CONTROL SHEET**

| <b>BHEL</b>       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                      |                                                                                                     |                                                                                                       |
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| REV. No<br>Date   | Description of Revision                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Prepared By                                                                                          | Checked By                                                                                          | Approved By                                                                                           |
| 00,<br>08.03.2019 | Original submission with change in NPCIL specification no PC-E/923 clauses 4.14 which shall be read as:<br><b>4.14 Non Destructive Examination:</b><br>Each finished tube shall be examined over the entire volume of the material. Each tube shall be examined by ultrasonic or eddy current examination methods after finish heat treatment and hydro test, except for U-bend tubes which may be examined prior to bending and subsequent hydro test. The procedure for ultrasonic and eddy current examination shall be generally in accordance with article 5 and 8 of ASME Section V. The standard for testing and acceptance criterion shall be as follows: | -Sd-<br>(ARUN KUMAR)                                                                                 | -Sd-<br>(N.SINGH)                                                                                   | -Sd-<br>(A.K.MAHOR)                                                                                   |
| 01,<br>24.03.2019 | Original submission with no change in NPCIL specification PC-E/923                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <br>(B.S. YADAV) | <br>(N. Singh) | <br>(A.K. MAHOR) |

**NUCLEAR POWER CORPORATION OF INDIA LTD.**  
(A Government of India Enterprise)

PROJECT : 700 MWe  
SPECIFICATION NO. : PC - E - 923

TECHNICAL SPECIFICATION  
FOR  
SEAMLESS ANNEALED NICKEL IRON CHROMIUM ALLOY  
(INCOLOY - 800) TUBES FOR D<sub>2</sub>O HEAT EXCHANGERS

REF. USI NO. : 33000

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|-----------------------------------------------|---|--------------|--|--|--|--|
| REVISION NO.                                  | : | 0            |  |  |  |  |
| DATE OF REVISION<br>(MONTH/YEAR)              | : | July<br>2013 |  |  |  |  |
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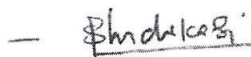
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PREPARED BY : LOKESH DWIVEDI



05-07-13

CHECKED BY : S DHARMADHIKARI



- 05.07.2013

REVIEWED BY : BABITA GUPTA



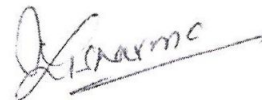
05.07.2013

S RAMESH



05.07.2013

APPROVED BY : M.K. SHARMA



08.07.2013

NAME

SIGNATURE

DATE

(For Revisions see Revision Control Sheet)

**REVISION CONTROL SHEET**

**DOCUMENT TYPE : ENGINEERING SPECIFICATION**

**NO. : PC-E-923-Rev.0**

**TITLE: SEAMLESS ANNEALED NICKEL IRON CHROMIUM ALLOY  
(INCOLOY-800) TUBES FOR D<sub>2</sub>O HEAT EXCHANGERS**

| REV.<br>NO. &<br>DATE | DESCRIPTION OF<br>REVISION | PREPARED<br>BY | CHECKED<br>BY | REVIEWED<br>BY | APPROVED<br>BY |
|-----------------------|----------------------------|----------------|---------------|----------------|----------------|
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| NUCLEAR POWER CORPORATION OF INDIA LTD.                                                                                                                             |                              |
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| ATOMIC POWER PROJECT (700 MWe)<br>SPECIFICATION FOR<br>SEAMLESS ANNEALED NICKEL - IRON - CHROMIUM ALLOY<br>(INCOLOY-800) TUBES FOR D <sub>2</sub> O HEAT EXCHANGERS | PAGE : 1 OF 17<br>REV. NO: 0 |

## 1.0 **SCOPE**

This specification covers the technical requirements for the supply of seamless annealed Nickel-Iron-Chromium alloy (Incoloy-800) tubes for heat exchangers. All the requirements in this specification represent minimum requirements.

## 2.0 **CONTENTS**

The requirements of this specification are presented under the following section headings:

|                                                  | Section |
|--------------------------------------------------|---------|
| Applicable Specification /Codes/ Standard        | 3.0     |
| Materials, process, Workmanship and requirements | 4.0     |
| Requirements of U-Bent Tubes                     | 5.0     |
| Bending Procedure Qualification                  | 6.0     |
| Packing and Shipment                             | 7.0     |
| Procedures, test reports and documentation       | 8.0     |
| QAP – Sample copy – Annexure- A                  |         |

## 3.0 **APPLICABLE SPECIFICATIONS**

The following codes and standards of the issue in effect at the time of issuing the tender document shall form part of this Specification. In the event that certain of the requirements of the codes / standards listed below conflict with the requirement of this Specification, the requirements which are more stringent shall govern

- (i) Relevant ASTM Standards
- (ii) ASME – Section II – Materials
- (iii) ASME - Section V – Non Destructive Examination

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#### 4.0 **MATERIALS, PROCESS, WORKMANSHIP AND REQUIREMENTS**

##### 4.1 Materials

The tubes shall comply with ASME-SB-163 Seamless Nickel and Nickel alloy condenser and heat exchanger tubes with particular requirements specified below. The alloy shall be that designated as annealed Nickel-Iron-Chromium alloy UNS No. 8800 with restricted chemical composition as specified in the Clause No. 4.4 below.

##### 4.2 Process

The tubes shall be manufactured by cold pilgering / drawing process. Materials, process and workmanship shall be of high quality and in accordance with good practice pertinent to the manufacture of nickel alloy condenser and heat exchanger tubes. Each rolled bar which will be used for tube manufacture shall be examined for internal soundness by taking macro specimens at each end of the bar and also subjected to chemical analysis which shall comply with clause 4.4 of this Specification. The manufacturing practice shall ensure no pickup of harmful impurities either during alloy making or during tube manufacturing. The cold working during final straightening process shall be kept to a minimum and the manufacturer shall indicate in the bid that value of residual stresses on finished tubes is not exceed 80 Mpa of sample from each lot. Hot extruded mother pipe must be used for manufacture of seamless tubes.

##### 4.3 Halogen and Sulphur Content

Chemicals, oils, lubricants etc. used during the manufacture, inspection / examination etc. of tubes shall not contain halogen and sulphur exceeding 25 ppm each. These shall also be free from lead. However, if for technical reasons the lubricants used for tube drawing purpose have to contain halogen in excess of above stipulated limit, these may be used provided that the manufacturing procedure i.e. temperature, speed of drawing etc. are such that excess presence of these halogen do not produce any harmful effect on quality of tubes on long term trouble free services (60 years) basis. Subsequent cleaning shall, however, ensure cleanliness requirements stipulated in Clause No. 4.19 of this Specification.

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#### 4.4 Chemical Composition

The chemical composition requirements for both product and ladle analysis are as follows :

| Element        | Composition Percent |
|----------------|---------------------|
| C              | 0.03 max.           |
| Si             | 0.30 to 0.70        |
| Mn             | 0.40 to 1.0         |
| P              | 0.015 max.          |
| S              | 0.015 max.          |
| Cr             | 20 to 23            |
| Ni             | 32 to 35            |
| Co             | 0.015 max.          |
| Al             | 0.15 to 0.45        |
| Ti             | 0.60 max.           |
| N <sub>2</sub> | 0.030 max.          |
| Cu             | 0.075 max.          |
| Fe             | Remainder           |

#### Stabilisation

|              |   |                    |
|--------------|---|--------------------|
| Ti           | = | 12 minimum         |
| -----<br>C   |   |                    |
| Ti           | = | 8 minimum          |
| -----<br>C+N |   |                    |
| (N + P)      | = | 0.04 maximum (aim) |

#### 4.5 Dimensions and Tolerance

The cross sectional dimensions (dia x wall thickness) and length of tubes shall be specified in pertinent tender document or purchase order.

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| ATOMIC POWER PROJECT (700 MWe)<br>SPECIFICATION FOR<br>SEAMLESS ANNEALED NICKEL - IRON - CHROMIUM ALLOY<br>(INCOLOY-800) TUBES FOR D <sub>2</sub> O HEAT EXCHANGERS | PAGE : 4 OF 17<br>REV. NO: 0 |

#### 4.6 Heat Treatment

The tube shall be Bright Annealed. The details of heat treatment (such as type of furnace, atmosphere in the furnace, rate of heating and cooling, soaking temperature and time etc.) shall be submitted for approval before start of manufacture. The details of heat treatment such as annealing temperature, soaking time, etc. shall be reported in Test Certificates. The qualification of production tube temperature shall be carried out in addition to the furnace temperature recording. The mechanical properties of tube after the heat treatment shall be guaranteed.

#### 4.7 Grain Size

The grain size shall be determined according to ASTM-E-112 and shall be ASTM micrograin size number 8 or finer. Attempts shall be made to achieve a grain size of 10 or finer.

#### 4.8 Surface Condition

The tube shall be in bright finish condition. The inside and outside surfaces of tubes shall be very smooth and the finish shall be on both OD and ID 1.6 microns (CLA) or better.

#### 4.9 Hardness Check

The hardness shall not be more than Rockwell B-95. However, minimum hardness shall not be less than B-85. The hardness values on sample bends shall be checked before and after tube bending.

#### 4.10 Drift (Flare) Test

Flare test shall be made on both the ends with an expanding tool having an included angle of 60° until the specified outside diameter has been increased by 20%. The surface area of expanded outside diameter shall not show any visible cracks in penetrant test examination.

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| ATOMIC POWER PROJECT (700 MWe)<br>SPECIFICATION FOR<br>SEAMLESS ANNEALED NICKEL - IRON - CHROMIUM ALLOY<br>(INCOLOY-800) TUBES FOR D <sub>2</sub> O HEAT EXCHANGERS | PAGE : 5 OF 17<br>REV. NO: 0 |

#### 4.11 Intergranular Corrosion Resistance Test

Intergranular corrosion resistance test shall be done in accordance with ASTM-G-28 on one sample from each melt and heat treatment batch. The specimen shall be sensitized by heating it up to 650°C, soaking for one hour and then water quenching. The heating shall be rapid and shall not take more than 1.5 min. The corrosion rate as calculated per G-28 shall not exceed 0.6 mm / year.

#### 4.12 Stress Corrosion Cracking Test

Stress corrosion cracking test shall be done in accordance with ASTM-G-36. The tube specimen shall be bent 180° to a radius of 28 mm. The bend shall be immersed in boiling MgCl<sub>2</sub> solution for 100 hours. The effect of 100 hours boiling shall show no crack by examining at 400 magnification and also by liquid penetrant examination.

In addition to above SCC test, one sample per melt shall be boiled for determination of time required for initiation of crack or maximum of 500 hrs..

#### 4.13 Test Coupon Numbers and Location

A 'Lot' shall consist of 300 tubes max. from the same melt and heat treatment batch. Test coupons shall be taken from the finished tubes after UT / ET testing.

4.13.1 One product analysis shall be made on each 'lot of tubes'.

4.13.2 One tension test shall be made on each lot of tubes at Room Temperature and 350°C.

|                              | Minimum Required Value |
|------------------------------|------------------------|
| Room Temperature             |                        |
| Tensile Strength             | 517 N/mm <sup>2</sup>  |
| Yield strength (0.2% offset) | 207 N/mm <sup>2</sup>  |
| % elongation                 | 30%                    |

The above values at 350°C shall be reported

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- 4.13.3 Hardness shall be measured on 1% of tubes in each lot on bend area.
- 4.13.4 One flare test per lot shall be made on both end of tubes prior to cutting to length.
- 4.13.5 Intergranular corrosion test shall be done on one sample from each melt and heat treatment batch.
- 4.13.6 Microstructure and grain size shall be determined on one sample from each 'Lot'. Micrographs are to be attached to test reports.
- 4.13.7 One stress corrosion cracking test is to be done on one sample from each lot refer sec. 4.12.
- 4.13.8 Surface roughness on OD and ID shall be measured on 1% tubes in each lot.
- 4.13.9 Residual stresses on finished tubes shall be determined on one sample per lot. This should be as low as possible and shall be aimed for 60 MPa (600 Kg/cm<sup>2</sup>) but not exceed 80 MPa.

A sampling plan indicating various tests, extent and sample selection is shown in Annexure-I to this specification as a guide line.

#### 4.14 Non Destructive Examination

Each finished tube shall be examined over the entire volume of the material. Each tube shall be examined by ultrasonic & eddy current examination methods as explained below after final bright annealing. The procedure for ultrasonic and eddy current examination shall be generally in accordance with article 5 and 8 of ASME Section V. The standard for testing and acceptance criterion shall be as follows :

- 4.14.1 The supplier has option to test tubes as per method 'A' or 'B' given below :

##### 4.14.1.1 Method A

The tubing shall be examined by ultrasonic method in two opposite circumferential direction and by eddy current method. Each method shall be calibrated to the appropriate standard that is, the ultrasonic method shall be

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calibrated to the axial notches or groves and the eddy current method shall be calibrated to circumferential notches and groves as well as radial through wall thickness holes.

OR

#### 4.14.1.2 Method B

As an alternative to the eddy current examination in method 'A' above or when eddy current examination does not yield meaningful results, an axial scan ultrasonic examination in two opposite axial direction shall be made. That is ultrasonic examination on tubes shall be made in 4 (four) directions (2 circumstantial and 2 axial)

#### 4.14.2 Reference Specimen and Acceptance Standard for method 'A'.

##### 4.14.2.1 For Ultrasonic Examination

The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat treated condition as the product being examined. For circumferential scanning, the standard defects shall be axial notches on outside and inside surface of the reference specimen and shall have a length not exceeding 25 mm (1inch), a width not exceeding twice the depth for square notch or U notch, a width proportional to depth for V-notch, and a depth not exceeding 0.076 mm (0.003 in). The rejection level shall be set at a minimum signal from above notches.

Any tube giving signal equal to or greater than the minimum echo height from above standard is not acceptable.

##### 4.14.2.2 For Eddy Current Examination

The reference specimen shall be a piece of, and shall be processed in the same manner as the product being examined. The reference specimen shall have following holes and notches.

3 (Three) through wall thickness radial holes along the tubes sufficiently apart placed at 120° with each other having dia 0.64 mm max. shall be made. Equivalent signal OD circumferential notches having depth not exceeding 0.076 mm (0.003 in) and width not more than twice the depth shall be made. Identical circumferential notches on I.D. shall be made.

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The rejection shall be set at the minimum of the signals from the holes OD/ID notches. Any tube showing signal equal to or greater than the minimum echo height from the above standard is not acceptable.

4.14.2.3 Reference Specimen and Acceptance Standard for Method 'B' (4 direction U.T.)

The reference specimen shall be of the same nominal diameter and thickness and of the same nominal composition and heat treated condition as the product being examined.

For circumferential scanning, the standard defect shall be axial notches, or grooves outside and inside surface of the reference specimen and shall have a length of approx. 25 mm (1 inch) or less a width proportional to depth for a V-notch and a depth not exceeding 0.076 mm (0.003 inch).

For axial scanning in accordance with ASTM-E-213, transverse (circumferential) notches shall be introduced on the inner and outer surface of the standard.

Dimension of transverse notch shall not exceed those of the longitudinal notch.

Rejection level shall be set at minimum signal from above notches.

Any tube giving signal equal to or greater than the minimum echo height from above standard is not acceptable.

4.14.2.4 OD and Thickness Measurement

Purchaser requires a very high degree of reliability for uniformity within required limits, of the thickness and OD all along the length of the tube. Continuous measurement of tube wall thickness and OD by employing continuous ultrasonic testing machine is required for each straight tube. Minimum and maximum measurement of tube wall thickness and OD over the length of the tube shall be recorded as part of inspection report. Any other better method other than continuous ultrasonic machine may be furnished during bidding stage. In case the proposal is acceptable, NPCIL will give acceptance after satisfactory demonstration of continuous wall thickness and OD measurement procedure. Supplier should be equipped with ultrasonic testing machine for tube wall thickness and OD measurement. The variation

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in wall thickness i.e. max - min in any one cross-section over the entire length of any one tube  $t_{min}$  shall be within 10%. Bidders shall submit along with the bid, measurement proposed, UTE, ECT, OD and wall thickness examination procedures.

#### 4.15 Repairs

Superficial external surface defects may be eliminated by mechanical means only provided the minimum wall thickness requirement after repair are still complied with and the surface area is blended smoothly. The repaired area shall be re-examined by appropriate non-destructive examination to ascertain freedom from defects and subjected to wall thickness measurement. The repair procedure shall be prepared by supplier and subject to purchaser's approval prior to its application on production tubes. Tubes repaired shall be clearly identified and reported to purchaser.

#### 4.16 Hydrostatic Testing

Each tube shall be hydrostatic tested using internal pressure of  $306^{+10.2/-0}$  kg/cm<sup>2</sup>, ( $30^{+1/-0}$  Mpa). The water used shall be demineralised water and shall have conductivity 10 µs/cm (max.) at inlet. An increase of 3 µs/cm (max.) at the outlet is permissible. The test pressure shall be maintained for a duration of 10 seconds minimum. The water used shall not have halogen and sulphur in excess of 25 ppm each.

#### 4.17 Straightness

The tube shall be free from kinks, bends, local distortion etc. and shall be straight 1 in 1000. This shall be checked by rolling the tubes on inspection bench for straight tubes as well as by comparing with certified straight edge placed side by side.

#### 4.18 Marking and Identification

The tube number shall be marked on each tube by electro etching or any other suitable permanent marking method, at approx. 200 mm from each end. Complete history of each tube shall be available in Check List / Test Certificate which shall be placed in the box containing the tube. As a minimum, following information shall be provided in the Check List : Material Specification, Melt, Heat No. & Lot No., Supply Condition. Tube Identification No. (having HX Tag No.) and Radius of Bend.

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#### 4.19 Cleaning

Each tube shall be thoroughly cleaned inside and outside prior to packing. Outside may be cleaned by wiping with cloth soaked in acetone. Inside cleaning shall be done by passing a clean felt sponge ball with the help of oil free dry air or Nitrogen until the ball at exit shows no discoloration during its passage through the tube. The cleanliness shall be checked by wiping test as follows :

Qualitative evaluation of unacceptable dust, oil etc.  
 Quantitative evaluation of chlorides, sulphur and silicon impurities shall be done on 1% of tubes in each production and supplying lot and they shall not exceed

|                  |                                                                       |
|------------------|-----------------------------------------------------------------------|
| Cl               | - 20 µg/dm <sup>2</sup>                                               |
| SiO <sub>2</sub> | - 30 µg/dm <sup>2</sup>                                               |
| F & S            | - to be agreed upon (bidder shall indicate in the bid proposed value) |

4.19  
4.20

#### Testing for Material Mix Up

Spectroscopic, semiquantitative, non destructive (sigma test) check shall be carried out to ascertain the tube of the same type of alloy from different quality manufacture are not mixed up during production and testing.

### 5.0 REQUIREMENTS OF U-BENT TUBES

- 5.1 The cross sectional dimensions, length and range of radii for U-Bent tubes shall be specified in pertinent tender document or purchase order. The U-bent tubes shall meet following requirements.
  - 5.1.1 After U-bending the bend shall be solution annealed. The solution annealed areas shall be bent portions plus 150 mm straight length portion on either side of the bends. The heat treatment of U-tubes may be carried out only on the tubes having upto 78.5 mm bend radius.
  - 5.1.2 Each tube shall be hydrostatic tested as per requirements of 4.16 of this specification. Hydrostatic test shall be done after bending. For such tubes hydrostatic test on straight length tubes prior to bending is not required.
  - 5.1.3 After hydrostatic test, U-Bend shall be examined by liquid penetrant method over complete U bend portion and 150 mm straight portion on either side of the bend. The scope of LP shall be as follows.

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5.1.3.1 All the tube bends covered under smaller bend radius shall be L.P. checked. In case of any unacceptable indication found in this examination, all the bends in next higher radius shall also be subjected to LP check. This process will continue till all the bends in a particular radius are defect free. The charges for this examination are considered to be included in the cost of the product.

5.1.3.2 For remaining tube bends not covered under 5.1.3.1 shall be subjected to random LP examination upto a maximum of 2% of the remaining tube bends at purchaser's option. If any unacceptable defect is found in the examination all the tube bends in that radius and all the bends in lower radii shall be subjected to LP examination.

5.1.3.3 With above limited LP examination scope, the manufacturer shall be obliged to replace (free of cost) all the tubes having unacceptable defect revealed during LP examination conducted by the purchaser.

5.1.4 In addition to LP examination of U-bend as described in 5.1.3., above, each end of all U bent tubes shall be subjected to LP examination upto a portion of 350 mm from tube end.

5.1.5 In U bent portion acceptable ovality shall be 5% max. Ovality shall be defined as :

$$\text{Ovality} = \frac{\text{OD Max.} - \text{OD Min.}}{\text{Min. OD before bending}}$$

OD = Outside diameter

5.1.6 In U bent portion wall thinning acceptable shall be 10% max. on outside of the bend.

5.1.7 Each bent tube shall be checked for passage by ball test using a ball size as specified in tender drawing.

5.1.8 The straightness requirements for the bent tubes shall be as follows, in lieu of para 4.17.

The straight portion of the bent tubes shall be free from kinks, bends, local distortion etc. and shall be straight within 1 in 1000.

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U-bent portion shall be free from kinks, local distortions etc. The tolerance on leg spacing shall be as per supplementary requirements of SB-163 Clause S3.1 'leg spacing'.

5.1.9 The tolerance on 'length of U-bend Tube Legs' and 'Squarances of Ends' shall be as per supplementary requirements of SB-163 Clause Nos. S1.2.4 and S1.2.5 respectively.

5.1.10 The operations / activities listed in Clause 4.18 to 4.20 and 7.0 shall be done after bending.

#### 5.1.10 BENDING PROCEDURE QUALIFICATION

Before bending, the procedure of bending shall be qualified as under :

6.1 For each 100 number or less number of tubes of smallest bend radius, 2 numbers (minimum) of bends of smallest radius shall be bent in each process of bending for qualification. These 2 sample bends shall be made in the presence of Purchaser or his Authorized Inspection Agency and subjected to following examinations :

6.1.1 Entire surface of bent tubes shall be visually examined for ripples, scratches and other surface defects. The cross sections at 2 positions minimum (to be agreed upon) for each bend shall be plotted by a suitable device to ascertain non-circularity and ovality.

6.1.2 Bending procedure qualification tubes shall be hydrostatic tested and after hydrostatic test entire bend surfaces shall be liquid penetrant tested. Radius of bend shall be checked by layout.

6.1.3 One of the two bends shall be cut transversely into eleven equally spaced sections starting at the start of the bend and finishing at the end of the bend (resulting in 10 rings) for further examination. The other bend is sectioned in longitudinal plane (Plane of flexure) into two halves for further examination.

6.1.4 Each of the above sections shall be examined for following :

- a) Visually examine internal surface for ripples , scratches and other surface defects.
- b) Check the surface finish on internals as well as external surface on each bend sections.

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- c) Measure the wall thickness at internal and external apex as well as at neutral bending axis for each section and compare with the wall thickness before bending, at minimum of 3 places.
- d) Measure the ovality and non-circularity at each section.
- e) Measure hardness on each cut piece, at minimum of 3 places.
- f) Optical illustration of the outline of the cross sections obtained by the two above said sectional planes (viz. Transverse and Longitudinal) for each of the test bends. Choice of the transverse sections for such illustration shall be exercised by the Purchaser or his authorized inspection agency.
- g) Non-circularity and ovality, thinning and other dimensions shall meet the requirements as specified in purchase drawing.

#### 7.0 PACKING AND SHIPMENT

- 7.1 After cleaning, each end of U-bend tube shall be plugged with two special plugs with removal tool along with one plastic cap (halogen free).

Each tube shall be packed in halogen free polythene sleeve and heat sealed on both ends. The U bends shall be packed in a proper sequence which will be indicated separately after award of contract for 'row by row' packing in a wooden case.

The tubes shall be packed full length in suitable padded weather proof containers suitable not only for transportation but also for long storage in tropical conditions. Special precautions shall be taken to ensure that no hard or sharp object such as nails etc. project into the container to possibly damage the tubing. Each package shall contain corresponding packing list and one set of full test reports in suitable book bound form. The container is likely to be subjected to multiple handling at docks in an event of trans shipment. The sturdily containers should be designed to withstand such multiple handling. Packing procedure shall be submitted to purchase for approval. The packing cases may be inspected on arrival as a precautionary measure by the Purchaser.

- 7.2 The supplier shall be responsible for the shipment and safe delivery of tubes to the destination, specified in the tender document or purchase order. The tubes shall be shipped 'UNDER DECK' only in the ship to avoid sea water entry into the boxes during the shipment. The tubes shall be protected and covered to prevent damages, corrosion and ingress of foreign material.

- 7.3 Identification during shipment

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Each package shall be clearly and legibly marked in suitable permanent manner with following information :

- a) Purchase Order Number
- b) Destination
- c) No. of tubes in the box with equipment identification tag..
- d) Project.

## 8.0 **PROCEDURES, TEST REPORTS AND DOCUMENTATION**

### 8.1 Procedures and Plans

The following procedures and plans shall be submitted to the Purchaser for review and approval in four copies each before start of manufacture.

- a) Manufacturing procedure giving sequence of operations right from melting ingot pouring, tube manufacturing and testing.
- b) Heat treatment plan.
- c) Mechanical testing procedures.
- d) Non Destructive Examination procedures.
- e) Wall thickness measurement procedure.
- f) Quality Assurance Plan
- g) Cleaning procedure adopted during various stages of manufacture.
- h) Repair procedure.
- i) Tube bending qualification and production bending / control procedures (to include measurement / plotting of ovality, non-circularity / cross section).
- j) Dimensional control procedures (for ID, OD and bend radius etc.).
- k) Surface finish measurement and inspection procedures.
- l) Hydrotest procedure for finished U-bend tubes
- m) Ball-pass test procedure
- n) Procedure for measurement of residual stresses on finished tubes.
- o) Quantitative measurement of contaminants such as Cl, SiO<sub>2</sub>, halogens, sulphur and lead.
- p) Tube handling procedure and precautions to be taken during fabrication of heat exchangers.
- q) Any other procedure having bearing on tube quality during tube insertion and testing.

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## 8.2 Reports

The following reports shall be submitted to the Purchaser in three (one original + Two copies) copies each. In addition of that four copies shall be prepared on computer compact disc (CD) with appropriate software for indexing & searching.

- a. Chemical analysis – ladle and product
- b. Mechanical test report
- c. Non destructive examination report (along with properly identified recording strips for Ultrasonic and Eddy Current Examinations showing defects accepted).
- d. Heat treatment charts
- e. Visual and dimensional inspection report
- f. Hardness survey report
- g. Metallurgical examination reports, with photographs (such as Macro-etch, Micro-structure / grain size).
- h. Illustrated catalog of defects
- i. Corrosion resistance test reports, with photographs.
- j. Residual stress measurement report
- k. Tube bending qualification and production bend reports.
- l. Surface finish reports
- m. Hydrotest reports
- n. Liquid penetrant examination reports.
- o. Ball-pass through test reports
- p. Cleanliness / quantitative measurement of contaminants reports.

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- q. Material mix up test reports
- r. Any other reports on examinations / inspections / tests conducted on tubes for ensuring tube quality.

One set of test reports / certificates including packing list shall be sent along with the material in a suitable fashion to facilitate inventory control identification, and release of material to fabricators of heat exchangers from Purchaser's stores.

- 8.3 The manufacturer shall note that the procedures, documents submitted along with the offer have been used only for the assessment of technical capabilities and the manufacturer shall submit all the procedures / documents for approval / information of the purchaser before commencement of manufacturing activity. The check list for all documents / procedures including end documentation shall be submitted immediately after the placement of order.

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# ANNEXURE-I

## SAMPLING PLAN

| TEST                                                                                   | EXTENT            | SAMPLE SELECTION           |
|----------------------------------------------------------------------------------------|-------------------|----------------------------|
| Heat analysis                                                                          | One per heat      | Pouring stream             |
| Check analysis                                                                         | Each bar          | Each end                   |
| Tensile test at RT                                                                     | One per lot       | At random                  |
| Tensile test at 350oC                                                                  | One per lot       | At random                  |
| Product analysis                                                                       | One per lot       | At random                  |
| Hardness test                                                                          | 1% per lot        | At random                  |
| Flaring test                                                                           | Each tube         | Both ends                  |
| Macro etching test                                                                     | Each bar          | Each end                   |
| Micro test                                                                             | One per lot       | At random                  |
| Corrosion test                                                                         | One per lot       | At random                  |
| Stress Corrosion test                                                                  | One per lot       | At random                  |
| Control of residual stress                                                             | One per lot       | At random                  |
| Surface roughness                                                                      | 1% per lot        | At random                  |
| Grade checking                                                                         | All tubes         |                            |
| Determination of Cl <sup>-</sup> , F <sup>-</sup> and (SO <sub>4</sub> ) <sup>2-</sup> | One per 100 tubes | At random prior to packing |