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TECHNICAL SPECIFICATION
FOR
QUENCHED & TEMPERED LOW ALLOY STEEL PLATES

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	NAME	Designation	SIGNATURE	DATE
PREPARED BY	Ajit Kumar Shit	Sr. EE	<i>Ashit</i>	01/10/13
	Braham Prakash	ACE	<i>Braham Prakash</i>	01.10.2013
CHECKED BY	P.B.Rshikesan	ACE	<i>P/B</i>	1/10/13
	D.Ganesh	ACE	<i>D.Ganesh</i>	1/10/13
	M.R.S.Saxena	ACE	<i>M.R.S.</i>	1/10/13
REVIEWED BY	S.N.Kamath	CE	<i>S.N.Kamath</i>	01/10/13
	M.K.Sharma	CE	<i>M.K.Sharma</i>	01/10/13
APPROVED BY	U.C.Muktibodh	ED (Engg.)	<i>U.C.Muktibodh</i>	01/10/2013

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October, 2013	Original (Pages 26)	Ajit kumar Shit Braham Prakash	P.B.Rshikesan D.Ganesh M.R.S.Saxena	S.N.Kamath M.K.Sharma	U.C. Muktibodh

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1.0 SCOPE

This specification establishes the minimum requirements for low alloy steel rolled plates used in the construction of Heat Exchangers and welded pressure vessels of highest quality standards.


The plates are required to be made out of fine grained, fully killed and vacuum de gassed low alloy steel equivalent to German material designation 20MnMoNi55 grade with modified chemical composition .The manufacturing process adopted shall ensure cleanliness of the highest order, superior fracture toughness and weldability.

This specification is applicable for 700MWe projects beyond RAPP 7&8.

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3.0

APPLICABLE CODES AND STANDARDS

The following codes and standards of the issue in effect on the date of issuing the tender document shall form part of this specification. The bidder shall indicate issue no. and dates of applicable documents which forms the basis of his quotation.

In case of conflict between the codes/ standards listed below and this specification, generally this specification will govern. The supplier must obtain necessary clarification from the Purchaser in such cases else the interpretation of Purchaser will be final and binding.

- i) ASME Section II – Part A – Ferrous materials
- ii) ASME Section III – Division 1 – Sub section NB
- iii) ASME Section V – Non destructive examination
- iv) ASTM - Relevant standards

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4.0 **PROCESS OF MANUFACTURE**

4.1 **Melting**

The steel shall be made by basic electric process and shall be vacuum degassed to remove objectionable gases particularly Hydrogen. Vacuum system should be of sufficient capacity to affect a blank-off pressure which is sufficiently low for considerably long duration.

4.2 **Grain Size**


Grain size shall be measured as per ASTM-E-112 and shall be 6 or finer. This grain size and microstructure shall be determined on specimens obtained from simulated heat treated test coupons as indicated in enclosed Figures-3 to 6.

The micrographs for assessing the microstructure shall be made at a magnification allowing unambiguous assessment (as a rule x 200).

5.0 **CHEMICAL COMPOSITION**

The chemical composition for analysis shall be as follows:

Element	Weight Percentage
C	0.17 – 0.23
Mn	1.20 – 1.50
Si	0.15 – 0.30
MO	0.40 – 0.55 (1)
Ni	0.50 – 0.80
Cr	0.20 Max
Cu	0.12 Max (1)
V	0.02 Max.
Al (Total)	0.010 – 0.040
Sn	0.011 Max. (1)
As	0.015 Max.

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Sb	0.007 Max
P	0.010 Max. (1)
S	0.008 Max. (1)
N ₂ (Total)	0.013 (1)
H ₂	1 ppm Max.
O ₂	20 ppm Max.

The above chemical composition slightly differs from DIN 20 Mn No Ni 55 grade. Subject to the approval of the purchaser, minor deviations may be permitted provided all other requirements of the specifications are met. In the likelihood of the above limits being exceeded, the guaranteed maximum values shall be highlighted in the technical bid itself for purchaser's consideration.


Note : 1 – If these figures are exceeded at check analysis levels of upto P < 0.015%, S < 0.015%, Mo < 0.63%, Cu < 0.18%, Sn < 0.016% and N (Total) < 0.015%, the inspection agency shall determine until further notice whether heat affected zone simulation tests and, where applicable, tangential section examinations are required. The acceptance then will be dependent on the review of test results.

If intermediate annealing at 550°C is planned in the course of further processing, the permissibility of this annealing temperature shall be demonstrated in the course of the aforementioned tests/ examinations. Extent and implementation of testing shall be agreed upon with the purchaser.

Analysis is to be carried out as per ASTM-A20. Chemical analysis shall be submitted to purchaser for approval. The supplier shall submit ladle and product analysis. Specimens for product analysis shall be taken from simulated heat treated test coupons indicated in figures 3 to 6.

6.0 **HEAT TREATMENT**

- 6.1 All plates to specification 20 Mn Mo Ni 55 shall be supplied in quenched and tempered condition. The plates shall be heated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium ensuring uniform cooling. The tempering temperature shall be between 650 to 680°C. The

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measured highest temperature during stress relief heat treatment shall not be higher than the measured lowest temperature during tempering.
The uniformity of temperature during any of the heat treatment shall be proved by continuous temperature recording by calibrated temperature recording instruments with the help of adequate number of thermocouples attached to the plates.

6.2 Simulated Heat Treatment (SHT)

The simulated heat treatment (SHT) is intended to simulate the heating cycles which the actual component may experience during the course of fabrication. Such heat treatment is given to some of the test coupons called Simulated Heat Treated Test Coupons (STC). Heating and cooling rates shall be as indicated in figure below:

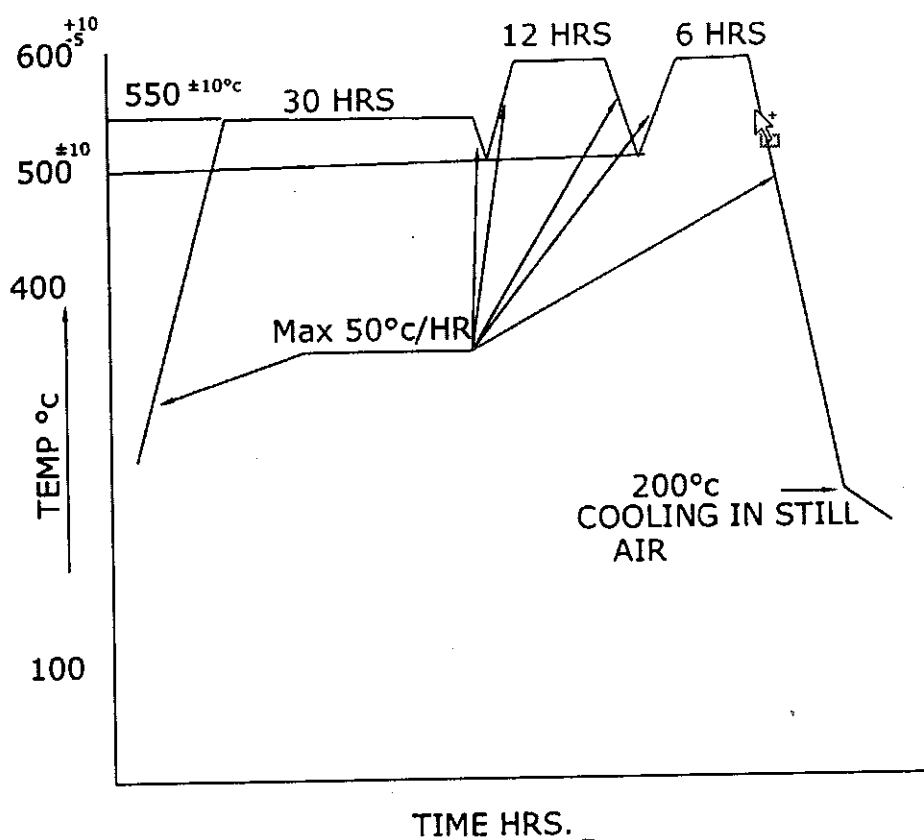



FIG.-1

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The specimens from the simulated heat treated coupons when tested, shall exhibit the mechanical test values to the requirements of para 7.0.

7.0 MECHANICAL PROPERTIES

- 7.1 The mechanical tests shall be conducted as per ASME SA-20 and ASME SA-370 (DIN 50115, DIN 50125 & DIN EN 10002-1). Following minimum requirements shall be met with both in quenched and tempered (RTC) and simulated heat treated condition (STC).

Minima pertaining to mechanical properties at room temperature and 350°C shall be as follows:

Test Temperature	Mechanical Properties	Unit	Thickness	
			< 125	125 – 300 mm
RT i.e. Room Temp. to be mentioned by Supplier	R _m (tr, n)	(N/mm ²)	570-670	560-660
	R _{PO.2} (tr, n)	(N/mm ²)	430	390
	A ₅ (tr, n)	(%)	18	18
	Z (tr, n)	(%)	45	45
350°C	R _m (tr, n)	(N/mm ²)	510	490
	R _{PO.2} (tr, n)	(N/mm ²)	363	343
	A ₅ (tr, n)	(%)	14	14
	Z (tr, n)	To be reported		

tr = Transverse i.e. perpendicular to direction of rolling (along width)

n = Normal i.e. in the direction of thickness

A₅ = % Elongation on 5d (in 50 mm minimum gauge length)

Z = % reduction in area

R_{PO.2} = Yield strength (0.2% offset)


R_m = Tensile strength

Maximum permissible difference of tensile strengths between head and foot is 60 N/mm² upto 10 M length and 70 N/mm², for greater than 10 M length but not more than 70 N/mm² between any two points.

7.2 Notch Toughness

7.2.1 Nil Ductility Transition Temperature (T-NDT)

The nil ductility transition temperature as determined by drop weight test in accordance with ASTM-E-208 shall not be higher than -15°C.

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In case, T-NDT has already been established for this type of material produced under similar conditions, complete details of the material production and test procedure and results will be reported which shall be subject to approval by the purchaser.

7.2.2 Reference Nil Ductility Transition Temperature R-TNDT

Three ISO-V transverse specimens will be tested at +18°C for certification of R-TNDT. The minimum absorbed energy and lateral expansion shall not be less than 68 J and 0.9 mm respectively for any of the specimens. The percent shear fracture shall be reported.

7.2.3 Transverse and through thickness ISO-V test specimens will exhibit the following minimum values at -15°C.

- i) Average of three (3) specimens 41 J.
- ii) Lowest single value 34 J.

7.2.4 CV – Impact Curve


Charpy V-notch impact strength Vs temperature curves shall be established. Tests shall be conducted at least at six different temperatures including -15°C and +18°C to fully define upper and lower energy shelves. The upper energy shelf shall have 100% shear fracture and lower energy shelf a maximum of 10% shear fracture. The test reports shall include absorbed energy, percent shear fracture and lateral expansion, plotted against temperature. The upper shelf energy shall be more than 100 J. The absorbed energy and lateral expansion values at +18°C and -15°C shall meet the requirements of 7.2.2 and 7.2.3.

7.3 Bend Test

Bend tests shall be carried out on specimens taken from STC coupons as shown in Table -1 and sketches 3 to 6. The outer surface of the bend specimen (tension side) shall be the as rolled surface of the plate. The specimens shall withstand being bent cold through 180° without cracking on the outside of the bend portion. The mandrel diameter shall be as per ASME SA-20.

7.4 Hardness Test

Hardness of each rolled plate shall be measured after tempering, along and perpendicular to the rolling direction and also over the thickness. Hardness shall

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be measured at every 200 mm along and perpendicular to the rolling direction and at every 75 mm across the thickness. However, minimum 3 hardness reading shall be taken in the thickness direction.

7.5 Sulfur Print Test

Sulfur print test shall be taken at the head and foot of the plate over the cross section in case the sulfur content exceeds 0.008% in both Heat & Check analysis. The length covered shall be at least 500 mm.

8.0 TEST COUPONS AND EXTENT OF TESTS

8.1 Categories of Test Coupons

Compliance of the material with the specification requirements shall be checked on various categories of test coupons described below:

- Raw Material Test Coupons (RTC) : Test coupons obtained from the quenched and tempered plates.
- Simulated Heat Treated Test Coupons (STC) : Test coupons obtained from the quenched and tempered plates and subjected to simulated heat treatment as described in Section 6.2.

8.2 Test Coupons Locations

Test coupons shall be taken from two opposite ends (Head and Foot) of each rolled plate at least 1't' away from nearest rolled edge, transverse to the rolling direction presuming that the main deformation direction lies in the head-foot direction.

In case the main deformation direction does not lie in the head-foot direction, longitudinal specimens are to be additionally tested.

Test coupons shall be removed after the final tempering of the plate.


Each test coupon shall be divided into two (STC and RTC).

Refer Figure-2 to 6 for locations of test coupons.

8.3 Test Specimen Locations

The test coupons shall be taken in such a way that the specimens shall have their longitudinal axis at least $\frac{1}{4}$ 't' from a rolled surface and with the mid length of the specimen at least 't' from any heat treated edge.

In the case of foot test coupons, additional test coupons shall be taken from just below the rolled surface and mid thickness ($\frac{1}{2}$ t). Bend test specimens from

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head and foot test coupons shall be taken such that the bend test specimen retains the top or bottom rolled surface.

8.4 Specimen Direction

The mechanical properties are to be established along the following three mutually perpendicular directions:

- i) Longitudinal - Parallel to the rolling direction
- ii) Transverse - Transverse to the rolling direction
- iii) Normal - Through thickness direction

8.5 Chemical Analysis

Chemical Analysis shall be carried out in accordance with ASTM E-30 and ASTM E-350. For product analysis, samples from each STC shall be analyzed.

8.6 Mechanical Tests

The extent of tests required is included in the enclosed table 1.

9.0 NON DESTRUCTIVE EXAMINATION

9.1 Magnetic Particle Examination

Each plate after final machining shall be examined by magnetic particle method on both surfaces and on all edges in accordance with ASME Section III, Para NB-2545. The acceptance standard shall be as per para NB-2545.3. The materials shall be demagnetised after the test.

9.2 Ultrasonic Examination

All the plates shall be ultrasonically tested by straight beam method in accordance with SA-578, "Specification for straight beam Ultrasonic Examination of plain and clad steel plates for special application".

The test shall be carried out after final tempering.

9.2.1 Extent of Examination

Scanning shall be continuous over 100% volume of plate.

9.2.2 Examination Technique

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9.2.2.1 Probes

Examination shall be carried out by using straight beam probes of frequency 2 to 4 MHz.

In case, other types of probes or different frequencies are employed, prior approval of purchaser will be required. The probe size shall be 25 mm to 28 mm in diameter or 25 mm square.

9.2.2.2 Calibration

The examination equipment shall be calibrated on a flawless section of the plate. At least the second back echo shall reach full CRT screen height.

9.2.2.3 Flaw Size Determination

The size of flaws longer than probe diameter shall be determined by half-value method.

In case of flaws smaller than probe diameter DGS method shall be employed.

9.2.2.4 Recording of Indications

Flaw indications greater than or equal to that from 6 mm dia flat bottom hole reference standard shall be recorded.

9.2.3 Acceptance Standards


9.2.3.1 The maximum permissible flaw size shall not be more than 100 mm². However, the maximum permissible length and number of flaw indications shall be restricted to the following, depending upon the plate thickness.

	<u>Max. Permissible length</u>	<u>Max. Permissible frequency</u>
t < 10 mm	10 mm	2 per m ²
t = 10 to 20 mm	20 mm	"
t = 20 to 40 mm	25 mm	"
t = 40 to 60 mm	30 mm	"
t = 60 to 120 mm	40 mm	"
t = 120 to 250 mm	40 mm	4 per m ²
t > 250 mm	40 mm	6 per m ²

Where t = Plate thickness as specified in tender document.

9.3 Angle Beam Ultrasonic Examination

All plates shall be examined by Angle Beam Ultrasonic Examination as per SA-577 "Standard

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Specification for Ultrasonic Examination of Steel Plates” and as supplemented by NB-2532.2 of ASME section III NB. The examination shall cover 100% volume of each plate. The acceptance shall be as per NB-2532.2.

9.4 Dimensional Check

Each plate shall be checked for length, width and thickness after the final tempering. The thickness shall be measured on grid lines of 300 mm x 300 mm. The actual dimensions shall be recorded. Measurement method shall be specified. The tolerances shall be as per ASTM A-20 unless otherwise specified.

10.0 REPAIRS


Repair is generally not permitted. Minor surface defects (< 2 mm depth) may be smoothly ground and blended without impairing the minimum wall thickness. No other repairs shall be carried out without prior approval of the purchaser or his authorized inspection agency.

Plans for all repairs requiring heat treatment shall be submitted to the Purchaser or his authorized inspection agency for review and approval, prior to taking up the job. Repairs involving welding are prohibited. All non-conformities shall be recorded and reported to the Purchaser to determine their disposal.

11.0 PROCEDURES, PLANS, REPORTS AND DOCUMENTATION

The following procedures and plans shall be submitted for purchaser's approval in six copies each before start of manufacture.

- Manufacturing plan indicating the sequence of operations, testing, and 'witness' and 'hold' points. 'Witness' point signifies that the manufacturer will intimate date of actual performance of that activity to the Purchaser sufficiently in advance so that Purchaser can witness the performance of the activity. However, in case Purchaser is not present, the manufacturer can proceed with the job. Hold point is similar to witness except that in case of Hold Point the manufacturer cannot proceed with the activity unless Purchaser is present or has given written waiver to proceed without his presence.
- Heat treatment plan.

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- c) Material testing and sampling plan with sketches showing various specimens.
- d) Non-destructive examination procedures
- e) Quality assurance plan

12.0 **QUALITY SURVEILLANCE**


The plates shall be subjected to quality surveillance by the Purchaser or his authorized agency during manufacture.

A schedule for sampling and testing shall be submitted to the Purchaser for review and approval. The test specimens shall be taken only after they are identified and stamped by Purchaser or his authorized inspection agency.

The Purchaser or his authorized inspection agency will witness the tests at various stages as indicated below. These stages shall be clearly identified in the manufacturing plan to be submitted by the supplier.

A minimum of 15 days notice shall be given by the supplier before each stage of testing/ examination and identified as witness or hold points in MSP or QAP. These may include the following:

- a) Heat treatment
- b) Identification of test coupons
- c) Simulated heat treatment on STC coupons
- d) Transfer of stamping on specimens
- e) Mechanical tests on specimens from STC and RTC.
- f) Hardness test
- g) Sulfur print test
- h) Magnetic particle examination
- i) Ultrasonic examination
- j) Dimensional check
- k) Final marking and stamping of plates

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- l) Documentation review and stamping

The plates shall be shipped only after issue of shipping release by the Purchaser/ his authorized agency.

13.0 **MARKING AND IDENTIFICATION**

13.1 **Identification**

The following shall be stamped on each plate at approximately 600 mm from head and foot


- Direction of rolling – Head and Foot
- Heat number / Melt number
- Plate number
- Specification
- Supply condition
- Manufacturer's name
- Inspection authority / purchaser seal

Stamping shall be done using round-nosed steel die stamps. The identification shall be encircled by using halogen and sulfur free paints for easy location. Test coupons shall also bear the above identifications.

13.2 **Marking**

The following shall be legally marked using halogen and sulfur free paint on each plate before dispatch.

- Purchaser order number
- Material specification and grade
- Size
- Destination
- Supply condition

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14.0 **REPORTS**

The following reports shall be submitted to the purchaser in ten copies (10) each. The reports shall be submitted in bound volume.

- a) Chemical analysis – ladle and product.
- b) Mechanical test report.
- c) CV impact curve.
- d) Non-destructive examination report.
- e) Heat treatment charts.
- f) Visual and dimensional inspection report.
- g) Sulfur prints.
- h) Hardness survey report.

Four copies of above reports shall be sent to the purchaser immediately on completion of tests/ inspection, prior to shipment of material. One set each shall be dispatched along with material for each unit. Final documentation containing all the above shall also be submitted in soft form (pdf format) with proper indexing.

15.0 **PACKING AND SHIPMENT**

Before shipment, suitable easily removable rust preventive coating shall be applied on the plates to ensure sea-worthiness and tropical storage for two years. The plates shall be suitably crated to prevent the surfaces of the plates coming in contact with any foreign objects. If the plates are stacked together they shall be separated by hard bound or craft paper to prevent surface to surface contact. Material of each unit requirement will be packed separately.

The supplier shall submit the preservation and packing plan (including no. of boxes and identification tags) for Purchaser's approval.



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TABLE - 1

EXTENT OF TESTS

S. No.	Description	Direction	Head		Foot		Remarks
			STC	RTC	STC	RTC	
1	Tensile at RT (See Note : 1)	tr	1	1	1*	1	* For plate thk. > 70 mm, the no. of coupons shall be 3
		n	1	3	1	3	
2	Tensile at 350° C (See Note : 1)	tr	1	-	1*	-	-do-
		n	1	-	1	-	
3	Impact at -15°C	n	3	-	3	-	
4.	Impact curve (-15°C, 18°C & 4 other temperatures)	tr	6 x 3 at ¼ t	-	6 x 3 at ¼ t 6 x 3 at ½ t 6 x 3 at ¾ t		-
5	Drop weight test	tr	2	-	2	-	Specimen P-2
6	Bend test	tr	2	-	2	-	
7	Grain size and micro-examination		2 (1 feritic grain + 1 austenitic grain)		6 (3 feritic grain + 3 austenitic grain)		Micro examination to be carried out both on longitudinal and transverse directions of each specimen from STC Coupons. (See Fig. 3 to 6)
8	Product analysis		1		3(1 each at ¼ t, ½ t and ¾ t)		From STC Coupons. (See Fig. 3 to 6)
9	Hardness and sulfur print tests						As specified in text
10	U.T. and M.P.I.						-do-

Note : 1. For plates 19 mm and under, test specimens shall be full thickness of plate

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ANNEXURE – 1 : LOW ALLOY STEEL PLATES – 16 Mo 3

1.0 SCOPE

This Annexure covers the technical requirements for the supply of low alloy steel plates conforming to DIN EN 10028-2 (latest edition) - Material no. 1.5415 or its equivalent.

The general requirements of delivery as per ASME SA-20 shall also apply. In case of conflicting requirements, more stringent requirements shall govern.

2.0 STEEL MELTING

The steel shall be fully killed and of fine grain. It shall be melted in an electric furnace and vacuum degassed.

3.0 HEAT TREATMENT

The plates shall be supplied in the normalized condition.

4.0 CHEMICAL COMPOSITION

Both ladle and product analysis shall be performed and the composition shall conform to that specified in DIN EN 10028-2 (latest edition) for Material no. 1.5415 with the exception that N₂ content shall not exceed 0.009%.

Both ladle and product analysis shall be recorded and reported to the Purchaser.


5.0 MECHANICAL TESTS

The test specimens for mechanical tests shall be taken transverse to the rolling direction. The test results shall meet the requirements of DIN EN 10028-2 (latest edition) for Material no. 1.5415 in totality.

5.1 Tests shall be carried out to check yield point at elevated temperature (350°C) for each plate.

5.2 Notched bar impact test at 20°C on ISO-V samples according to DIN 50115 shall be carried out for each plate.

5.3 Bend test shall be performed in accordance with ASME SA-20. The specimen shall be bent cold through 180° without cracking on the outside of the bent portion.

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ANNEXURE – 1 : LOW ALLOY STEEL PLATES – 16 Mo 3 – CONTD...

- 5.4 In addition to the transverse tensile tests, plates of thickness 70 mm and above shall also be subjected to “through thickness” tensile tests at room temperature. Three tensile specimens each shall be tested from the middle width at the top and bottom end of each rolled plate after the final heat treatment. The through thickness tensile properties shall also meet the minimum specified values for the plate material.

6.0 **NON DESTRUCTIVE EXAMINATION**

Magnetic particle examination and ultrasonic examination shall be carried out on each plate as per Clauses 9.1 and 9.2 of PC-M-964.

7.0 **DIMENSIONAL CHECK**

Thickness shall be measured on each plate by ultrasonic means. Length and width of each plate shall also be measured.

8.0 **REPAIRS**

No repairs are generally permitted. However, minor surface defects (< 2 mm depth) can be removed by means of grinding provided the minimum thickness requirements are met.

9.0 **PROCEDURE, PLANS AND DOCUMENTATION**

Refer Para 11 of PC-M-964.

10.0 **QUALITY SURVEILLANCE**

As per Clause Nos. 12 of PC-M-964.

11.0 **MARKING AND IDENTIFICATION**


As per Clause Nos. 13.0 of PC-M-964.

12.0 **REPORTS**

Refer Para 14 of PC-M-964.

13.0 **PACKING AND SHIPMENT**

Refer Para 15 of PC-M-964

 ननपीसीआईएल NPCIL	NUCLEAR POWER CORPORATION OF INDIA LTD	
	ATOMIC POWER PROJECT	Page No. : 18 of 22
	<u>TECHNICAL SPECIFICATION FOR</u> <u>QUENCHED & TEMPERED</u> <u>LOW ALLOY STEEL PLATES</u>	Rev. No. : 0

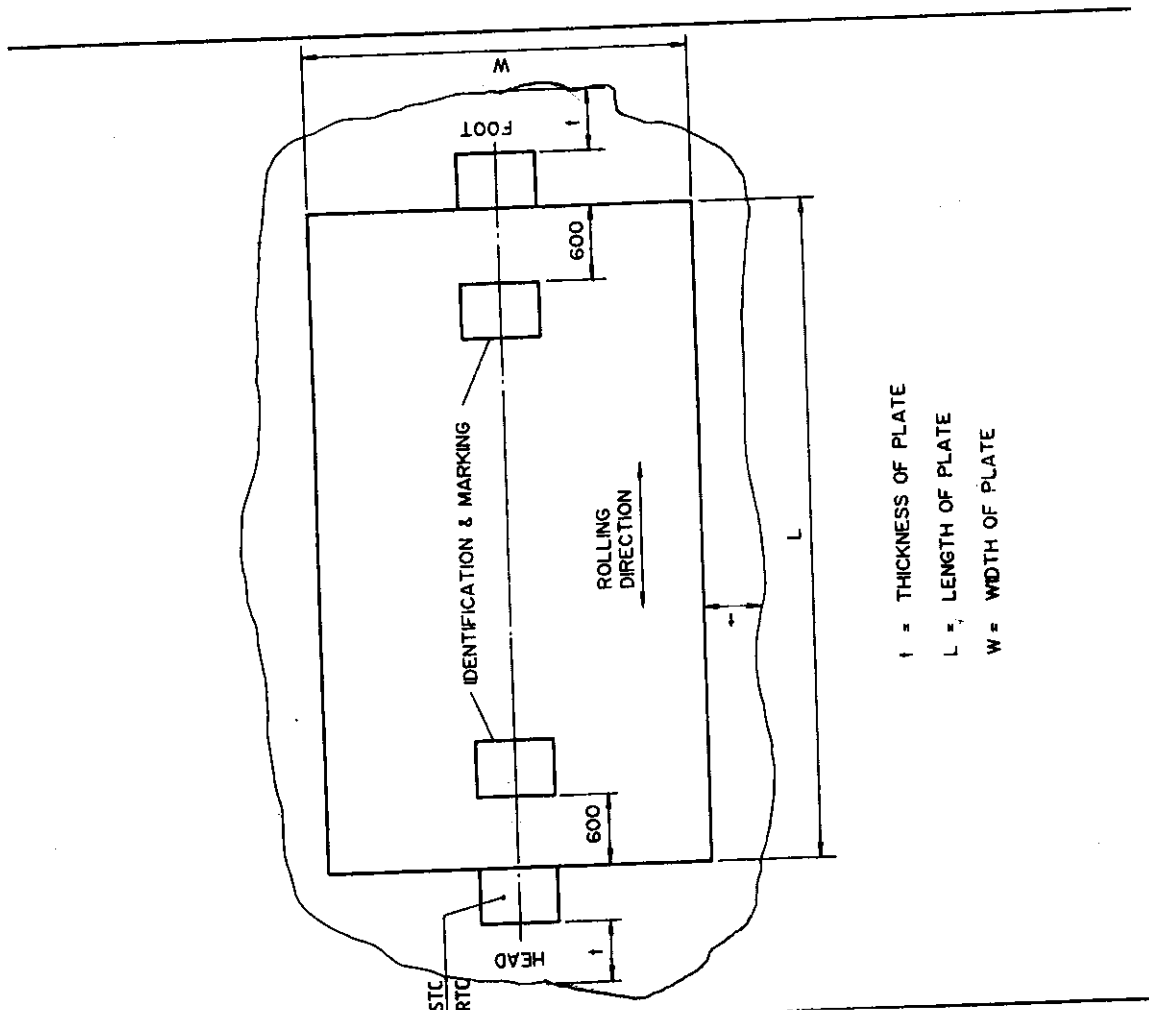


FIGURE - 2

**TECHNICAL SPECIFICATION FOR
QUENCHED & TEMPERED
LOW ALLOY STEEL PLATES**

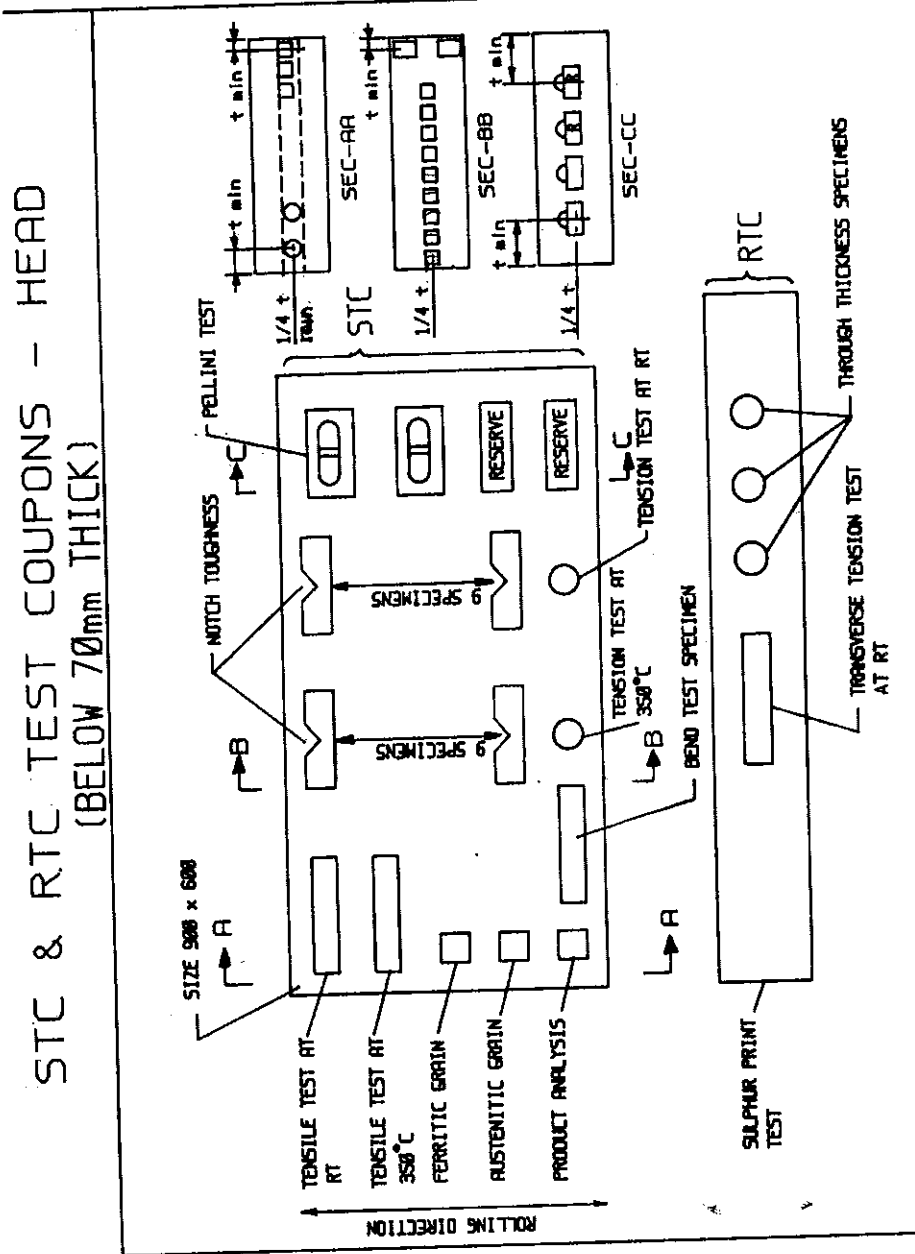


FIGURE - 3

**TECHNICAL SPECIFICATION FOR
QUENCHED & TEMPERED
LOW ALLOY STEEL PLATES**

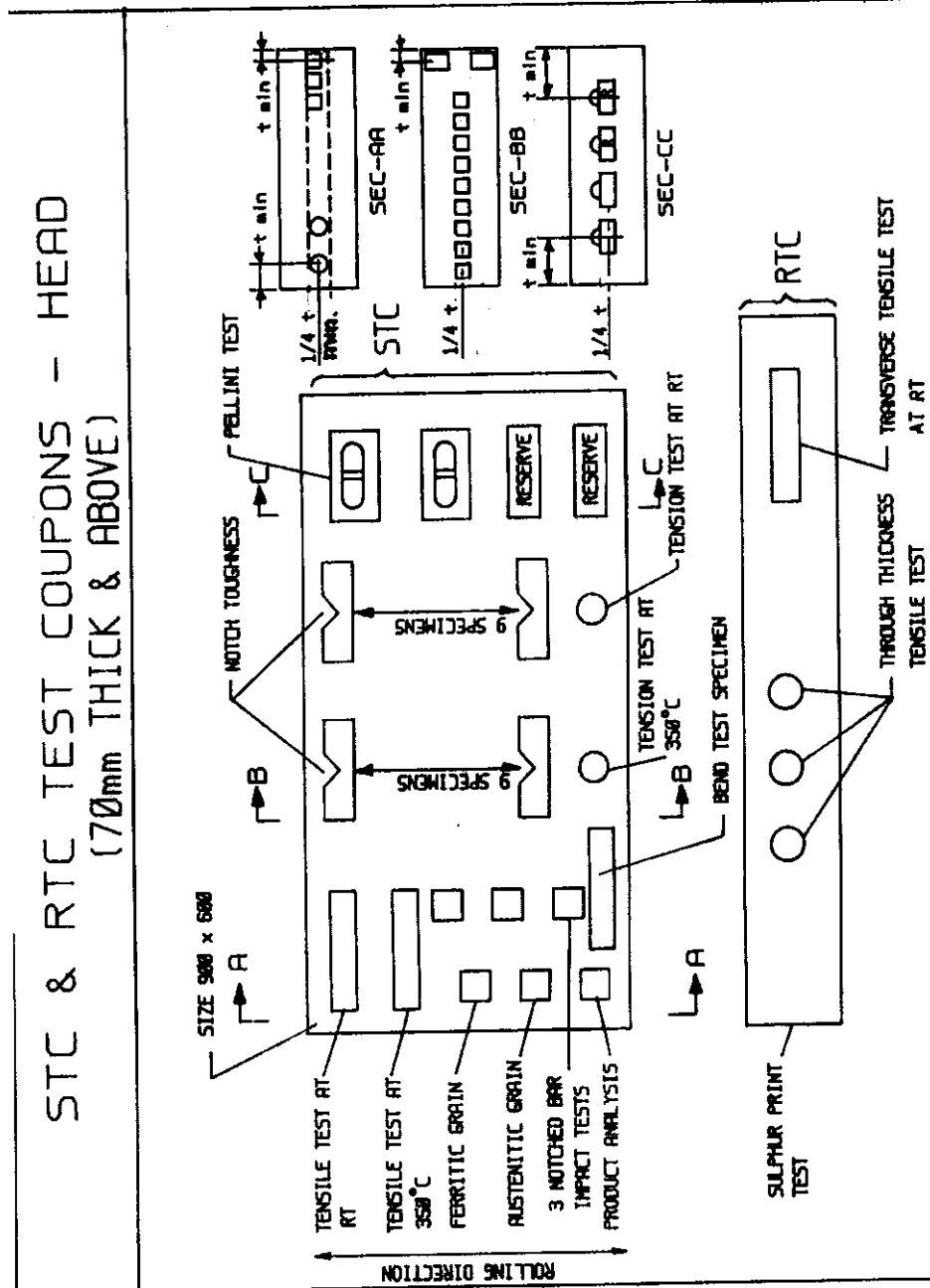


FIGURE - 4

**TECHNICAL SPECIFICATION FOR
 QUENCHED & TEMPERED
 LOW ALLOY STEEL PLATES**

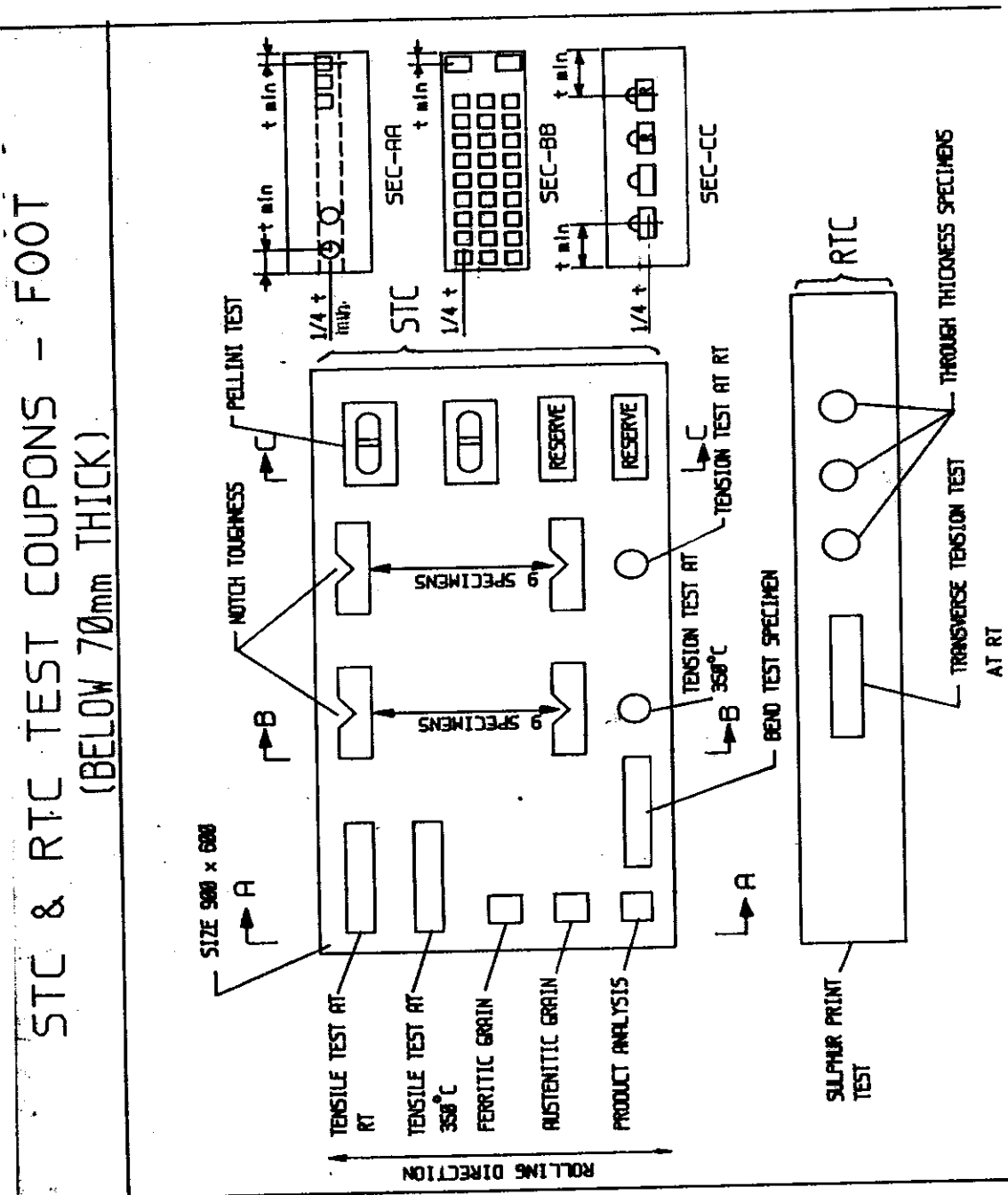


FIGURE - 5

**TECHNICAL SPECIFICATION FOR
QUENCHED & TEMPERED
LOW ALLOY STEEL PLATES**

**STC & RTC TEST COUPONS - FOOT
(70mm THICK & ABOVE)**

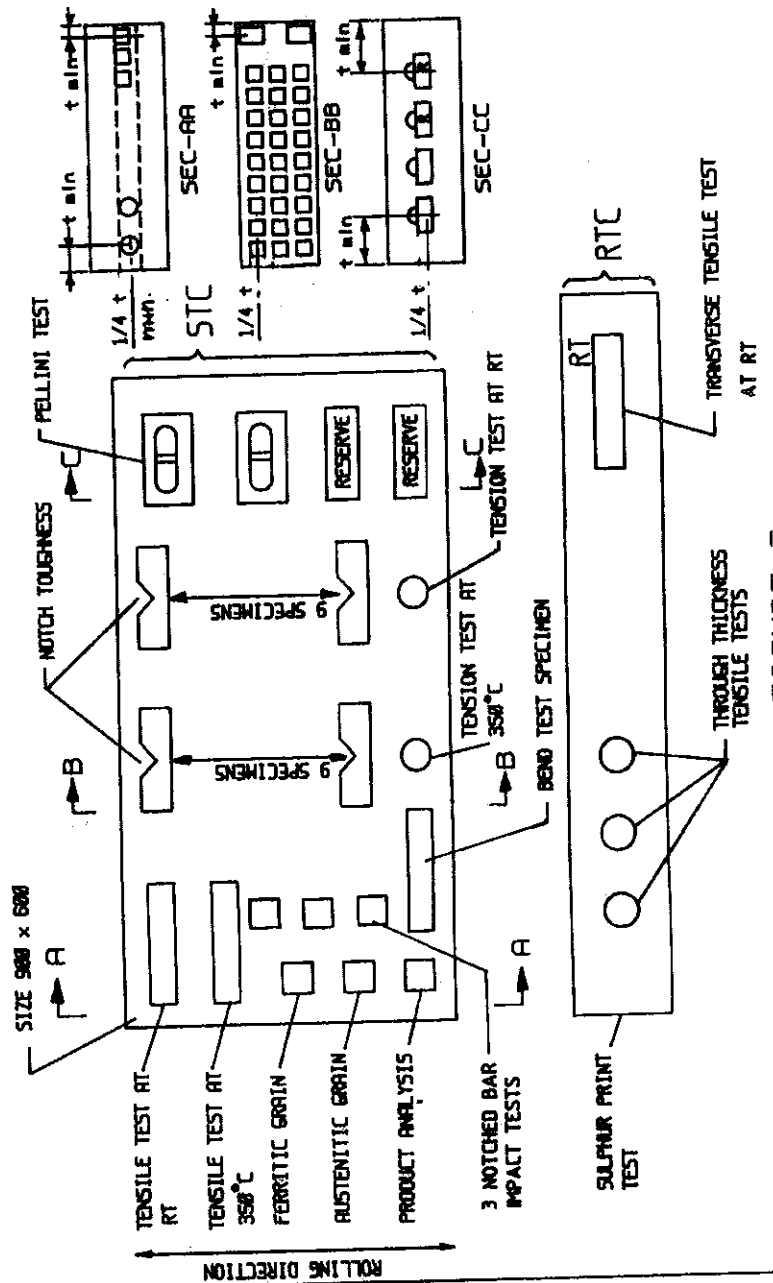


FIGURE - 6