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RAKSHA MANTRALAYA
MINISTRY OF DEFENCE
DEPARTMENTAL SPECIFICATION

MATERIAL SPECIFICATION FOR THE ROLLED

AND HEAT TREATED JACKAL PLATES

AND BULLET PROOF PHANTUM STEEL PLATES

ISSUED BY :

CONTROLLERATE OF QUALITY ASSURANCE (METALS)
MINISTRY OF DEFENCE (DGQA)
GOVERNMENT OF INDIA
P.O. ICHAPUR-NAWABGANJ
DIST. 24 PARGANAS (WEST BENGAL)
PIN 743 144

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RECORD OF AMENDMENTS

Amendment No.	Sub-heading to which amendment pertains	Authority	Incorporated by "Name and Rank" in block capitals	Initials
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DEPARTMENTAL SPECIFICATION

FOREWORD

This specification has been prepared by Controllerate of Quality Assurance (Metals), Ichapur, in consultation with Defence Metallurgical Research Laboratory, Hyderabad, on the authority of Ministry of Defence u.o.No. 1(18)/81/DP(plg.III) dated 28 Nov.'83.

This specification is approved by the Controller of Quality Assurance(Met), Ministry of Defence, Ichapur, and is mandatory for use in Defence Services. The information contained in this specification is not to be communicated either directly or indirectly to press or any person not authorised to receive it.

This specification should be used to guide design, manufacture, inspection and procurement of the Jackal Plates.

Enquiries regarding this specification in relation to any contractual conditions should be addressed to the Controller, Controllerate of Quality Assurance(Metals), Ministry of Defence(DGQA), Government of India, P.O. Ichapur, Nawabganj, District-24 Parganas(North), PIN 743-144, West-Bengal.

Copies of the specification can be obtained from :-

The Controller
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SPECIFICATION FOR ROLLED AND HEAT TREATED JACKAL PLATES

SCOPE

a) This specification defines the requirements for the supply and inspection of rolled steel plates, named hereinafter JACKAL PLATES, to be used in normalised or hardened and tempered condition for the manufacture of armour components. This specification will cover manufacture and supply of steel plates for thicknesses from 4.0mm to 80.0mm.

b) This specification is arranged in Sections as follows :-

Section 1	.....	Inspection
Section 2	.....	Composition
Section 3	.....	Manufacture
Section 4	.....	Treatment
Section 5	.....	Analysis and Testing
Section 6	.....	Firing Trial
Section 7	.....	Quality Assurance Documentation
Section 8	.....	Jackal Plates for B.P.Application

c) Metric units are used throughout the specification and where quoted are to be regarded as standard.

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RELATED SPECIFICATIONS

2.1 Reference is made in this specification to :-

- IS-228 - Method of Chemical analysis of metals
- IS-1499 - Method for Charpy Impact Test (U-Notch) for metals
- IS-1500 - Method of Brinnel hardness for steels
- IS-1608 / - Method for Tensile testing of steel products
- IS-4163 / - Method for determination of inclusion content in steel by microscopic method
- IS-4748 - Method for determination of average grain size of metals
- ASTM-E-381 - Standard method for rating of macro etched steel
- ASTM A604 - Method for macro etch testing of consumable electrode vacuum arc remelting steel bars & billets
- ASTM E 975 - Practice for X-Ray determination of retained austenite in steel with near random crystallographic orientation
- & - 84 (1989)
- CIM 48 - Procedure for carrying out ballistic test for homogenous Jackal armour steel plates 4mm to 22mm nominal thickness

2.2 Reference in this specification to an Indian Standard (undated) means in any tender or contract, the edition current at the date of such tender or contract.

SECTION ONE - INSPECTION

3.0 GENERAL

3.1 The steel/plate maker is to inform the Quality Assurance Authority when he is in a position to start work and is to inform him of all subcontracts in connection with this contract as soon as they are placed in order that arrangements may be made for tests and inspection

4.0 INSPECTION

4.1 The steel may be inspected at any time during manufacture and is subjected to the approval of and acceptance by the Quality Assurance Authority. The steel/plate maker, when he is about to commence manufacture, is to give sufficient notice for arrangements to be made for the attendance of the representative of the Quality Assurance Authority.

5.0 TESTING

5.1 Casts are to be certified as complying with the specified composition as per section 2 by the Quality Assurance Authority on the results of analysis. When technical tests are called for, these are to be witnessed by the representative of the Quality Assurance Authority carried out by him as he may decide.

5.2 The test samples are to be selected and the tests carried out as specified in Section 2, 3 and 5.

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SECTION TWO - COMPOSITION

6.0 COMPOSITION

6.1 The composition of the steel (Ladle analysis) shall be as per Table No.1 when analysed in accordance with IS - 228.

Table - 1

Carbon	0.28 - 0.33	percent
Silicon	0.55 - 0.75	percent
Manganese	0.75 - 1.00	percent
Chromium	0.75 - 1.00	percent
Molybdenum	0.25 - 0.35	percent
Sulphur	0.015	percent maximum
Phosphorus	0.015	percent maximum
Zirconium	0.10 - 0.20	percent
Cerium	0.03 - 0.06	percent
Hydrogen	2 ppm	maximum
Nitrogen	60 ppm	maximum

Note : For Zirconium and Cerium elements, method of estimation shall be got approved from the Quality Assurance Authority.

6.2 On product analysis the steel shall conform to the above limits with the variations being allowed as per Table No - 2.

Table - 2

Elements	Permissible deviation
Carbon	+ 0.02/-0.00
Manganese	± 0.04
Silicon	± 0.03
Chromium	± 0.03
Molybdenum	± 0.02
Phosphorous	+ 0.003
Sulphur	+ 0.003

7.0 ADDITIONAL ELEMENTS

7.1 The steelmaker is not to introduce deliberately into steel any element not permitted without the agreement of Quality Assurance Authority and is to take all reasonable precautions to prevent such elements from being introduced from scrap or other materials.

8.0 SPECIFIED ANALYSIS

8.1 The specified ranges of chemical composition are based on certified ladle analysis and the steel maker is to supply a certificate of analysis of the steel for the specified elements.

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SECTION THREE - MANUFACTURE

9.0 GENERAL

9.1 The steel is to be killed and free from harmful defects such as seams, flaws, piping, cracks and surface defects. Vacuum degassing followed by annealing of slab ingots will be carried out at the option of the steel maker though, if called for in enquiry, contract or order, details of the process are to be agreed between the steelmaker and the purchaser.

9.2 The steel is to be manufactured by:

9.2.1 The open hearth, Electric Arc Furnace, oxygen Process or ESR Process.

9.2.2 Any other process acceptable by the Quality Assurance Authority for which prior approval from the Quality Assurance Authority is necessary.

9.3 Ingots are to be kept vertical position until completely solidified. The size, shape and method of production of the ingots are to be so selected as to minimise segregation and axial unsoundness.

9.4 Ingots are to be cast wide-end up unless other methods are approved by the Quality Assurance Authority. The method of casting to be used is to be declared by the steelmaker.

10.0 DISCARD

10.1 15% top below hot top and 10% bottom discards are to be given to ensure cleanliness and freedom from harmful defects like segregation, flakes, gassy flute, cracks, ring pattern, piping etc. This will be checked at billet stage by macro etching as per ASTM-E-381 to the satisfaction of the Quality Assurance Officer.

10.1.1 In addition if required by the purchaser degree of severity of defects like freckles, white spot, radial mark, segregation and ring patterns shall be determined by macro etching as per ASTM-A-604 and shall not be more than 'A' for ESR and 'C' for VAR steel.

11.0 DESEAMING AND REMOVAL OF SURFACE DEFECTS

11.1 All harmful defects on billets/blooms/slabs are to be removed to the satisfaction of the Quality Assurance Authority.

12.0 ROLLING OF PLATE

12.1 The rolling schedule of ingots/blooms/billets/slabs/plates should be got approved by the Quality Assurance Authority prior to commencement of bulk production.

12.2 All harmful surface defects are to be removed from the slabs/plates prior to rolling to final size.

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13.0 ANNEALING OF PLATES

13.1 After rolling has been carried out all plates shall be annealed as per clause 18.1. Necessary care should be taken to ensure that the plates are not heavily decarburised. The total complete plus partial decarburisation on both sides shall not be more than 8% of nominal thickness of plates. Hardness of the plates to be supplied in annealed condition shall be 220 HB maximum.

14.0 SURFACE DEFECTS

14.1 Annealed plates shall be abrasive blasted or adequately cleaned and inspected for surface condition. The surface shall be free from cracks, laminations, blisters, rolled scale and other harmful defects. Scales, pittings and other surface imperfections may be removed by grinding to the satisfaction of Quality Assurance Officer provided the thickness is not reduced below the specified thickness limits and ground area is well faired into the surrounding material. Inspection of plates shall be enforced to check the surface defects of finished plates on 100% basis. However, neither pickling nor grinding should be carried out after hardening and tempering.

15.0 DIMENSION AND TOLERANCES

15.1 The plates shall be rolled such that the heat treated and trimmed plates meet the dimensional requirements as per contract.

15.1.1 Tolerances : Unless otherwise specified in the drawings, the tolerances of the plates shall be as Table-3 appended below.

Table - 3

Thickness of Plates	Tolerance
i) 4mm and upto and including 6mm nominal thickness	: +0.70mm/ - 0.00 mm
ii) Over 6mm and upto and including 10mm nominal thickness	: +1.20mm/ - 0.00 mm
iii) Over 10mm and upto and including 20mm nominal thickness	: +1.30mm/ - 0.00 mm
iv) Over 20mm and upto and including 22mm nominal thickness	: +1.75mm/ - 0.25 mm
v) For a nominal thickness of 25mm	: + 1.30mm/- 0.60 mm
vi) For a nominal thickness of 30mm	: + 1.50 mm/-0.80 mm
vii) For a nominal thickness of 40mm	: + 2.00 mm/-1.00 mm
viii) For a nominal thickness of 80mm	: + 4.00 mm/-2.00 mm

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	<u>Width Tolerance</u>		<u>Tolerance</u>
i)	4mm to 6mm	+ 10/-00
ii)	8mm to 15mm	+ 50/-00
iii)	16mm to 80mm	+ 50/-00
<u>Length Tolerance</u>			
i)	4mm to 6mm	.....	+ 15/-00
ii)	8mm to 80mm	.....	+ 75/-00

15.1.2 The plates of 4mm to 10mm thickness shall be sheared or flame cut. Plates 11mm thick and above may be flame cut to size. When the plates are flame cut, the hard edge formed during the process must be softened or removed by an approved method, (a) if the edge is subsequently to be machined, or (b) if softening is required by the drawings.

15.2.0 Flatness

Plates must conform to the flatness tolerances specified on drawing. A code of standard flatness tolerance for use in the drawings is given in Table-4 below:-

Table-4

<u>Code letter</u>	<u>Tolerance</u>	<u>Code letter</u>	<u>Tolerance</u>
'A'	0.80 mm	'D'	4.75 mm
'B'	1.60 mm	'E'	6.35 mm
'C'	3.20 mm		

15.2.1 The flatness of the plates must be such that when laid down on the surface table, the space between the plate and the table must in no way exceed the specified tolerance over a length not exceeding 1820 mm in any direction.

15.2.2 Where flatness tolerances are not stated in drawing, plates shall conform to Code 'D'. Any questions relating to flatness are to be referred to the Quality Assurance Authority.

6.0 IDENTIFICATION

6.1 All accepted plates are to be identified with the Quality Assurance Officer's stamp and such other markings as will enable the following details to be established :-

- (a) Specification
- (b) Manufacturer
- (c) Cast Number
- (d) Heat Treated Batch

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SECTION FOUR - TREATMENT

17.0 HEAT TREATMENT

17.1 The following heat treatment cycle is given a guideline to achieve the desired properties after heat treatment.

18.0 ANNEALING CYCLE

18.1 Heated upto 710/720 degree C at the rate of 25-30 degree C per hour, soaked for 16 hours and cooled inside the furnace.

19.0 HARDENING AND TEMPERING

19.1 HARDENING

- (a) Charge the plate at 900 degree C ± 10 degree C
- (b) Attain the temperature of 900 degree C
- (c) Soak for a period of 1.0 min/mm (minimum 20 min)
- (d) Oil quenching :
 - i) From the furnace to quenching time allowed is 10 secs.
 - ii) Holding time in oil tank 2 min/mm (stirring the oil-temperature not to exceed 60 degree C).

19.2 TEMPERING CYCLE FOR 4mm - 14mm THICKNESS PLATES

Tempering should be done immediately after hardening. Expected hardness : 470 - 530 HB.

- (a) Charge the plates at 250 degree C ± 10 degree C
- (b) Attain the temperature of 250 degree C
- (c) Holding time
 - i) For 4 - 6mm thickness: 60 min. on line tempering followed by air cooling.
 - ii) For 7 - 10mm thickness: 60 min. on line tempering followed by Stress Relieving for 150 min. and air cooling.
 - iii) For 11- 14mm thickness: 60 min. on line tempering followed by Stress Relieving for 210 min. and air cooling.

19.3 TEMPERING CYCLE FOR 15mm - 22mm THICKNESS PLATES

Tempering should be done immediately after hardening operation.

- (a) Tempering temperature 500 degree C (to be charged at 500 degree C)
- (b) Holding time - 4 min/mm thickness
- (c) Air cooling

NOTE : QUALITY ASSURANCE AGENCY TO MONITOR THE ABOVE IN ORDER TO ENSURE THAT HEAT TREATMENT CYCLE HAS BEEN STRICTLY FOLLOWED.

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19.3.1 HEAT TREATMENT OF ARMOUR PLATES/COMPONENTS THAT ARE NOT SUBJECTED TO BALLISTIC TESTS:

Armour components manufactured from different thickness Jackal plates for Article 675 and not subjected to ballistic test shall have the following hardness and heat treatment schedules.

Hardness (BHN)	Hardening* and Tempering cycle	Thickness of plates
285-340	Temp.range 470 to 630 degree C	2.5mm to 80mm
200-270	" " 640 to 680 degree C	2.5mm to 30mm
230-285	" " 630 to 670 degree C	2.5mm to 14mm

i) * Hardening Temperature: 900 degree C for all thickness plates. Soaking time 1 minute per mm for plates upto 14mm and 30 sec per mm for plates of 15mm & above thickness.

ii) Tempering cycle for all thickness plates will be 4 min/mm

SECTION FIVE - ANALYSIS AND TESTING

20.0 GENERAL

20.1 The manufacturer will supply the ladle analysis/cast analysis to the Quality Assurance Officer. Plates are to be submitted for inspection/testing in the following manner : -

- (a) Chemical Analysis
- (b) Ultrasonic Test - 100% surface scanning before heat treatment
- (c) Tensile Test)
- (d) Impact Test) Castwise after final heat treatment
- (e) Inclusion Rating) for continuous process and batchwise
- (f) Grain Size) for non - continuous process
- (g) Retained Austenite Content)
- (h) Hardness Test - 100% after final heat treatment
- (i) Decarburisation Test -
 - i) 100% for plates upto 6mm thickness
 - ii) One sample from a batch of 15 to 20 heat treated plates having acceptable hardness for each thickness beyond 6mm
 - iii) The total complete plus partial decarburisation on both sides shall not be more than 8% of nominal thickness of plates.

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1.0 CHECK ANALYSIS

1.1 One sample plate may be cut from each cast and subjected to chemical analysis. Chemical analysis of the sample shall conform to the chemical composition as per clause 6.1.

2.0 MECHANICAL TESTS

2.1 Brinell hardness test in accordance with IS 1500 shall be carried out on all plates after heat treatment. The number of measurements to be made on each plate shall be agreed upon by the contractor and the Quality Assurance Authority. The hardness results should comply with the requirements given in Table-6. Variation of hardness in each plate should be restricted to 20 points.

2.1.1 Tensile tests are to be conducted in accordance with IS-1608 and the test results should meet the requirements given in Table - 6

3.0 CHARPY IMPACT TEST

3.1 Charpy Impact Test (U-Notch) is to be carried out in accordance with IS 1499 and the result should comply with the requirement given in Table - 6.

Note: Mechanical test samples shall be cut from the two diagonally opposite corners of two fully heat treated plates per batch. One tensile and three impact test pieces shall be cut from a position midway between the centre plane and the surface.

or

Method of selection of test piece may be mutually agreed between the manufacturer and the Quality Assurance Officer.

4.0 ULTRASONIC EXAMINATION

4.1 Each plate shall be subjected to ultrasonic examination for internal defects before final heat treatment. Condition of testing and acceptance criterion shall be agreed between the Quality Assurance Authority and the supplier.

5.0 TEST FOR CLEANLINESS

5.1 Inclusion Rating : Determination of Inclusion Rating shall be done in accordance with Specification IS : 4163 and should meet the requirements as given in Table - 5

Table-5

Inclusion Type	Rating
Sulphide Type (A)	1 - 2 T
Alumina Type (B)	1 - 2 T
Silicate Type (C)	2 T
Globular oxide Type (D)	2 T
Nitride Type	2 T

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STRUCTURE

Structure: Microstructure of fully heat treated plates will be tempered martensitic structure with prominent accicularity. The plates tempered at lower temperatures and with comparative lesser accicularity for the plates tempered at higher temperature.

Retained Austenite: For plates having thickness upto 14mm, the volume fraction of retained Austenite should be estimated in accordance with ASTM E975-84 (1989) for two plates from each batch after tempering and it should not exceed 2.5%.

Grain size: Test pieces should be made from the samples selected as per clause 20.1 and should show the grain size as IS Micro Grain Number 7(min) as per IS-4748.

MECHANICAL PROPERTIES: Mechanical properties of the heat treated plates (after hardening and tempering) should conform those given in table-6.

TABLE-6

Property	Thickness of plates		
	4-10mm	11-14mm	15-22mm
Hardness, HB	470-530	470-530	370-430
YS, Min. (MPa)	1420	1420	980
TS, Min. (MPa)	1560	1560	1180
E1, Min.	5 *	8 **	9 **
RA, Min.	20 *	30 **	35 **
CUN, Min. (J)			
i) At RT	--	10	30
ii) At -40 deg. C	--	5	20

* With flat tensile test specimens.
** With round tensile test specimens.

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SECTION SIX - FIRING TRIAL

28.0 FIRING TRIAL

28.1 Notwithstanding the compliance with the requirements of the foregoing paras, final acceptance of plates depends on the results of firing trial to be conducted according to Specification CIM 48 which cover plates between 4mm to 22mm thicknesses.

28.1.1 Jackal plates above 22mm thickness are not to be ballistically tested

28.1.2 From each cast for proof purpose, two plates of different thicknesses are selected from top part of two different ingots. Proof plates should be so selected that all the thicknesses meant for proof are covered in a period of time.

SECTION SEVEN - QUALITY ASSURANCE DOCUMENTATION

29.0 QUALITY ASSURANCE DOCUMENTATION

29.1 Quality assurance documents giving the following information will be supplied to the consignee along with the material :-
Cast number, cast analysis, plate numbers derived from cast, copies of test certificates of the tests mentioned in clause 20.1 above, hardness and thickness.

29.1.1 Each plate will be identified with the marking which will relate to its relative documents.

29.1.2 Compliance of the strict quality assurance is expected both by the manufacturer & the Quality Assurance Officer with respect to high hardness plates.

SECTION EIGHT - JACKAL PLATES FOR B.P. APPLICATION

30.0 JACKAL PLATES FOR B.P. APPLICATION

With respect to Jackal plates for Bullet Proof application (for thickness upto 6mm) conforming to the requirement of firing seven rounds of AK-47/7.62 SLR shots from 10M range, following guideline should be adhered to heat treated plates.

- i) Hardness 490-530 HB
- ii) Thickness Tolerance +0.5mm
-0.0
- iii) Decarb layer 5% max.

This would be in addition to the stipulations already furnished in this specification.

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