VACUUM DEGASSED / ESR STAINLESS STEEL BARS FOR STEAM TURBINE BLADES, HARDENED & TEMPERED (GRADE: X20 Cr 13)

1.0 GENERAL:

This specification governs the requirements of vacuum degassed / ESR processed, hardened & tempered stainless steel bars of grade X 20 Cr 13 for steam turbine blades.

2.0 APPLICATION:

For manufacture of steam turbine blades suitable for working temperatures up to 400°C.

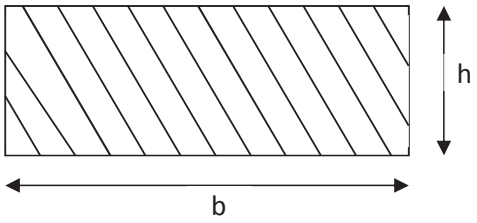
3.0 CONDITION OF DELIVERY:

Hot rolled/forged, Hardened & Tempered, sand/shot blasted and suitably protected with rust preventive coating, meeting the dimensions and tolerances required as per clause 4.0.

4.0 DIMENSIONS AND TOLERANCES:

4.1 Dimensions: Unless otherwise specified in the order, the bars shall be supplied in random lengths of 2 to 5 meters with a maximum of 10% shorts down to 1 metre. Other dimensions shall be as specified in the order.

4.2 Tolerances: The tolerances on cross sectional dimensions shall be as follows**.**



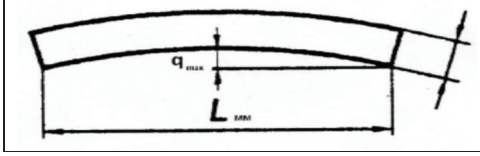
Note: The corners of the flats shall not have any radius.

4.2.1 Tolerances and Dimensions:

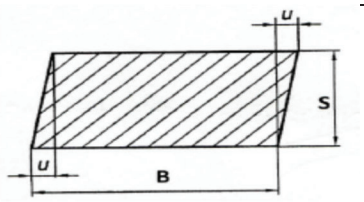
'b'width across flats, mm	Allowable deviation on 'b' mm	'h' thickness mm	Allowable deviation on 'h' mm
Upto 35	+1.5	Upto 20	+ 1.0
Over 35 and upto 75	+ 2.0	Over 20 and upto 40	+ 2.0
Over 75	+ 3.0	Over 40	+ 3.0

Note: Bending of the bars shall not be more than 1mm/metre at any section throughout the length of bars in supply condition. Bulging on the sides shall not be more than 0.01 x b and 0.01 x h respectively.

4.2.2 Straightness tolerances (q_{max}) for rectangular section bar:

Straightness	Value of q_{max} (mm)	Condition
	(Lx1.5)/2000	B & S both ≤ 110
	(Lx2)/2000	B or S > 110

4.2.3 Out of section tolerance for rectangular section bar:

Out of section	Nominal Thickness (mm)	Tolerance (mm)
	10 < S ≤ 25	u ≤ 0.5
	25 < S ≤ 40	u ≤ 1.0
	40 < S ≤ 80	u ≤ 1.5
	S > 80	u ≤ 3.0

5.0 MANUFACTURING AND INSPECTION SEQUENCE PLAN (MIP):

Before starting production, the manufacturer shall submit the following documentation to BHEL.

5.1 A manufacturing & inspection sequence plan (MIP) which is released after the prototype qualification, establishing the quality assured sequence of operations like steel melting, rolling/forging, heat treatment and inspection plan. Information about internal & external specifications shall also be mentioned in MIP. Every change in the established process or MIP needs written permission of BHEL.

5.2 Test instructions for non-destructive testing & destructive testing, which are performed, as part of manufacturer's quality assurance shall also be submitted. The test instructions shall include precise information on the test procedures, sample location plan (illustrated by sketches).

6.0 MANUFACTURE:

6.1 The steel shall be manufactured by basic electric furnace process and subsequently vacuum degassed / electroslag remelted.

6.2 The vacuum system shall have the capacity to maintain a vacuum of 2 torr or lesser during vacuum degassing process for the sufficient time so as to lower the gas contents in the steel.

6.3 The ingot castings shall be used for the manufacture of bars. A reduction ratio of 4 (minimum) shall be maintained from the ingot to final bar size. The information regarding the ingot size to the concerned final bar size shall be mentioned in the MIP.

7.0 HEAT TREATMENT

7.1 The following heat treatment is suggested to achieve the mechanical properties specified in Cl.12.0 of this specification.

Harden in air or oil at 900 - 1050°C
Tempering temperature shall not be less than 650°C

7.2 If the bars need be straightened after heat treatment then the bars shall be stress relieved after the straightening operation at 30° C below the actual tempering temperature with a slow cooling rate.

7.3 The process parameters shall be selected with a view to achieve lowest possible residual stresses. The distortion of the finish machined part caused by slight residual stresses from the rolling/forging & heat treatment process shall not occur.

8.0 FREEDOM FROM DEFECTS:

8.1 The bars shall be free from cracks, scabs, seams and other harmful defects.

8.2 Decarburization and other material defects shall not exceed the dimensional tolerances as specified in clause 4.2.

9.0 FINISH:

9.1 The surface of the bars shall be smooth without any laps, rolled in scales etc. Dents roll marks, and scratches are permitted provided their depth does not exceed half the tolerance limits specified in clause 4.0.

9.2 The edges of bars shall be cut square by sawing or shearing and no crop ends are permissible.

10.0 TEST SAMPLES:

10.1 **For Chemical Analysis:** One sample for chemical analysis shall be taken from each melt.

10.2 **For Mechanical tests:** Bars of same size shall be grouped into lots belonging to same melt and heat treatment batch. This shall be treated as a single test unit and subjected to mechanical testing as per following plan.

10.2.1 The uniformity of the strength of the bars belonging to one lot (same melt and heat treatment batch of same size of bars = test unit) shall be verified by hardness test as per EN ISO 6506-1 or any other reputed international method. The hardness test shall be performed on 10% of each test unit, however on atleast 10 bars or on all the bars if the test unit comprises of less than 10 bars. The greatest permissible difference in hardness in a lot (test unit) shall not exceed 35 HBW.

10.2.2 Hardness tests are to be performed after all heat treatments including a possible stress relieving are undertaken.

10.2.3 Mechanical properties shall be determined on the hardest and softest bars identified by the hardness tests conducted as per 10.2.1 and 10.2.2.

10.2.4 The test samples locations shall be as per Annexure A and B. If the cross section of the bar is more than 200 cm^2, then mechanical properties must be determined both in the centre of the bar and at the side of the bar. With the exception of toughness, the difference in the properties across the bar cross section shall not exceed 7.5%.

10.2.5 The specimen for Metallography shall be taken in longitudinal direction with a minimum cross section area of 320 mm^2.

The positions of the specimens given in the Annexure A and B are meant for guidance only. Details concerning the locations of the specimens are to be agreed mutually and must be included in MIP with a sketch.

11.0 CHEMICAL COMPOSITION:

Heat analysis (in weight %) shall be achieved as follows**.**

Element	C	Si	Mn	P	S	Cr	Ni
Minimum	0.17	0.10	0.30	--	--	12.50	0.30
Maximum	0.22	0.60	0.80	0.030	0.020	14.00	0.80

12.0 MECHANICAL PROPERTIES:

The material in final delivery condition shall comply with the following mechanical properties.

Properties	0.2 %Yield Strength N/mm^2	Tensile Strength N/mm^2	% Elongation	Reduction in area %	Impact energy, J	Hardness HBW
Minimum	600	800	15	50	20	240
Maximum	--	950	--	--	--	280

NOTE: 1) The tensile test shall be carried out in accordance with EN10002 resp. ASTM E8M (round tension test specimen with L_o = 50 mm and d_o = 10 mm) or any other reputed National/International standard.

2) The Charpy V – notch impact test shall be performed with standard test specimens in accordance with EN: 10045 or any other reputed National/International standard. An impact test shall consist of three specimens from a single test location; the minimum average value shall be as specified above. Only one value of the three can be below the specified minimum, but in no case below 14 J. All the three test results shall be reported in test certificate.

3) HBW 10/3000 or HBW 5/750 shall be used for hardness tests.

13.0 METALLOGRAPHY TESTS:

The examination of the cleanliness must be performed in the centre of one bar per lot. It can be conducted before or after the heat treatment. The microstructure must be uniform and free from porosity, excessive segregation and other in-homogeneities. The following properties concerning delta-ferrite and inclusions shall be achieved.

13.1 Delta ferrite content shall be less than 5%. Delta ferrite content shall be determined in a manner consistent with the evaluation technique described in ASTM E 45 Method A (Worst Field Method at a Magnification of 100X) with the specimen orientation in longitudinal direction. The distribution and size of delta ferrite must be such that it does not result in indication during MPI examination of the ready-machined surface.

13.2 Inclusion content shall be tested as per ASTM E 45 Method A and with following limits.

13.2.1 "Thin series" inclusions shall not exceed 2.0 for Type A, B, C and 2.5 for Type D.

13.2.2 "Heavy series" inclusions shall not exceed 1.5 for all Types i.e. A, B, C and D.

13.2.3 All the type and sizes of the inclusions mentioned in 13.2.1 and 13.2.2 can exist simultaneously.

13.2.4 Maximum number and size of globular inclusions (type D):

IR (D) = (n1 + 2.5 n2) $\leq$ 10
IR (D) is converted to an area of 160 mm^2.
n= number of globular inclusions.

n1 (25 μm – 50 μm); n2 (51 μm – 75 μm)

The size pertains not only to the globular inclusions themselves, but also the subsequent cavities, which can occur beside them. Inclusions and cavities which are more than 75 μm are not allowed.

13.3 **Grain size:** The grain size must be measured at the softest and the hardest bar after all heat treatments are performed. Grain size 4 or finer per ASTM E 112 or DIN 50601 must be achieved.

A deviation from the average size of more than 2 grain size is not permissible.

14.0 EXTERNAL AND INTERNAL QUALITY/NON DESTRUCTIVE TESTING:

14.1 **Test Scope:** The following NDT inspections shall be performed after all heat treatments are performed including stress relieving operations.

- Visual inspection of all bars
- UT of all flats shall be subjected to ultrasonic testing as per BHEL Standard HY 0850179, Rev 01 and acceptance norm shall be as per HY 0850179, Rev. 01. The UT shall be carried out in dispatch condition

  Requirements: 100% of the volume shall be examined with the stipulated recording level of the material.

14.2 Criteria for Recording Limits and Decision on Further Use:

a) Surface defects: Indication of surface defects, e.g., scoring caused by the rolling process are to be ground at least at both ends, in the center of the indications and in increments of ca.250 mm to check the extension below the surface. Surface defects extending $\geq$1 mm or greater than half the specified dimensional tolerances below the surface are not permissible.

15.0 MATERIAL IDENTITY TEST:

At the time of delivery, all the bars shall be subjected to identification test by Spark test method or any other reliable means to ascertain that the material supplied is as required by the specification. Details of the instrument and the methodology followed shall be reported in Test certificate.

16.0 PROCESS QUALIFICATION:

A qualification review, performed jointly by the purchaser and supplier, is required before starting production for the first order. The process qualification review will include following as a minimum requirement.

16.1 This initial process qualification is required for each manufacturing, heat treatment and testing facility

16.2 The parameters used or stipulated during this phase form the basis of the MIP.

16.3 In addition to the scope of testing and examination stipulated in this specification, the following tests and examinations shall be performed.

16.3.1 Tensile and impact tests in transverse direction. If required, the sub-size test specimens may be used for the testing.

16.3.2 Hot tensile test: In accordance with ISO 6892-2 or equivalent standard, a tensile test in longitudinal direction has to be performed at 500^0C**.** The following properties must be achieved:

0.2% Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Reduction in area (%)
≥380	≥480	≥20	≥60

16.3.3 Determination of FATT according to ASTM A 370. FATT of < 30°C shall be achieved. Testing shall be carried out on minimum 10 specimens.

16.3.4 Magnetic particle testing: The distribution, type and size of micro-structural in-homogeneities (e.g. delta ferrite and segregation) shall not cause MP indications.

16.4 The MIP plan shall include the hot yield test. The manufacturer shall submit the results of tests conducted on the hardened and tempered samples of the steel produced by them of this grade of material.

17.0 INSPECTION AT SUPPLIER'S WORKS:

The representative of BHEL shall have free access to the supplier's works at all times during the execution of the order, to satisfy himself that the material is produced as per the quality requirements of this specification. All reasonable facilities shall be extended to him free of charge. He may also witness the sampling testing and marking called for in this specification.

18.0 QUALITY PLAN:

18.1 Vendor shall follow the Quality Plan Ref. BHEL/HY10764/Blade flats S-QAP Rev.02 attached as Annexure 'C' unless conditions stipulated in Cl.18.2 & 18.3 are applicable. A duly signed and stamped copy of this QAP shall be submitted by the vendor along with the technical offer.

18.2 In case Customer / Project related additional requirements are applicable in the enquiry / tender, vendor may be asked to submit a separate QP including such requirements.

18.3 In case of new vendors or first time supplies for the sizes mentioned in BHEL enquiry, a separate QP shall be submitted for approval by BHEL.

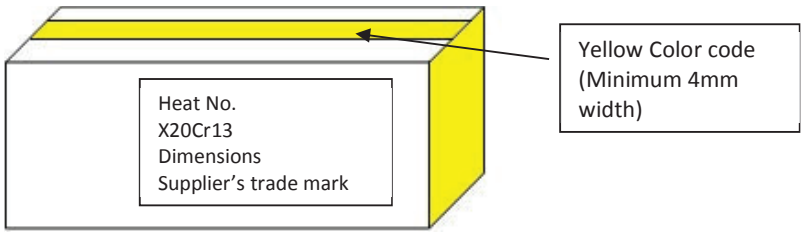
19.0 TEST CERTIFICATE:

Three copies of the test certificate shall be furnished (in English) giving the following details:

a) Specification No.: HY10764 Rev.11
b) BHEL Order No.
c) Name of the supplier.
d) Melt No.
e) Process of Manufacture
f) Heat treatment batch no. and HT charts
g) Results of chemical analysis and mechanical tests (including hardness test results).
h) Results of Metallographic tests with representative Photomicrographs.
i) Results of Ultrasonic tests.
j) Dimensional Inspection Report
k) Results of any additional test (if applicable as per order)
l) Confirmation of 'Material identity test' on all bars

20.0 MATERIAL IDENTIFICATION MARKING:

Marking of each individual bar at the front and side face shall be done as given below. For easy identification of the material during usage, each bar shall be painted with Yellow color code along the length of the bar on any of its face as indicated below:



Supplier shall ensure that the 'Yellow color' code is clearly visible in the final dispatch condition of the material.

21.0 PACKING:

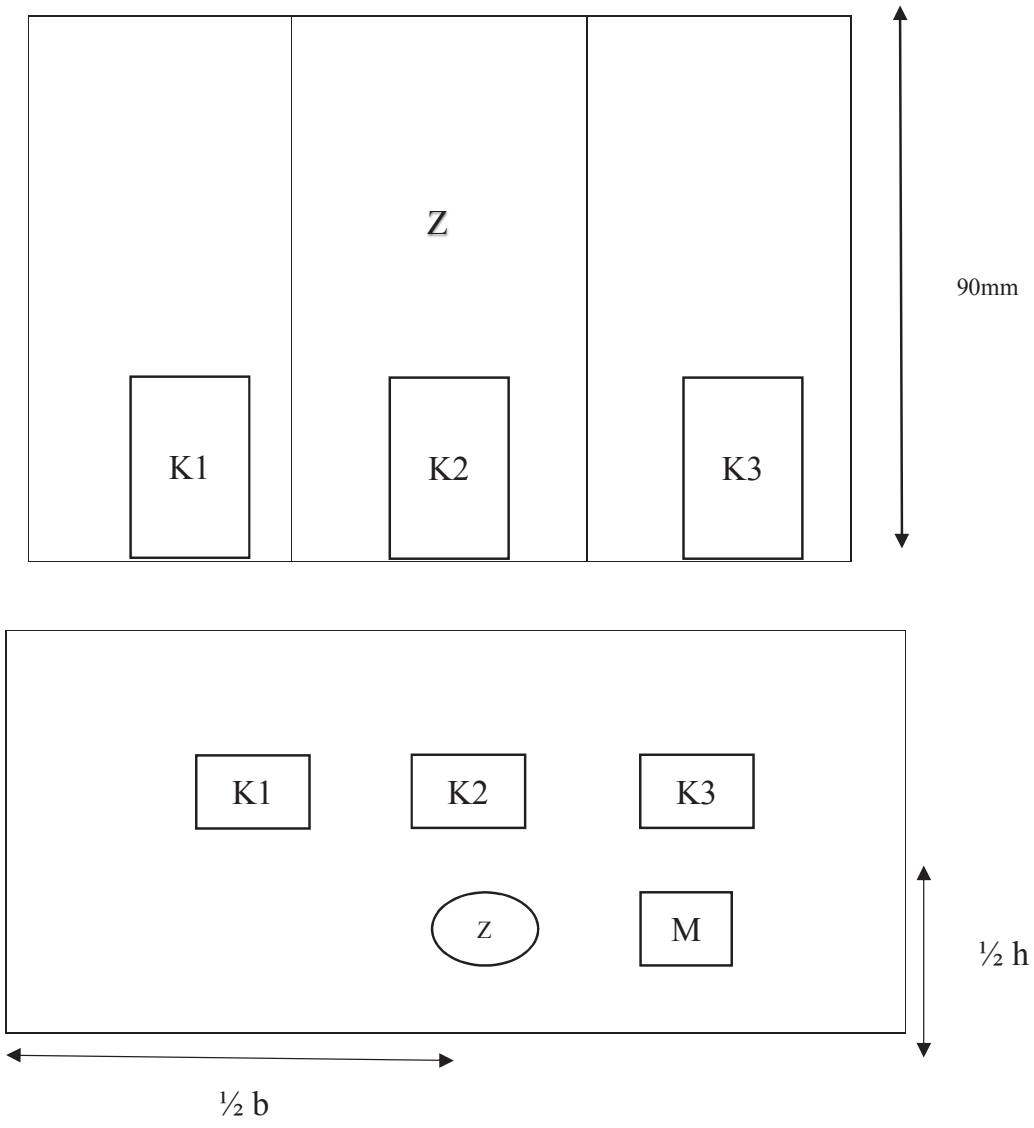
The bars shall be suitably packed to prevent from corrosion and damage during transit.

22.0 REJECTION AND REPLACEMENT:

In the event of any material proving defective during the course of further processing or testing at BHEL, such material shall be rejected and the supplier shall make immediate arrangements to replace the same free of cost after all the commercial terms and conditions are satisfied.

ANNEXURE A

TEST SAMPLES LOCATIONS PLAN (CROSS SECTION AREA < = 200 CM^2)

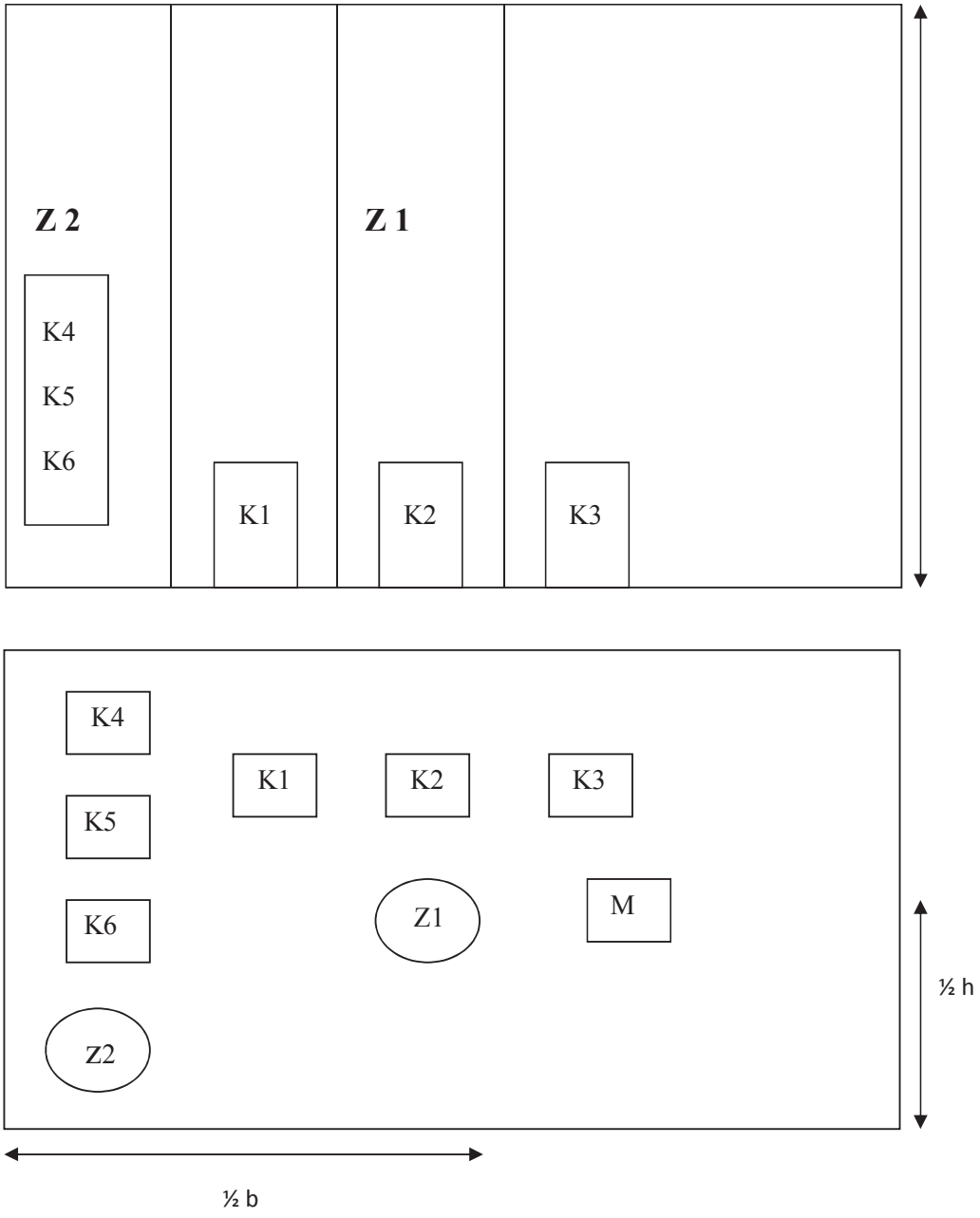


Z = TENSILE SPECIMENS (LONGITUDINAL DIRECTION)
K1, K2 & K3 = IMPACT SPECIMENS
M = METALLOGRAPHY SPECIMENS

NOTE: Make sure that all specimens are located in the middle of the material thickness

ANNEXURE B

TEST SAMPLES LOCATIONS PLAN (CROSS SECTIONAL AREA > 200 CM²)



Z1, Z2 = TENSILE SPECIMENS (LONGITUDINAL DIRECTION)
K1 TO K6 = IMPACT SPECIMENS
M = METALLOGRAPHY SPECIMENS

Annexure C

VENDOR'S NAME & ADDRESS			**STANDARD QUALITY PLAN (BLADE FLATS)**					**HY 10764 REV 11 (PAGE 10 OF 11)**					
			BHEL ENQ/ P.O. No.					QP No.: BHEL/HY10764/Blade flats SQAP Rev.03					
			Date					PAGE 1 of 2					
SL No	Operation	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
1.	Melting & Refining (ESR or VD Process)	Chemical composition	Major	Chemical analysis	Each melt	HY 10764 Rev. 11	HY 10764 Rev. 11	Test certificate	√	2	-	1	
2.	Hot rolling / Forging & Cutting	Dimensions	Minor	Dimensional	100%	Internal Standard	Internal Standard			2	-	1	
3.	Heat treatment	Soaking time & temperature	Major	Verification of HT time & temperature charts	All cycles	HY 10764 Rev. 11	HY 10764 Rev. 11	Original HT charts	√	2	-	1	
4.	Dimensional inspection	Dimension & tolerances	Major	Dimensional checking	100%	As per PO & Spec.	As per PO & Spec.	Dimensional report	√	2	1	-	Refer Note - 4
5.a	Mechanical properties	Hardness	Major	Hardness test	Each lot	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	1	-	
5.b		Tensile properties (0.2% Y.S, UTS, %El, % RA) & toughness	Major	Tensile & Impact testing	Hardest & softest bar from each lot	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	1	-	
6.a	NDT	Visual	Major	Surface defects & finish	Each bar	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	1	-	
6.b		UT	Major	Sub-surface defects	Each bar	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	1	-	

Legend:	Prepared by	Approved by	#Vendor's confirmation
• P Perform; W Witness; V Verification; • Indicate 1 for BHEL or BHEL nominated Inspection agency & 2 for vendor/sub vendor as appropriate against each component /characteristic under P, W & V columns. • * For items marked √ (tick) in column D, test certificates shall be submitted to BHEL for records.	Signature and Stamp Sachin Kaliyar वरिष्ठ अभियंता / गुणवत्ता आश्वासन Engineer / Quality Assurance भा.ह.इ.लि. हैदराबाद BHEL HYD	Signature and Stamp QUALITY ASSURANCE BHEL HYDERABAD B.Ashok Kumar AGM / QA 8-7-21	Signature and Stamp

Annexure C

VENDOR'S NAME & ADDRESS	STANDARD QUALITY PLAN (BLADE FLATS)	HY 10764 REV 11 (PAGE 11 OF 11)
	BHEL ENQ. /P.O No.	QP No.: BHEL/HY10764/Blade flats S-QAP Rev.03
	Date	PAGE 2 of 2

SL No.	Operation	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
7.a	Metallurgical testing	Inclusion rating, microstructure & % delta ferrite	Major	Microstructure	One sample per lot	HY 10764 Rev. 11	HY 10764 Rev. 11	TC with micro-structure photographs	√	2	-	1	
7.b		Grain size	Major	Microstructure	On hardest & softest bar per lot	HY 10764 Rev. 11	HY 10764 Rev. 11		√	2	-	1	
8.	Material identity test	Material grade	Major	Chemical analysis	Each bars	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	1	-	
9.	Packing, marking & color code	Packing & marking	Major	Hard Punching and Colour code	All bars	HY 10764 Rev. 11	HY 10764 Rev. 11			2	-	1	
10.	Verification & Certification	Documentation	major	Verification	All bars	HY 10764 Rev. 11	HY 10764 Rev. 11	TC	√	2	-	1	Endorsement of all documents by TPIA

Note:

1) This SQAP is applicable along with BHEL approved frozen Manufacturing Process Plan only.
2) Additional requirements as per BHEL customer / project and purchase order will also be applicable.
3) This SQAP is not applicable for first time supplies of the material as per HY10764, for which a separate MPP and QAP shall be submitted. In such cases process qualification requirements will be also be applicable.
4) The following shall be ensure & certified:
   a. Size & Length of each bar as per purchase order.
   b. Straightness of all bars.
   c. Defect free surfaces.
   d. Marking & punching on all bars.

Legend:	Prepared by	Approved by	#Vendor's confirmation
• P Perform; W Witness; V Verification; • Indicate 1 for BHEL or BHEL nominated Inspection agency & 2 for vendor/sub vendor as appropriate against each component /characteristic under P, W & V columns. • * For items marked √ (tick) in column D, test certificates shall be submitted to BHEL for records.	Signature and Stamp सचिन कटियार Sachin Katiyar वरिष्ठ अभियंता / गुणवत्ता आश्वासन Sr. Engineer / Quality Assurance भेल हैदराबाद BHEL.HYD-32	Signature and Stamp B.Ashok Kumar AGM / QA 5-7-21 BHEL QUALITY ASSURANCE HYDERABAD	Signature and Stamp

#To be submitted along with the technical offer.

VACUUM DEGASSED / ESR STAINLESS STEEL BARS FOR STEAM TURBINE BLADES, HARDENED & TEMPERED (GRADE: X22 Cr Mo V 121)

1.0 GENERAL:

This specification governs the requirements of vacuum degassed / ESR processed, hardened & tempered stainless steel bars of grade X 22 Cr Mo V121 for steam turbine blades.

2.0 APPLICATION:

For manufacture of steam turbine blades suitable for working temperature from 400-550°C.

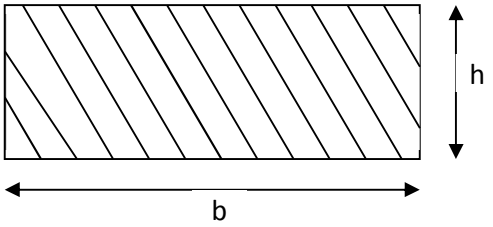
3.0 CONDITION OF DELIVERY:

Hot rolled/forged, Hardened & Tempered, sand/shot blasted and protected with rust preventive coating, meeting the dimensions and tolerances required as per Clause 4.0.

4.0 DIMENSIONS AND TOLERANCES:

4.1 Dimensions: Unless otherwise specified in the order, the bars shall be supplied in random lengths of 2 to 5 meters with a maximum of 10% shorts down to 1 metre. Other dimensions shall be as specified in the order.

4.2 Tolerances: The tolerances on cross sectional dimensions shall be as follows**.**



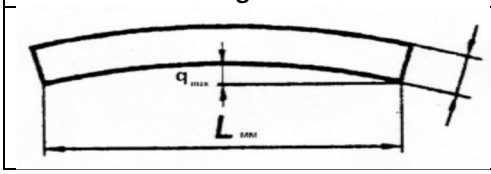
Note: The corners of the flats shall not have any radius.

4.2.1 Tolerance on dimensions:

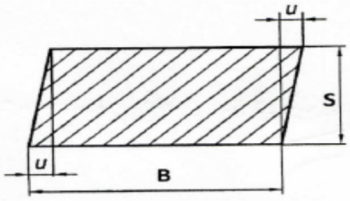
'b'width across flats, mm	Allowable deviation on 'b' mm	'h' thickness mm	Allowable deviation on 'h' mm
Upto 35	+1.5	Upto 20	+ 1.0
Over 35 and upto 75	+ 2.0	Over 20 and upto 40	+ 2.0
Over 75	+ 3.0	Over 40	+ 3.0

Note: Bending of the bars shall not be more than 1mm/metre throughout the length of bars in supply condition. Bulging on the sides shall not be more than 0.01 x b and 0.01 x h respectively.

4.2.2 Straightness tolerances (q_{max}) for rectangular section bar:

Straightness	Value of q_{max} (mm)	Condition
	(Lx1.5)/2000	B & S both ≤ 110
	(Lx2)/2000	B or S > 110

4.2.3 Out of section tolerance for rectangular section bar:

Out of section	Nominal Thickness (mm)	Tolerance (mm)
	10 < S ≤ 25	u ≤ 0.5
	25 < S ≤ 40	u ≤ 1.0
	40 < S ≤ 80	u ≤ 1.5
	S > 80	u ≤ 3.0

5.0 MANUFACTURING AND INSPECTION SEQUENCE PLAN (MIP):

Before starting production the manufacturer shall submit the following documentation to BHEL.

5.1 A manufacturing & inspection sequence plan (MIP) included with tensile test at 600^0C and creep test released after the prototype qualification, establishing the quality assured sequence of operations like steel melting, rolling/forging, heat treatment and inspection plan. Information about internal & external specifications shall also be mentioned in MIP. Every change in the established process or MIP needs written permission of BHEL.

5.2 Test instructions for non-destructive testing & destructive testing, which are performed, as part of manufacturer's quality assurance shall also be submitted. The test instructions shall include precise information on the test procedures, sample location plan (illustrated by sketches).

6.0 MANUFACTURE:

6.1 The steel shall be manufactured by basic electric furnace process and subsequently vacuum degassed / electroslag remelted.

6.2 The vacuum system shall have the capacity to maintain a vacuum of 2 torr or lesser during vacuum degassing process for the sufficient time so as to lower the gas contents in the steel.

6.3 The ingot castings shall be used for the manufacture of bars. A reduction ratio of 4 (minimum) shall be maintained from the ingot to final bar size. The information regarding the ingot size to the concerned final bar size shall be mentioned in the MIP.

7.0 HEAT TREATMENT

7.1 The following heat treatment is suggested to achieve the mechanical properties specified in Cl.12.0 of this specification.

Harden in air or oil at 1020-1070°C
Tempering temperature shall not be less than 650°C

7.2 If the bars need be straightened after heat treatment then the bars shall be stress relieved after the straightening operation at 30° C below the actual tempering temperature with a slow cooling rate.

7.3 The process parameters shall be selected with a view to achieve lowest possible residual stresses. The distortion of the finish machined part caused by slight residual stresses from the rolling & heat treatment process shall not occur.

7.4 The details of the actual heat treatment cycle followed shall be furnished in the Test Certificate.

8.0 FREEDOM FROM DEFECTS:

8.1 The bars shall be free from cracks, scabs, seams and other harmful defects.

8.2 Decarburization and other material defects shall not exceed the dimensional tolerances as specified in Cl. 4.2

9.0 FINISH:

9.1 The surface of the bars shall be smooth without any laps, rolled in scales etc. Dents roll marks, and scratches are permitted provided their depth does not exceed half the tolerance limits specified in clause 4.

9.2 The edges of bars shall be cut square by sawing or shearing and no crop ends are permissible.

10.0 TEST SAMPLES:

10.1 **For Chemical Analysis:** One sample for chemical analysis shall be taken from each melt.

10.2 **For Mechanical tests:** Bars of same size shall be grouped into lots belonging to same melt and heat treatment batch. This shall be treated as a single test unit and subjected to mechanical testing as per following plan.

10.2.1 The uniformity of the strength of the bars belonging to one lot (same melt and heat treatment batch of same size of bars = test unit) shall be verified by hardness test as per EN ISO 6506-1 or any other reputed international method. The hardness test shall be performed on 10% of each test unit, however on atleast 10 bars or on all the bars if the test unit comprises of less than 10 bars. The greatest permissible difference in hardness in a lot (test unit) shall not exceed 35 HBW.

10.2.2 Hardness tests are to be performed after all heat treatments including a possible stress relieving are undertaken.

10.2.3 Mechanical properties shall be determined on the hardest and softest bars identified by the hardness tests conducted as per 10.2.1 and 10.2.2.

10.2.4 The test samples locations may be as per Annexure A and B. If the cross section of the bar is more than 200 cm^2, then mechanical properties must be determined both in the centre of the bar and at the side of the bar. With the exception of toughness, the difference in the properties across the bar cross section shall not exceed 7.5%.

10.2.5 The specimen for Metallography shall be taken in longitudinal direction with a minimum cross section area of 320 mm^2.

The positions of the specimens given in the Annexure A and B are meant for guidance only. Details concerning the locations of the specimens are to be agreed mutually and must be included in MIP with a sketch.

11.0 CHEMICAL COMPOSITION:

Heat analysis (in weight %) shall be achieved as follows**.**

Element	C	Si	Mn	P	S	Cr	Mo	Ni	V
Minimum	0.18	0.10	0.30	--	--	11.00	0.80	0.30	0.25
Maximum	0.24	0.50	0.80	0.020	0.020	12.50	1.20	0.80	0.35

12.0 MECHANICAL PROPERTIES:

The material in final delivery condition shall comply with the following mechanical properties.

Properties	0.2 %Yield Strength, N/mm^2	Tensile Strength, N/mm^2	% Elongation	% Reduction in area	Impact energy, J	Hardness (BHN)
Minimum	700	900	11	35	20	265
Maximum	--	1050	--	--	--	310

NOTE: 1) The tensile test shall be carried out accordance with EN10002 resp. ASTM E8M (round tension test specimen with L_o = 50 mm and d_o = 10 mm) or any other reputed National/International standard.

2) The Charpy V – notch impact test shall be performed with standard test specimens in accordance with EN: 10045 or any other reputed National/International standard. An impact test shall consist of three specimens from a single test location; the minimum average value shall be as specified above. Only one value of the three can be below the specified minimum, but in no case below 14 J. All the three test results shall be reported in test certificate.

3) HBW 10/3000 or HBW 5/750 shall be used for hardness tests.

13.0 METALLOGRAPHY TESTS:

The examination of the cleanliness must be performed in the centre of one bar per lot. It can be conducted before or after the heat treatment. The microstructure must be uniform and free from porosity, excessive segregation and other in-homogeneities. The following properties concerning delta-ferrite and inclusions shall be achieved.

13.1 Delta ferrite content shall be less than 5%. Delta ferrite content shall be determined in a manner consistent with the evaluation technique described in ASTM E 45 Method A (Worst Field Method at a Magnification of 100X) with the specimen orientation in longitudinal direction. The distribution and size of delta ferrite must be such that it does not result in indication during MPI examination of the ready-machined surface.

13.2 Inclusion content shall be tested as per ASTM E 45 Method A and with following limits.

13.2.1 "Thin series" inclusions shall not exceed 2.0 for Type A, B, C and 2.5 for Type D.

13.2.2 "Heavy series" inclusions shall not exceed 1.5 for all Types i.e. A, B, C and D.

13.2.3 All the type and sizes of the inclusions mentioned in 13.2.1 and 13.2.2 can exist simultaneously.

13.2.4 Maximum number and size of globular inclusions (type D):

IR (D) = (n1 + 2.5 n2) $\leq$ 10
IR (D) is converted to an area of 160 mm^2.
n= number of globular inclusions.

n1 (25 μm – 50 μm); n2 (51 μm – 75 μm)

The size pertains not only to the globular inclusions themselves, but also the subsequent cavities, which can occur beside them. Inclusions and cavities which are more than 75 μm are not allowed.

13.3 **Grain size:** The grain size must be measured at the softest and the hardest bar after all heat treatments are performed. Grain size 4 or finer per ASTM E 112 or DIN 50601 must be achieved.

A deviation from the average size of more than 2 grain size is not permissible.

14.0 EXTERNAL AND INTERNAL QUALITY/NON DESTRUCTIVE TESTING:

14.1 Test Scope: The following NDT inspections shall be performed after all heat treatments including stress relieving operations are completed on the bars

- Visual inspection of all bars
- UT: All flats shall be subjected to ultrasonic testing as per BHEL Standard HY 0850179, Rev. 01 and acceptance norm shall be as per HY 0850179, Rev. 01. The UT shall be carried out in dispatch condition of the material.

14.2 Criteria for Recording Limits and Decision on Further Use:

a) Surface defects: Indication of surface defects, e.g., scoring caused by the rolling process are to be ground at least at both ends, in the center of the indications and in increments of ca.250 mm to check the extension below the surface. Surface defects extending $\geq$1 mm or greater than half the specified dimensional tolerances below the surface are not permissible.

15.0 HIGH TEMPERATURE PROPERTIES:

The supplier shall guarantee the elevated temperature properties as per EN10269 for this grade of material.

16.0 MATERIAL IDENTITY TEST:

At the time of delivery, all the bars shall be subjected to identification test by Spark test method or any other reliable means to ascertain that the material supplied is as required by the specification. Details of the instrument and the methodology followed shall be reported in Test certificate.

17.0 PROCESS QUALIFICATION:

A qualification review, performed jointly by the purchaser and supplier, is required before starting production for the first order. The process qualification review will include the following as a minimum requirement.

17.1 This initial process qualification is required for each manufacturing, heat treatment and testing facility

17.2 The parameters used or stipulated during this phase form the basis of the MIP.

17.3 In addition to the scope of testing and examination stipulated in this specification, the following tests and examinations shall be performed.

17.3.1 Tensile and impact tests in transverse direction. If required, the sub-size test specimens may be used for the testing.

17.3.2 Hot tensile test: In accordance with ISO 6892-2 or equivalent standard, a tensile test in longitudinal direction has to be performed at 600^0C**.** The following properties must be achieved:

0.2% Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)	Reduction in area (%)
≥285	≥380	≥18	≥60

17.3.3 Determination of FATT according to ASTM A 370. FATT of < 25°C shall be achieved. Testing shall be carried out on minimum 10 specimens.

17.3.4 Magnetic particle testing: The distribution, type and size of micro-structural in-homogeneities (e.g. delta ferrite and segregation) shall not cause MP indications.

17.4 The manufacturer shall provide the sample to BHEL for evaluation or testing before carrying out creep tests at any suitable labs. Only sample which are evaluated and certified by BHEL shall be subjected to creep tests.

17.5 The MIP plan shall include the Creep and hot yield test. The manufacturer shall submit the results of creep tests conducted on the hardened and tempered samples of the steel produced by them of this grade of material. The test parameters like test temperature, duration of test and number of test samples shall be mutually agreed upon between the manufacturer and BHEL. The results of these creep tests shall form the basis of high temperature property guarantee to be given by the manufacturer for their supplies of blade flats as per Cl.15.0.

18.0 INSPECTION AT SUPPLIER'S WORKS:

The representative of BHEL shall have free access to the supplier's works at all times during the execution of the order, to satisfy himself that the material is produced as per the quality requirements of this specification. All reasonable facilities shall be extended to him free of charge. He may also witness the sampling testing and marking called for in this specification.

19.0 QUALITY PLAN:

19.1 Vendor shall follow the Quality Plan Ref. BHEL/HY10766/Blade flats S-QAP Rev.02 attached as Annexure 'C' unless conditions stipulated in Cl.19.2 & 19.3 are applicable. A duly signed and stamped copy of this QAP shall be submitted by the vendor along with the technical offer.

19.2 In case Customer / Project related additional requirements are applicable in the enquiry / tender, vendor may be asked to submit a separate QP including such requirements.

19.3 In case of new vendors or first time supplies for the sizes mentioned in BHEL enquiry, a separate QP shall be submitted for approval by BHEL.

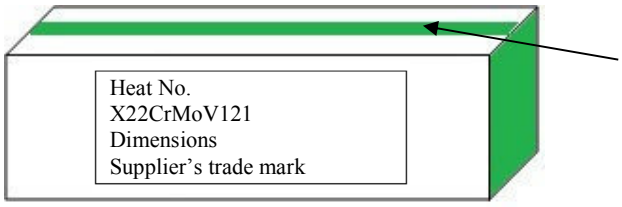
20.0 TEST CERTIFICATE:

Three copies of the test certificate shall be furnished (in English) giving the following details:

a) Specification No.: HY10766 Rev.11
b) BHEL Order No.
c) Name of the supplier.
d) Melt No.
e) Process of Manufacture
f) Heat treatment batch no. and HT charts.
g) Results of chemical analysis and mechanical tests (including hardness test results).
h) Results of Metallographic tests with representative Photomicrographs.
i) Results of Ultrasonic tests.
j) Dimensional inspection report
k) High temperature guarantee certificate
l) Confirmation of 'Material identity test' on all bars
m) Results of any additional test (if applicable as per order)

21.0 MATERIAL IDENTIFICATION MARKING:

Marking of each individual bar at the front and side face shall be done as given below. For easy identification of the material during usage, each bar shall be painted with Green color code along the length of the bar on any of its face as indicated below:



Supplier shall ensure that the green color code is clearly visible in the final dispatch condition of the material.

22.0 PACKING:

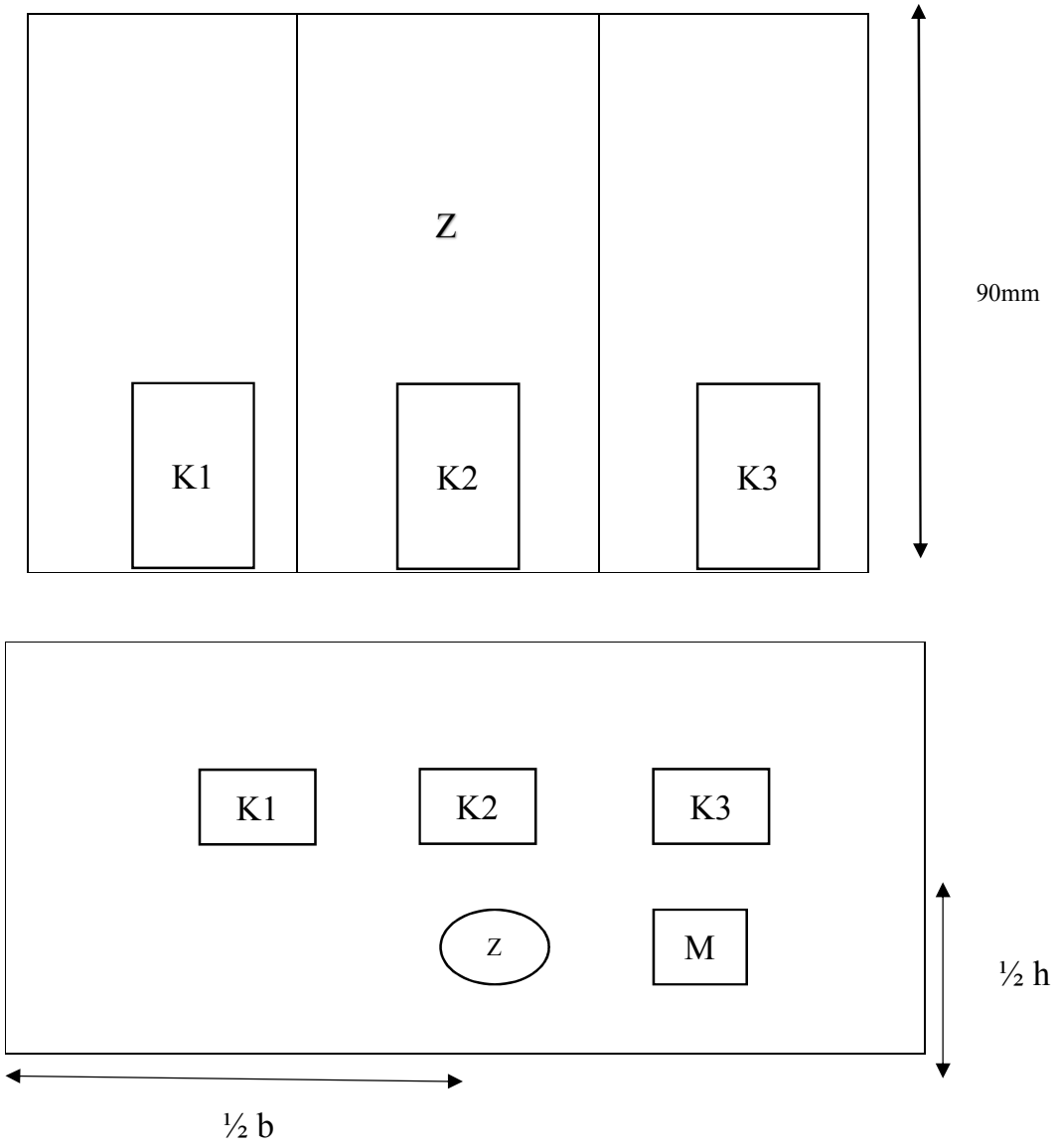
The bars shall be suitable packed to prevent from corrosion and damage during transit. Bars of lengths within 1 metre variation are to be separately bundled to avoid bending during transit or storage.

23.0 REJECTION AND REPLACEMENT:

In the event of any material proving defective during the course of further processing or testing at BHEL, such material shall be rejected and the supplier shall make immediate arrangements to replace the same free of cost after all the commercial terms and conditions are satisfied.

ANNEXURE A

TEST SAMPLES LOCATIONS PLAN (CROSS SECTION AREA < = 200 CM^2)

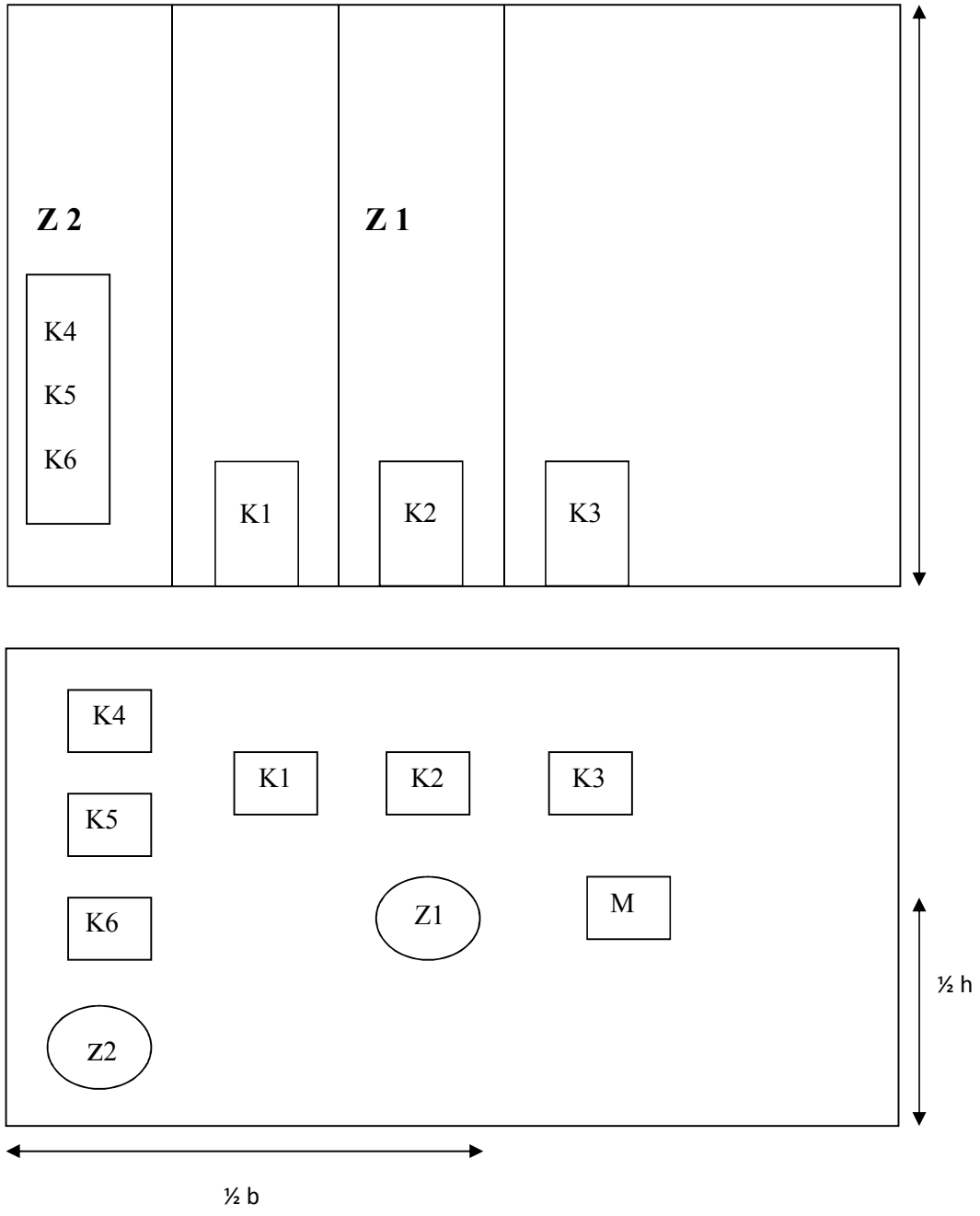


Z = TENSILE SPECIMENS (LONGITUDINAL DIRECTION)
K1, K2 & K3 = IMPACT SPECIMENS
M = METALLOGRAPHY SPECIMENS

NOTE: Make sure that all specimens are located in the middle of the material thickness

ANNEXURE B

TEST SAMPLES LOCATIONS PLAN (CROSS SECTIONAL AREA > 200 CM²)



Z1, Z2 = TENSILE SPECIMENS (LONGITUDINAL DIRECTION)
K1 TO K6 = IMPACT SPECIMENS
M = METALLOGRAPHY SPECIMENS

Annexure C

VENDOR'S NAME & ADDRESS	QUALITY PLAN (BLADE FLATS)	HY 10766 REV 11 (PAGE 10 OF 11)
	BHEL ENQ/ P.O. No.	QP No.: BHEL/HY10766/Blade flats SQAP Rev.03 PAGE 1 of 2
	Date	

SL No	Operation	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
1.	Melting & Refining (ESR or VD Process)	Chemical composition	Major	Chemical analysis	Each melt	HY 10766 Rev. 11	HY 10766 Rev. 11	Test certificate	√	2	-	1	
2.	Hot rolling / Forging & Cutting	Dimensions	Minor	Dimensional	100%	Internal Standard	Internal Standard			2	-	1	
3.	Heat treatment	Soaking time & temperature	Major	Verification of HT time & temperature charts	All cycles	HY 10766 Rev. 11	HY 10766 Rev. 11	Original HT charts	√	2	-	1	
4.	Dimensional inspection	Dimension & tolerances	Major	Dimensional checking	100%	As per PO & Spec.	As per PO & Spec.	Dimensional report	√	2	1	-	Refer Note - 4
5.a	Mechanical properties	Hardness	Major	Hardness test	Each lot	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	1	-	
5.b		Tensile properties (0.2% Y.S, UTS, %El, % RA) & toughness	Major	Tensile & Impact testing	Hardest & softest bar from each lot	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	1	-	
6.a	NDT	Visual	Major	Surface defects & finish	Each bar	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	1	-	
6.b		UT	Major	Sub-surface defects	Each bar	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	1	-	

Legend:

- P Perform; W Witness; V Verification;
- Indicate 1 for BHEL or BHEL nominated Inspection agency & 2 for vendor/sub vendor as appropriate against each component /characteristic under P, W & V columns.
- * For items marked √ (tick) in column D, test certificates shall be submitted to BHEL for records.

Prepared by	Approved by	#Vendor's confirmation
Signature and Stamp सचिन कटियार Sachin Katiyar वरिष्ठ अभियंता / गुणवत्ता आश्वासन Engineer / Quality Assurance बी एच ई एल, हैदराबाद, BHEL,HYD-32	Signature and Stamp QUALITY ASSURANCE BHEL HYDERABAD B.Ashok Kumar AGM / QA 8-7-24	Signature and Stamp

Annexure C

VENDOR'S NAME & ADDRESS	**QUALITY PLAN (BLADE FLATS)**	HY 10766 REV 11 (PAGE 11 OF 11)
	BHEL ENQ. /P.O No. Date	QP No.: BHEL/HY10766/Blade flats SQAP Rev.03 PAGE 2 of 2

SL No.	Operation	Characteristics	Class	Type of check	Quantum of Check	Reference Document	Acceptance Norms	Format of Record	* D	Agency P	Agency W	Agency V	Remarks
7.a	Metallurgical testing	Inclusion rating, microstructure & % delta ferrite	Major	Microstructure	One sample per lot	HY 10766 Rev. 11	HY 10766 Rev. 11	TC with micro-structure photographs	√	2	-	1	
7.b		Grain size	Major	Microstructure	On hardest & softest bar per lot	HY 10766 Rev. 11	HY 10766 Rev. 11		√	2	-	1	
8.	Material identity test	Material grade	Major	Chemical analysis	Each bars	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	1	-	
9.	High temp. properties	Guarantee for elevated temperature properties as per EN10269.				HY 10766 Rev. 11	HY 10766 Rev. 11		√	2	-	1	Guarantee certificate shall be submitted
10.	Packing, marking & color code	Packing & marking	Major	Hard punching & colour code	All bars	HY 10766 Rev. 11	HY 10766 Rev. 11			2	-	1	
11.	Verification & Certification	Documentation	major	Verification	All bars	HY 10766 Rev. 11	HY 10766 Rev. 11	TC	√	2	-	1	Endorsement of all documents by TPIA

Note:

1) This SQAP is applicable along with BHEL approved frozen Manufacturing Process Plan (MPP) only.
2) Additional requirements as per BHEL customer / project and purchase order will also be applicable.
3) This SQAP is not applicable for first time supplies of the material as per HY10766, for which a separate MPP and QAP shall be submitted. In such case process qualification requirements will be also be applicable.
4) The following shall be ensure & certified:
   a. Size & Length of each bar as per purchase order.
   b. Straightness of all bars.
   c. Defect free surfaces.
   d. Marking & punching on all bars.

Legend:	Prepared by	Approved by	#Vendor's confirmation
• P Perform; W Witness; V Verification; • Indicate 1 for BHEL or BHEL nominated Inspection agency & 2 for vendor/sub vendor as appropriate against each component /characteristic under P, W & V columns. • * For items marked √ (tick) in column D, test certificates shall be submitted to BHEL for records.	Signature and Stamp सचिन कटियार Sachin Katiyar वरिष्ठ अभियंता / गुणवत्ता आश्वासन Sr. Engineer / Quality Assurance एच.ई.एल. हैदराबाद, BHEL,HYD-32	Signature and Stamp QUALITY ASSURANCE BHEL HYDERABAD B.Ashok Kumar AGM / QA 8-7-21	Signature and Stamp

#To be submitted along with the technical offer.