HEAT RESISTANT STEEL BARS FOR TURBINE BLADES
Grade X19CrMoNbVN11- 1

1.0 GENERAL:

This specification governs the quality of steel bars in steel grade X19CrMoNbVN 11-1(material no. 1.4913).

2.0 APPLICATION:

Bars are required for machining of guide and moving blades for steam turbine.

3.0 CONDITION OF DELIVERY:

Bars shall be supplied in hot rolled or forged and milled, heat-treated condition. The bars should be straight and free from waviness.

4.0 COMPLIANE WITH NATIONAL/INTERNATIONAL STANDARD:

Based on TLV 9367/05

5.0 DIMENSION AND TOLERANCES:

Unless otherwise stated in purchase order, bars shall be supplied in length of 3 to 6 meters with maximum 10% short down to 1 meter.

Tolerances shall be as per Table 1.

6.0 GENERAL REQUIREMENTS:

The manufacturer must demonstrate that he has implemented a quality system that meets the requirements stipulated in ISO 9000. The stipulations of the present purchasing specification apply for all the manufacturer's productions shops, as well as their sub-suppliers. Any manufacturing steps given to sub suppliers must be got approved from BHEL in writing. When

qualification" must be performed. Separate process qualification is required for each fabrication facility of the manufacturer.

For cross sections or semi-finished parts that have not been delivered to date, it must be agreed to with the BHEL as to whether or not a process qualification is needed.

Before starting the production, the manufacturer shall submit the following documents to BHEL:

- A manufacturing and inspection sequence plan (MIP) released after the prototype qualification, establishing the quality assured sequence of operations, of heat treatment and the inspection program. Information about internal and external specifications is also given in the MIP. BHEL may review the manufacturers internal MIP. Every change in the MIP needs written release by BHEL. Also any manufacturing steps given to a subcontractor must be released by BHEL. The release of manufacturing or inspection processes by the BHEL or the subsequent approval to changes of the MIP shall not influence the supplier's responsibility for the manufacturing process and the product quality.
- Test instructions for non – destructive testing which are performed as part of his own quality assurance measures. The test instructions shall include precise information on the test, illustrated by sketches if necessary. General references to other specifications are not sufficient.

7.0 MANUFACTURE:

7.1 General:

Degassed steel, e. g. vacuum treated steel shall be used. The use of any other steel treatment shall be agreed upon in advance with BHEL in each individual case.

Ingot castings shall be used for manufacturing of these bars.

7.2 Prefabrication from Bar Material:

If semi -finished parts are cut from the bar material, (rough part dimensions of the blade), sections shall only be cut in the longitudinal direction.

The cross section of the bars and the partitioning used shall be stipulated in the MIP.

7.3 Heat Treatment:

Bars shall be delivered in quenched and tempered condition.

Quenched: 1100 – 1130°C / air or oil

Tempered: 670 – 750 °C, min 2 hours

Minimum residual stress shall be achieved by selecting sufficient tempering times and slow

cooling rates after tempering. Heat treatment of bundled items is not permissible. If it is necessary to straighten bars after the heat treatment, stress relief annealing is mandatory after completion of the overall straightening process. Stress relief annealing shall be performed at 20-30°C below the tempering temperature and with a slow cooling rate.

Process parameters shall be selected with a view to achieving the lowest possible residual stresses. Distortion of the finish machined part caused by slight residual stresses from the rolling and heat treatment process shall not occur.

8.0 PROPERTIES AND TESTS:

8.1 Chemical composition:

Heat analysis in weight %

C	Si	Mn	P	S	Cr	Mo
0.17 – 0.23	**≤0.50**	**0.40 – 0.90**	**≤ 0.025**	**≤ 0.015**	**10.0 -11.5**	**0.50 – 0.80**

Ni	V	Nb	N	B	Al
0.20 – 0.60	**0.10 – 0.30**	**0.25 – 0.55**	**0.05 – 0.1**	**≤ 0.0015**	**≤ 0.020 (≤ 0.010 to be aimed)**

8.2 Properties and structure:

Specimen extraction is to be done as per attachment 1 and 2. The specimens are to be taken in longitudinal direction (Attachment 1 and2).

To determine metallurgical properties, a minimum area of 320mm^2 must be examined.

The positions of the specimens given in the attachment are meant to serve only as an example. Details concerning the locations of specimens, both at bar material and at semi - finished parts made of bar material, are to be agreed upon by BHEL and must be given in the MIP, including a sketch of the specimen location.

8.2.1 Mechanical Properties:

The mechanical properties shall be determined after all heat treatment steps are finished (including a possible stress relieving). They shall be determined on the hardest and softest bar per melt and heat treatment batch. If the cross section are > 200cm^2 then the mechanical properties must be determined both in the centre of the bar and at the side of the bar (attachment 2). It shall be ensured that the required mechanical properties are achieved throughout the entire bar cross section. With the exception of toughness, the difference in properties across the bar cross section shall not exceed 7.5%.

Tensile testing shall be conducted according to EN 10002 resp. ASTM E8M (round tension

test specimen with L_0 = 50 mm and d_0 = 10 mm) or ASTM E8 (Standard specimen" per drg. 8). Impact testing shall be performed with standard test pieces with V-notch according to EN 10045. The following properties at room temperature must be demonstrated by the following tests:

0.2 % Yield strength (N/mm^2)	≥ 780
Tensile Strength (N/mm^2)	900 – 1050
% Elong. (l_0 = 5 d)	≥ 12
R A (%)	≥ 40
Impact energy (J)	≥ 20 *
Hardness (HB)	265 - 310

* Average of 3 specimens and minimum value for two specimens per EN 10021, where the lowest value shall be at least 14 J.

The uniformity of the strength of the bars of a given delivery (per melt and heat treatment batch = test unit) shall be verified by a hardness test per ISO 6506 -1. Hardness tests are to be performed after all heat treatments (including a possible stress relieving) are undertaken. HBW 10/3000 or HBW 5/750 shall be used. The hardness tests shall be performed on 10% of each test unit, however on at least 10 bars, or if the test unit comprises less than 10 bars on every bar.

The greatest permissible difference in hardness shall not exceed 35 HBW. Mechanical properties shall be determined on the hardest and softest bar identified by this test.

8.2.2 Microstructure:

- The examination of 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:
- Delta ferrite content: < 5%

(Determined in a manner consistent with the evaluation technique described in

ASTM E 45 / Method A, "Worst Field Method" at V = 100, specimen orientation: longitudinal.

The distribution and size of delta ferrite must be such that it does not result in indication in magnetic particle testing of the ready-machined surface.)

- Inclusion content per ASTM E 45/Method A.
  - "Thin series" inclusions: Type A, B, C max.2, Type D max. 2.5
  - "Heavy series" inclusions: Type A, B, C, D max 1.5
  - Maximum number and size of globular inclusions (Type D):

  $IR(D) = n1 + 2.5n2 \leq 10$

  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. Inclusion and cavities, which are > 75 µm are not allowed.

The grain size must be measured at the softest and the hardest bar after all heat treatments are performed. The following properties must be achieved:

- Grain size 4 or finer per ASTM E112 or ISO 643. A deviation from the average grain size of more than 2 grain sizes is not permissible.

8.3 External and internal Quality / Non-destructive Testing:

8.3.1 Test Scope:

The following NDT inspections shall be performed after all heat treatments are performed:

- Visual inspection of all bars
- UT of all bars as per SEP 1923, inspection number D3 or D2 with dual (twin) crystal search unit. 100% of the volume shall be examined with the stipulated recording level.

8.3.2 Criteria for recording limits and decision on further use:

a) Surface defects:

Indications 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 approximately 250 mm to check the extension below the surface.

Surface defects with extension ≥ 1mm below the surface not permissible.

b) Ultrasonic Test:

Criteria stipulated in SEP 1923 quality class 2 b shall be applied with following modification: EE (single echo) and VE (numerous single echoes) without extension ≥ 2 mm EFS not permitted.

Defects above the recording limit shall be marked and it shall be ensured that these bars are not included in the lot delivered.

BHEL shall receive written confirmation that all bar sections that contain defects above the recording limit were cut out of the respective bars.

8.4 Material Identity Test:

An identity test must be conducted in the as – delivered condition. The inspection scope is:

Bars: 100%

Cut pieces: 10%

In case that cut pieces are made from the bars then the marking must be performed directly after cutting to prevent any mix-up from occurring during the subsequent processes.

9.0 Identification Marking:

All bars are to be marked with purchase order number, size, material designation and supplier's identification. The details are to be clearly stamped and encircled by oil paint. Each bar shall be painted with gold colour at one end. All the bars shall be suitably packed to protect them against corrosion and damage during transportation.

Bars having maximum and minimum hardness (from which test samples are taken) shall be clearly marked by oil paint for easy identification. Their respective hardness values shall also be punched on these bars.

10.0 Documentation:

Prior to, but in no case later than the delivery of the material, an inspection certificate as per EN 10204 shall be provided to BHEL in duplicate; this certificate must contain the following data:

(a) Material code no and P.O. number

(b) Material designation

(c) Heat no., heat analysis and melting methods

(d) Mechanical test results including hardness range and the metallurgical examination.

(e) Complete information on all heat treatments performed.

(f) Results of NDT tests performed.

(g) Confirmation of material identification check

(h) Confirmation of dimensional and visual check

11.0 Non Conformances:

Any non-conformances with this delivery specification must be reported to BHEL immediately using a Non-conformance Report as per Appendix 6.

A non-conformance is considered accepted only if BHEL has agreed in writing to approve or tolerate.

In case of non-conformance with specified properties, BHEL is entitled to reject the material supplied even if proof testing was not called for.

12.0 Release:

Release is based on the collective result of all tests performed. Release does not relieve the manufacturer from his responsibility for hidden defect that are discovered at later stage of manufacturing.

13.0 Process Qualification:

For other than Siemens approved suppliers, a process qualification is required before starting production for the first order. Qualification review shall be performed jointly by BHEL and supplier.

This initial process qualification is required for each fabrication facility. The fabrication and inspection parameters stipulated during this phase form the basis of the manufacturing and inspection sequence plan (MIP) which the supplier prepares at his own responsibility. Manufacturing is commenced after release by BHEL and depends on the result of the qualification review. If necessary, the manufacturing parameters are to be further optimized.

Unless otherwise stipulated by BHEL, the process qualification shall also be required for the first three orders in addition.

If desired, process qualification can also be called for as verification of the reliability of fabrication.

In addition to the scope of testing and examination stipulated in this purchase specification, the following tests and examinations shall be performed (Attachment 3):

- Tensile tests and impact test[1)]
- Determination of FATT (Fracture Appearance Transition Temperature) according to ASTM A370, FATT < 25° C must be achieved; testing scope no less than 10 specimens.

• Magnetic particle testing [2)]

The distribution, type and size of micro structural in-homogeneities (e.g. segregation and δ ferrite) shall not cause MP indications.

[1)] Specimens in transverse direction for information. If it is not possible to take standard specimen in transverse direction, the following specimen shall be used:

• For tensile testing, a round tensile test specimen of $L_0 = 5\ d_0$ or sheet type specimen with a coefficient of proportionality of k = 5.65 shall be used. If ASTM E8 is applied, small size specimens per Fig. 8 may be used.

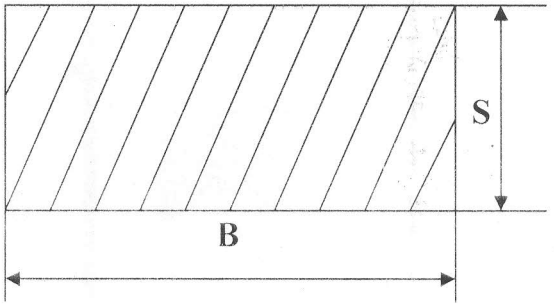
• For impact testing, a subsidiary test piece according to EN 10045 shall be used.

Any size or geometry deviating from the standard specimen must be indicated in MIP.

[2)] = magnetic flux leakage technique, phase shifted alternating current, field strength 20 -65 A/cm.

14.0 <u>Cross Referred Standard:</u> EN ISO 9000ff, EN 10002-1, ASTM E8M, ASTM E8, EN10045, EN10021, EN ISO 6506-1, ASTM E112, DIN 50601, ASTM E45, SEP 1923, EN 10204, ASTM A370, MUN 106.2/1.

Table 1



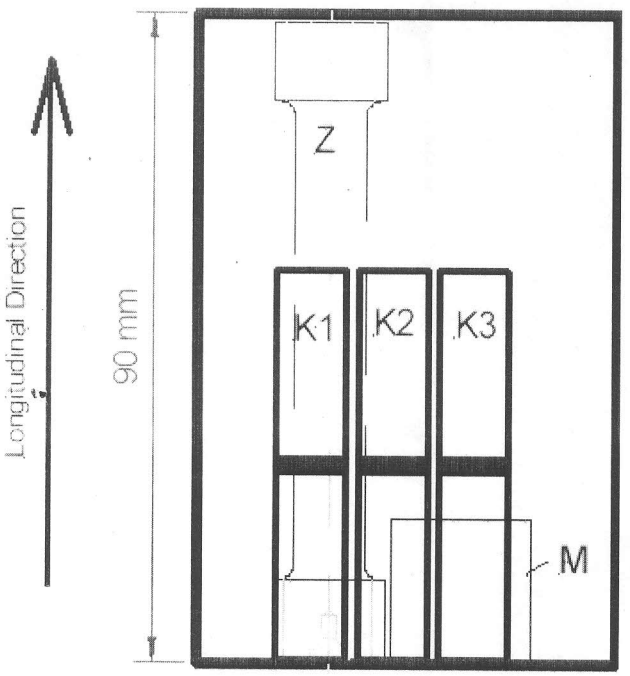
B, width across flats (mm)	Allowable deviation on B, mm	S, thickness (mm)	Allowable deviation on S, mm
B ≤ 35	+1.5	S ≤ 20	+ 1
35< B ≤ 75	+ 2	20< S ≤ 40	+ 2
B > 75	+ 3	S > 40	+ 3

Note: Other tolerances shall be as per DIN 1017. Twisting & bending of the bars shall not exceed 0.001 X length of the bar. Bulging on the sides shall not be more than 0.01 X B and 0.02 X S respectively.

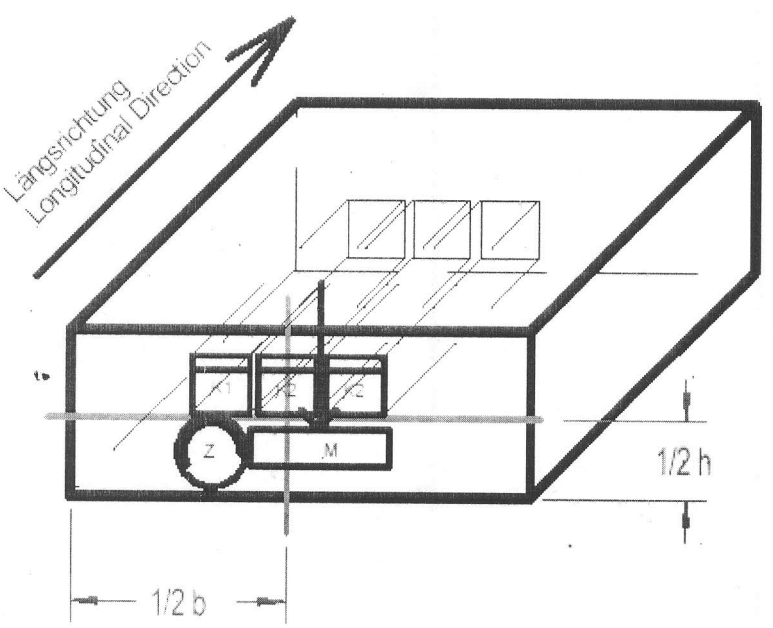
Attachment 1

Standard Testing **Cross Sectional Area ≤ 200 cm²**

Make sure that all specimens are located in the middle of material.



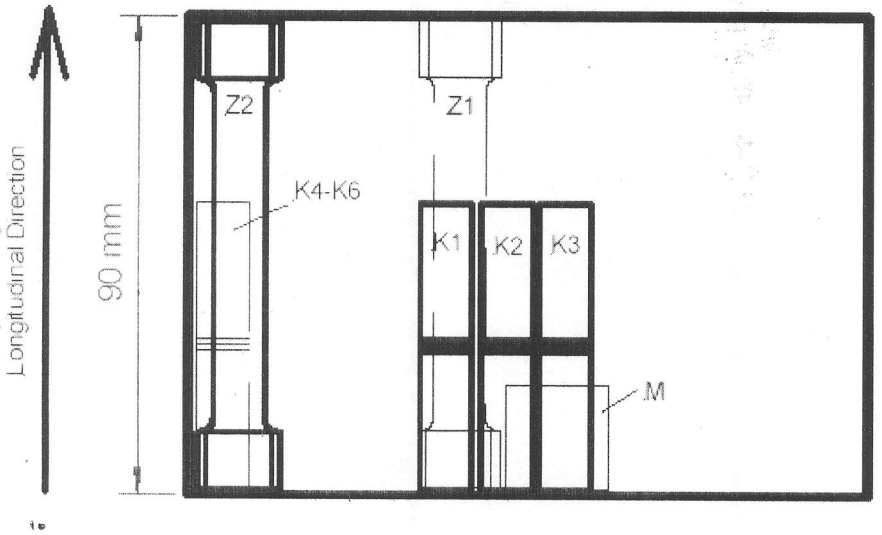
Z	Tensile Specimen
K1 – K3	Charpy Impact Specimen
M	Microspecimen

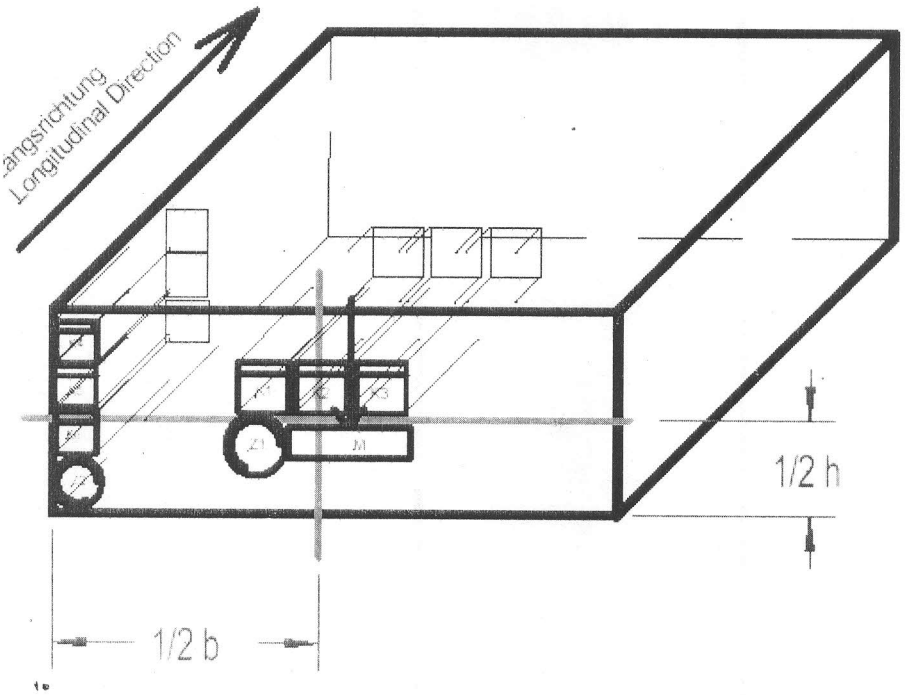


Attachment 2

Standard Testing (Cross-sectional Area > 200cm^2)

Make sure that all specimens are located in the middle of material.





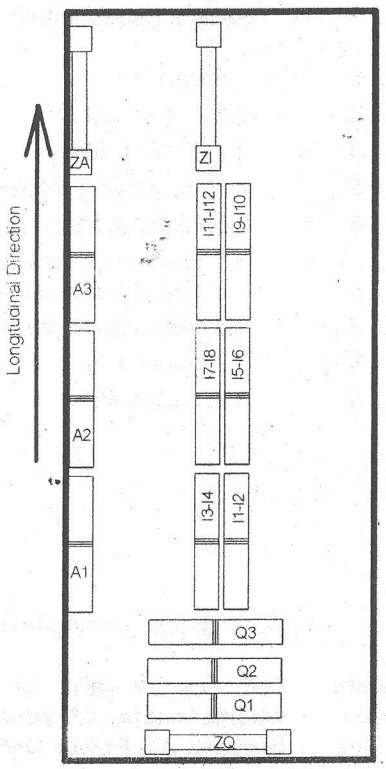
Z 1 Z2	Tensile Specimen
K1 – K6	Charpy Impact Specimen
M	Microspecimen

Attachment 3

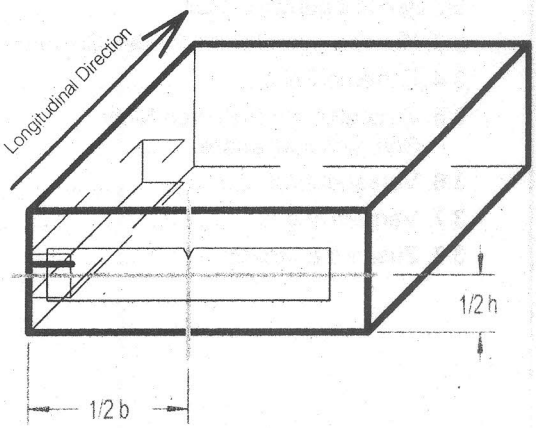
Page 1/2

Process Qualification

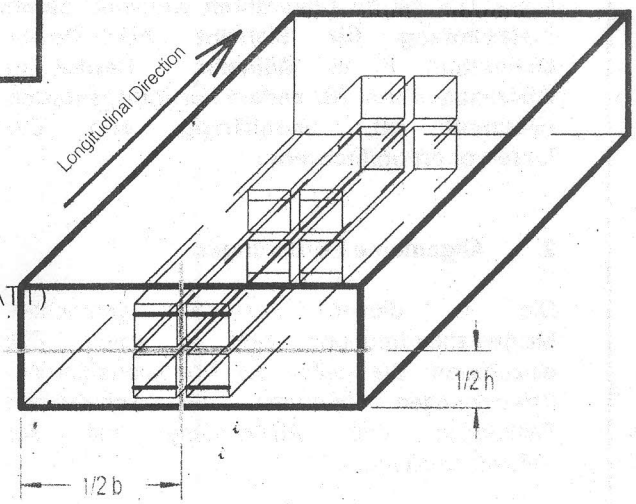
Make sure that all specimens are located in the middle of material.



Make sure that all specimens are located in the middle of material.



Charpy-Specimen for FATT-Testing

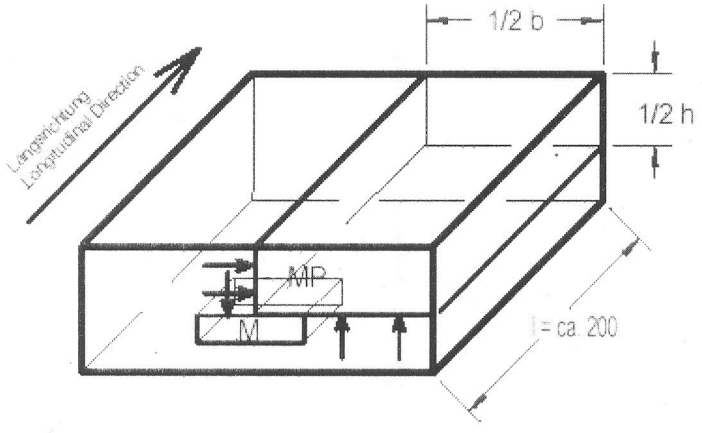


Z1	Tensile Specimen
I1 – I12	Charpy impact specimen (FATT)
ZA	Tensile Specimen
A1 – A3	Charpy Impact Specimen
ZQ	Tensile Specimen
Q1-Q3	Charpy Impact Specimen

Attachment 3

Page 2/2

Process Qualification



M Microspecimen

MP Specimen for Magnetic Particle Test