

ANNEX V

**TECHNICAL SPECIFICATIONS FOR
MANUFACTURE AND SUPPLY OF 60E2 RAIL
SECTION WITH “R350HTor R350LHT” CEN
STEEL GRADE OR “HIGH STRENGTH RAIL”
AREMA STEEL**

1. SCOPE

This technical specification refers to the manufacture and supply of 60E2 rail section having R350HT or R350LHT steel grade or alternatively having AREMA Steel Grade for High Strength Rail with Standard or Low Alloy Chemistry composition for use by the VALEC Engenharia, Construções e Ferrovias S.A., Brazil.

2. GENERAL REQUIREMENTS

2.1 Unless otherwise and to the extent specified hereafter, the rails shall comply in every aspect with the latest edition of EN 13674-1-“Vignole railway rails 46 kg/m and above” and some aspects with the “Properties of AREMA Rail Grades, Chapter 4-Rail, Part2-Manufacture of Rail” from the latest version of AREMA Manual for Railway Engineering. 2.2 The 60E2 steel rail section shall be made of steel Grade R350HT and R350LHT according EN 136741:2011 or alternatively the 60E2 steel rail section shall be made of AREMA Grades according High Strength Rail specifications. The manufacturing process shall be continuous casting and no other process shall be approved. 2.3 This specification is referenced to the technical requirements expressed by CEN standards and by the latest version AREMA Rail Manual standards. However, in cases where the requirements of this specification collide or are more stringent than the provisions already mentioned, they prevailed over those published international standards. 2.4 The rails steel shall be in accordance with EN 13674-1:2011, • Table 5a-Chemical composition/Mechanical properties,

- Minimum tensile strength: 1175 MPa
- Elongation minimum: 9%
- Maximum hydrogen content: 1.5 ppm in accord with AREMA 2006 item 2.1.7, continuous control;
- Hardness -point on the top of center line of rail head: 350 - 390 HBW
- Table 5b – Maximum residual elements

CEN Steel grade	% by mass								
	C	Mn	Si	P max	S max	Cr	Al max	V max	N max
R350HT	0,70 to 0,82	0,65 to 1,25	0,13 to 0,60	0,025	0,030	≤ 0,15	0,004	0,030	0,010
R350LHT	0,70 to 0,82	0,65 to 1,25	0,13 to 0,60	0,025	0,030	≤ 0,30	0,004	0,030	0,010

HT = Heat Treated and LHT = Low Alloy Heat Treated

CEN Steel grade	ppm by mass max.		Tensile strength R_m (MPa)	Elongation A (%) min.	Hardness of rail running surface centre line (HBW)
	O	H			
R350HT	20	1,5	1175	9	350 to 390
R350LHT	20	1,5	1175	9	350 to 390

2.5 The rails steel alternatively shall be in accordance with Chapter 4-Rail, Part2-“Manufacture of Rail” of AREMA Manual for Railway Engineering latest version,

- Table 4-2-1-4-1a and 2a-Chemical compositions,
- Table 4-2-1-4-1b and 2b-Minimum Surface Brinell Hardness: 370 HB
- Table 4-2-1-4-1c and 2c- Minimum tensile strength: 1190 MPa (171ksi)
- Elongation minimum: 9%
- Maximum hydrogen content: 1.5 ppm in accord with AREMA 2006 item 2.1.7, continuous control;

AREMA Steel grade	% by mass								
	C	Mn	Si	P max	S max	Cr	Al max	V max	N max
High Strength Standard Chemistry	0,72 to 0,86	0,75 to 1,25	0,10 to 0,60	0,020	0,020	0,30	0,010	0,010	0,250
High Strength Low Alloy Chemistry	0,75 to 0,82	0,70 to 1,25	0,10 to 0,50	0,020	0,020	0,40 to 0,70	0,005	0,030	0,015

AREMA Steel grade	ppm by mass max. H	Tensile strength (MPa)	Yeld strength (MPa)	Elongation A (%) min.	Minimum Surface Brinell Hardness (HB)
High Strength Standard Chemistry	≤ 1,5	1192 (171ksi)	837 (120 ksi)	9	370
High Strength Low Alloy Chemistry	≤ 1,5	1192 (171ksi)	837 (120 ksi)	9	370

2.6 All rail dimensional tolerances shall be in compliance with EN13674-1:2011 item 9.2

- Table 7 - Profile tolerances, profile class X.
- Table 8 - Straightness, surface flatness and twist tolerances, class A.
- Body vertical flatness $d \leq 0.3$ mm along a length of 3 meter and $d \leq 0.2$ mm along a length of 1 meter. • Body Horizontal flatness $d \leq 0.45$ mm along a length of 1.5 meter.
- End length - 2 meter.
- End vertical straightness $d \leq 0.4$ mm along a length of 2 meter and $d \leq 0.3$ mm along a length of 1 meter and $e \leq 0.2$ mm. • End Horizontal straightness $d \leq 0.6$ mm along a length of 2 meter and $d \leq 0.4$ mm along length of 1 meter.
- Overlap length -2 meter.
- Overlap length vertical flatness $d \leq 0.3$ mm along a length of 2 meter.
- Overlap length horizontal flatness $d \leq 0.6$ mm along a length of 2 meter.
- Whole rail upsweep and down-sweep 10 mm.
- Twist whole rail max. gap of 2.5 mm. Twist End Max. Rotational twist of 0.2° and max. relative twist of $0.0035xc$ (see EN13674-1:2011 fig. 11).

2.7 The standard length of rails shall be 18 meters. Rail tolerance shall be in according with EN13674-1:2011, Table 9. The surface condition and surface quality of all rails shall be in compliance with EN13673-1:201, surface quality requirements item 9.4.2.

2.8 Each rail shall be supplied undrilled at both of its ends. The squareness of rail ends tolerance shall be in accordance with EN136741:2011 Table 9.

2.9 The rail manufacturing process shall be complied with the requirements according with EN13674-1:2011, item 7.

2.10 The rails, R350HT and R350LHT, identification branding and stamping shall be according with EN13674-1:2011, item 7.4. The rails, High Strength Rail made by AREMA chemistry grade, identification branding and stamping shall be according with item 2.1.6 section 2.1 of the AREMA Manual.

2.11 The chemical composition adopted by the manufacturer shall guarantee total weldability of the rails (see paragraph 7 from this spec.).

3. QUALITY CONTROL AND QUALITY TESTS

The Manufacturer shall demonstrate compliance including documented evidence with the factory control system required. Manufacturers having a factory production shall submit together with his Proposal, a comprehensive quality control manufacturer instruction manual follow by ISO9001:2008 according EN13674-1:2011 and this technical specification.

4. QUALIFYING TESTS

4.1 The rails qualifying tests shall be in according to EN 13674-1:2011, item 8.

4.2 The manufacturer shall carry out qualifying testing on the 60E2 profile.

4.3 The manufacturer shall describe any bloom slow cooling or isothermal treatment process used to demonstrate compliance with the requirements.

4.4 The manufacturer shall give access to all test records, calibrations and calculations that contribute to the final results and the results for the steel grades to be supplied shall be provided at the time of tendering.

5. ACCEPTANCE TESTS

5.1 The manufacturer shall perform all the acceptance tests described in EN 13674-1:2011 item 9 and provide a complete set of results for these tests.

5.2 Chemical composition shall be in compliance with EN 13674-1:2011, item 9.1.3.

5.3 The microstructure shall be fully perlitic with no martensite, bainite or grain boundary cementite.

5.4. Testing frequency:

Test (on)	Reference in EN13674-1:2011	Steel Grades	
		R350HT, R350LHT	AREMA High Strength Rail
Chemical Composition	9.1.3	One per heat	One per heat
Hydrogen content	9.1.3.2	One per heat (2 test from first heat in sequence)	One per heat (2 test from first heat in sequence)
Total oxygen	9.1.3.3	One per sequence	One per sequence
Microstructure	9.1.4	One per 100 tonnes	One per 100 tonnes
Descarburisation	9.1.5	One per 500 tonnes	One per 500 tonnes
Oxide Cleanness b or c	9.1.6	One per sequence	One per sequence
Sulfur macro etch test a,b or c	9.1.7	One per 500 tonnes	One per 500 tonnes
Hardness a, c	9.1.8	One test per 100 tonnes	One test per 100 tonnes
Tensile strength/Elongation	8.7 and 9.1.9	One test per 1000 tonnes	One test per 1000 tonnes
Residual Stress	8.5	One finish rail from each 24 hours production	One finish rail from each 24 hours production
a - Samples shall be taken at random but only rails from blooms outside the mixing zone between heats when continuously cast in sequence. b - Samples shall be cut after rolling. c - Samples shall be cut from heat treated rails.			

5.5 The Manufacturer's acceptance tests process, shall also include the following tests and be subject to the following quality requirements:

5.5.1 Residual Stress Test - Free from Broken Rails at foot and Broken Welds from HSW (Horizontal Split Web Crack) Longitudinal residual stresses induced by roller straightening process at middle of rail foot shall be limited to a maximum of +200 MPa. The manufacturer shall guarantee this maximum level of residual stress in all rails delivered to VALEC. Vertical residual stress induced by roller straightening process at upper rail web region shall

be limited to a maximum of +50 MPa. Longitudinal and vertical residual stress shall be determined by strain-gauge instrumentations according to EN 13674-1:2011 item 8.5 methodologies. Test should be carried out by a certified laboratory and under VALEC approval. The point at the upper region of rail web to setup the strain-gages it will be under the head/web filet at the distance ($h_3 - 20\text{mm}$) fig. A.24 in EN13674-1:2011. Rail samples to residual stress test shall be taken from the longest length rail produced by the manufacturer 3 meters from the rail end. One finished rail from 24 hours production shall be subjected to residual stress testing. One rail shall also be tested after each roll change or mechanical adjustment of the roller straightener. The result of the tests will be reported to VALEC which will have total access to all test records.

Alternatively, tests of residual stress will be performed for the rail web and for the rail foot as follows:

It will accepted the maximum value of +250 MPa for residual stress in the rail foot, according to the provisions in item 8.6 of EN13674-1/2003, and all the other tests listed in this standard shall be performed, especially items 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6 of this standard. For purposes of testing it is applied the sampling of standard considering the size of a remittance batch equal to each supply portion. Also be applied as set out in Annex B of this EN 13674-1-2003. For the residual stress in the rail web, according to 2.1.13.2 and 2.1.14 item's AREMA 2009, for each sample, considering the size of a lot like each supply portion.

5.5.2 Oxide Cleanness Evaluation (Steel Cleanliness) - Free from Detail Fractures from Rail Shelling and RCF Cracks. The metallurgical cleanliness of the rail steel (nevertheless R350HT or AREMA steel grades) shall be determined from samples taken from the finished rail section. One sample from each heat of steel or sequence shall be tested according EN 13674-1:201, item 9.1.6, figure 8 and the EN 10247. A minimum of every tenth heat must be tested. VALEC reserves the right to require 100% testing of all heats should it is deemed necessary. In case of dispute or if test specimen fails to meet the required micro cleanliness of EN 13674-1:2011 standards the following micro cleanliness limits can be adopted:

- a) Mean particle size: The mean particle size shall not exceed $30 \mu\text{m}^2$;
- b) Particle length: The length of any inclusion in the transverse direction shall not exceed $10\mu\text{m}$;
- c) Particle width: The width of any inclusion in the transverse direction shall not exceed $10\mu\text{m}$;
- d) Inclusion count density: The total inclusion count density shall not exceed $100 \text{ particles}/\text{mm}^2$;
- e) Total area fraction: The total sample area shall contain no more than 0,100% of inclusions.
- f) Total number of inclusions: The total number of inclusions per sample shall not exceed 250 in number.
- g) If any specimen fails to meet these limits, two additional specimens shall be taken one from the rail in front and one from the rail in back of the original specimen and the rail between the two retest positions shall be rejected. If any retest specimen fails, testing shall be continued in a similar manner until a rail with acceptable quality is exhibited.

5.5.3 Macro etch Segregation Test - Free from broken rails due VSH (Vertical Split Head Crack) and Piped Rail (Web Internal Crack)

Segregation tests shall be assessed and classified according item 8.8 and limiting figures of annex D in EN13674-1:2011 A test piece shall be macro etched representing a rail from each strand from the beginning of each sequence of continuous cast steel and whenever a new ladle is begun, which is the point representative of the lowest level in the tundish (i.e. the point of lowest ferrostatic pressure). One additional sample from the end of each strand of the last heat in the sequence shall also be tested. A new tundish is considered to be the beginning of a new sequence. Upon receipt the VALEC representative has the right to examine any rail from any part of a heat at his option, and if the VALEC representative determines that the rail sample selected is rejectionable, the entire heat shall be reevaluated according to the following criteria below:

- a) If any specimen fails to meet the macroetch standard for interior quality, two additional samples of rail representative of the same strand shall be obtained;
- b) If any retest fails, testing shall continue until acceptable internal quality is exhibited;
- c) All rails represented by failed tests shall be rejected

In the event that there is a question of seriousness of the indication, further examination may be performed at high magnification.

- a) Inspect sample with stereo microscope up to 5x;
- b) A polished sample may be inspected at 100x for metallographic interpretation

5.5.4 Ultrasonic Test - Free from internal defects Ultrasonic tests shall be performed on 100% of the rails, by a continuous process ensuring that the entire length and specified cross-sectional area is inspected with particular emphasis on the rail ends. The technique used shall ensure that a minimum cross area shall be covered by the inspection is no less than: (a) 70% of the head. (b) 60% of the web. (c) All the central part of the foot included below the maximum width of the web. These areas are based on projecting the nominal crystal size of the probe. The rail head shall be tested from both sides and from the running surface. The method of inspection shall be subject to approval by the VALEC. Together with the proposal, a detailed description of the ultrasonic test method he intends to employ, including the locations and dimensions of the artificial defects in the rail head, web and foot shall be submitted. Where the testing system cannot cover the rail ends, separate ultrasonic manual tests shall be performed on each side of the rail ends.

5.5.5 Rail Surface Condition - Free from Hot marks, Protrusions, Cold Scratches All rails shall be inspected visually on four sides and both ends to ensure free of injurious defects. All foreign material that tends to hide surface imperfections shall be removed by manual means prior to the inspection for acceptance. Rails with any protrusion of excess metal extending from surface of the rail, such as those caused by a hole in a roll or a roll parting in the web, will be rejected if the protrusion affects the fit of the joint bar, or causes the fishing template to stand out more than 1.6 mm laterally. Rails with any protrusion in the web greater than 1.6 mm high and greater than 323 mm² in area will be rejected. No protrusions of excess metal will be permitted on the running surface of the rail or on the bottom surface of the base. All protrusions on the running surface or the underside of the foot shall be dressed.

5.5.6 Free from Surface Microstructural Damage (Dressing out at protrusion spots) Any sign of surface microstructure damage resulting in martensite or white phase shall be dressed or the rail shall be rejected. The dressed area shall be proved by appropriate hardness. The hardness of the dressed area shall not exceed that surrounding area by more than 50 HB.

5.5.7 Free from Surface Imperfections (Automated head/foot inspection) Each rail shall be continuous and automatically inspected on all faces for surface imperfections. The equipment used shall be able to detect surface imperfections on the underside of the foot with sizes as shown in the table below:

Dimensions of test imperfections (mm)		
Depth	Length	Width
1,0	20	0,5
1,5	10	0,5

For artificial imperfections, a tolerance of +/- 0,1mm shall apply. A detailed description of the automatic test method intends to employ, including the locations and dimensions of the artificial defects in the rail head and foot shall be submitted by the manufacturer to VALEC.

5.5.8 Decarburisation Decarburisation tests shall be assessed by hardness test of 0.5 mm depth according item 9.1.5 in EN13674-1:2011.

5.5.9 Tensile strength and elongation tests Monitoring and management procedures for execution and calculations procedures reports of tensile strength and elongation shall be submit according item 8.7 in EN136741:2011.

6. LABORATORY CERTIFICATES The laboratory performing the qualifying and acceptance tests shall be certified with at least the following certifications:

- A laboratory certified in accordance with ISO/IEC17025 in the field of steel quality testing.
- A laboratory accredited by national laboratory accreditation authority in the field of steel quality testing.

7. WELDABILITY - RAIL WELDING REQUIREMENTS

7.1 The chemistry composition adopted by the manufacturer shall preserve the weldability of the rails. To accomplish this purpose the Carbon Equivalent (CE) of the High Strength Low Alloy chemistry (AREMA steel grade) must be held below and it should not exceed the value of 1,25.

7.2 The manufacturer shall inform to the representatives of VALEC his own formula to determine the Carbon Equivalent, or the CE value will be defined by the following formula: $CE = C\% + \%Mn/6 + \% (Cr+V+Mo)/5 + \%(Ni+Cu)/15$.

7.3 The manufacturer shall send with the first shipment a metallurgical specialist to some VALEC properties, in order to perform the welding machine (flash-butt) setup for his rail steel grade.

7.4 The manufacturer shall submit process for welding rails (mobile flash-but and aluminothermy process) with R350HT grade and for welding of two rails one with standard carbon chemistry and the other R350HT. The same welding requirements shall be performed in regard to the High Strength Rails from AREMA steel grade.

8. INSPECTION BY REPRESENTATIVES OF THE VALEC

8.1 The VALEC will appoint a representative who shall inspect the manufacturing processes and the quality control tests, as specified in EN13674-1:2011 and in this technical specification. The manufacturer shall extend to the said VALEC representative all necessary assistance and cooperation.

8.2 The manufacturer shall be responsible to coordinate inspection schedule with the VALEC.

8.3 The manufacturer shall report all qualifying and/or acceptance tests results to VALEC representative for approval for every order.

9. LOADING AND PACKING OF THE RAILS

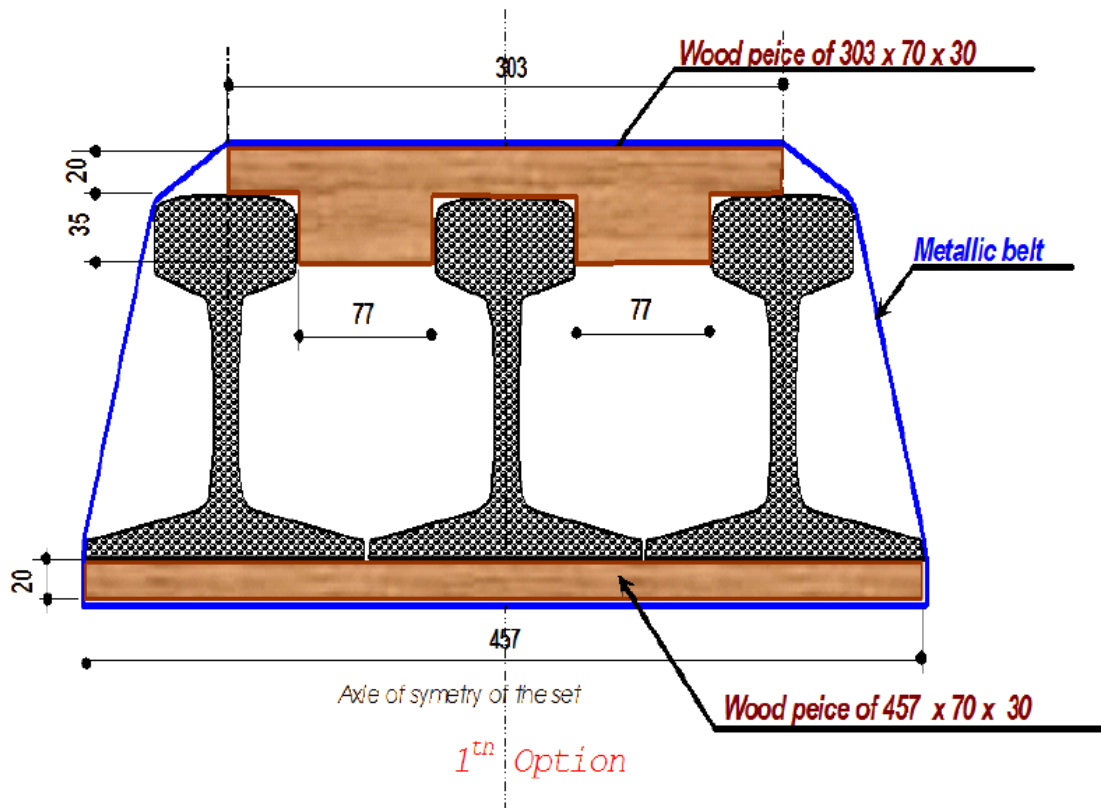
9.1 All rails shall be handled carefully to avoid mechanical damage on foot and rail head and shall be loaded head up with wood timbers between layers, and the branding marks on all rails facing the same direction.

9.2 The use of chains in direct contact with rail is prohibited.

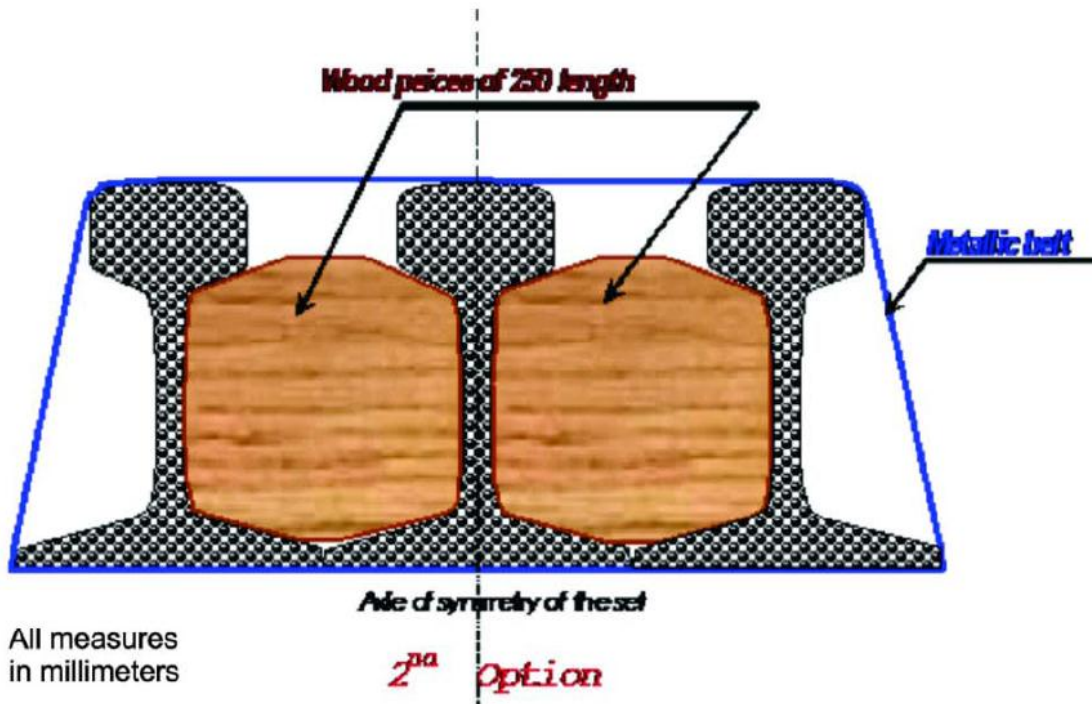
9.3 Rails of different lengths (short) shall not be accepted. It is understood that short rails are those that are outside the tolerance specified in item 2.7.

9.4 The manufacture shall make a description of the method of handling, loading, securing, transporting, unloading and stockpiling the rail. Include such working drawings and illustrative sketches as necessary to clearly show the stacking and securing arrangements, and any other features of the work.

9.5 Appropriate spaces shall be kept between the rails on the ship in order to enable unloading with a similar device. It is recommended the use of rails packed in fastening of 03 (three) rails with metallic tape and wood spacers. The maximum distance between each set of wood and tape shall be of 3,00m. The rail heads shall be faced upwards. The fastening shall be in accordance with one of the following illustrated options below:



Note: Alternative packaging may be proposed for approval.



All measures
in millimeters

10. LIST OF DOCUMENTS TO BE SUBMITTED IN QUALIFICATION

10.1 The manufacturer shall submit documentation demonstrates continuing compliance, including documented evidences, with the factory production and control system complies with EN 13674-1:2011 and ISO9001:2008.

10.2 The manufacturer shall submit the following certificates of the laboratory where all the tests should be carried out: • A laboratory certified in accordance with ISO/IEC17025:2005 in the field of steel quality testing, or • A laboratory accredited by international accreditation authority in the field of steel quality testing.

10.3 The manufacturer shall submit 05 (five) qualifying tests reports from the last five years and the test records, reports, calibrations and calculations that contribute to the final qualifying results EN 13674-1:2011, item 8 or version of the same European Standard in effect at the time of tests.

10.4 The manufacturer shall describe any bloom slow cooling or isothermal treatment process used to demonstrate compliance with the requirements in EN13674-1:2011, item 9.1.3.2.

10.5 The manufacturer shall submit the results for the steel grade to be supplied at the time of tendering, EN13674-1:2011, item 8.1.2.

10.6 The manufacturer shall submit a detailed description of the ultrasonic test method he intends to employ, including the locations and dimensions of the artificial defects in the rail head, web and foot.

10.7 Technical references - a list of FREIGHT RAILROADS supplied with rails from the bidder in the last five years must be present for qualification.

11. INSPECTION TEMPLATES

11.1 The drawing of rail cross section shall be submitted by the manufacture soon after the order is concluded and all templates describe in item 9.3 and annex E of EN13674-1:2011 and necessary to carry out the rail inspection shall be furnished by the manufacturer at his own expense.

11.2 Two sets of templates and profile gages will remain with VALEC representatives, one set at manufacturing plant and the other one at the point of reception of VALEC facility in Brazil.

12. GUARANTEE

12.1 The Rails shall be guaranteed by the manufacturer against any manufacturing defects which were undetected during acceptance.

12.2 If, during the guarantee period, one or more of more of the rails have to be removed from service due to a fracture or other defect, either VALEC or joint inspection with the manufacturer will be performed. Specialist analysis may be done to determine the root cause of the problems.

12.3 VALEC shall undertake to place at the manufacturer's disposal, on request, sample portions cut from the defective rails for the purpose of the examination mentioned above. The sample portions will be cut at positions selected by the manufacturer, in order that he may investigate the causes of the defect.

12.4 The manufacturer will have a period of 30 consecutive days to present a report on his observations, counting from the date of notification assuming all costs to perform the necessary tests and submit the results to VALEC through report on its investigation.

12.5 The rails shall be guaranteed by the manufacturer against harmful inclusions, sulfur segregations, grooves and intern cracks. However they will not be guaranteed for RCF (Rolling Contact Fatigue).

13. GUARANTEE REQUIREMENT

13.1 If there are discrepancies in the results, new tests will be performed in an institution mutually agreed between the supplier and VALEC.

13.2 The results of these tests will be considered as final by the parties.

13.3 The rails that should be replaced by the hired company and that have not been removed within 30 days from the date of substitution become property of VALEC without any cost to VALEC.