A division of Transnet SOC Ltd

ICTM (TRACK TECHNOLOGY)

SPECIFICATION S170

FLASH BUTT WELDING RAILS

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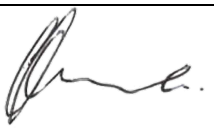
Author:	T. Sitimela (Pr.Eng.)	Engineer Rail Network Technical	
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Circulation restricted to: Transnet Freight Rail

Transnet and Relevant Third Parties

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AMENDMENTS TABLE

VERSION NO.	AMENDMENT ACTIONS	CLAUSE NUMBER	DATE REVISED
06-00	Remove AREMA specification from the document - Change reference from EN 14587-1,2:2009 to EN 14587-1,2:2018	References clause 2.0	2022/03/15
06-00	Remove clause 3.4: Composite rails - Remove clause 3.9: H.C.O.B - Add clause 3.11: Principal Engineer Definition -	Definition clause 3.0	2022/03/15
06-00	Addition of Table 1	Rail Identification clause 4.0	2022/03/15
PART 01			
06-00	Addition of "The major overhaul shall be as defined in the supplier's equipment maintenance strategy."	2.1	2022/03/15
06-00	Addition of "The stripping of the upset metal on the welded joint shall be automated to within thirty(30) seconds after completion of the welding cycle without any residual flashing material"	2.6.1	2022/03/15
06-00	Addition of clause 4.1 and 4.2	4.0	2022/03/15
06-00	Addition of Table 2	4.4	2022/03/15
06-00	Revised tolerance from 0.8mm to 0.5mm	5.7	2022/03/15
06-00	Addition of clause 6.3	6.3	2022/03/15

06-00	**Removal of PART 2**		2022/03/15
06-00	**PART 3**		
06-00	Addition of Table 6	2.4	2022/03/15
06-00	Addition of Table 7	3.4.1	2022/03/15
06-00	Removal of clause 3.4.3	3.4.3	2022/03/15
06-01	Amendment of bend test loads for rail profiles and grades on Table 6	2.4	2023/01/25

LIST OF TABLES

1.0 SCOPE

1.1 This specification covers the requirements for flash butt welding of flat bottom rails in the welding workshop (using a fixed flash butt welding facility) and using the mobile flash butt welding machines.

1.2 The scope of Part 1 covers the flash butt welding of:

- New flat bottom rails using the workshop or fixed facilities.
- New flat bottom rails using the “on track” or temporary fixed facilities.

1.3 This specification supersedes all previous published versions.

2.0 REFERENCES

2.1 EN 14587-2 “Railway Applications-Track- Flash butt welding of rails-Part2: New R220, R260, R260Mn and R350HT grade rails by mobile machines at sites other than a fixed plant”, December 2018.

2.2 E-11-041AB “Technical specifications for the Flash Butt Welding of Rails by Mobile Welding Machine”, October 2009.

2.3 EN 14587-1 “Railway Applications-Infrastructure- Flash butt welding of new rails-Part1: New R220, R260, R260Mn, R350HT, R350LHT, R370CrHT and 400HT grade rails in a fixed plant”, December 2018.

2.4 BBF 9298 Procedure for ultrasonic testing of flash butt welded joints for quality control purposes

3.0 DEFINITIONS

3.1 Long rails: These are rails of a minimum length of 36 meters.

3.2 Long welded rails: These are rails welded together into lengths longer than 36 meters to a maximum of 240m

- Rails used in obtaining the required lengths as per clause 3.1 and 3.2 may be of any length subject to a minimum of 18 m. These rails must be of same mass, section, and chemical composition, unless a written approved concession is granted by the Principal Engineer, Track Technology, or Infrastructure.

3.3 Junction rails: These are rails of different heights and profiles welded together.

3.4 Standard grade rail: These are grades of R260(grade 900) rails previously known as UIC A grade rails.

3.5 Head hardened rails: These are rails of various compositions, which have been heat treated to produce a hard wear resistant cap on the crown of the rail. The rails supplied will be of grade R350LHT,R370CrHT and R400HT.

3.6 Chrome manganese rails: These are R320Cr (grade 1100) rails containing approximately1% chrome and 1% manganese.

3.7 Inspector: This refers to an inspector appointed by the Principal Engineer.

3.8 UIC B and UIC C rails may only be welded with special written permission from the Principal Engineer.

3.9 Dip Joint: This is a phenomenon that occurs when the rail weld has sagged fromthe vertical straightness of the rail crown.

3.10 Proud Joint (Hog): This phenomenon occurs when the rail joint has been bend upwards in the vertical plane.

3.11 Principal Engineer – The responsible Engineering professional (Pr.Eng) from Rail Network or Technology Management.

4.0 RAIL IDENTIFICATION

4.1 Rail identification is done by the rolling marks and occasionally hot stampedmarkings that are present on the web of the rail.

4.2 Rails manufactured prior to 2000 will have the following information.

- Rolling Direction
- Nominal mass (kg/m)
- Steel grade
- Manufacturer's identification of bloom
- Year of manufacture (last two digits of the year)
- Receiving railway.

E.g.

4.3 Rails manufactured after 2000 will have the following information: Manufacturers' identification.

The year of manufacture (last two digits of the

year)The rail profile

The

steel

grade E

.g.:

Rolling Mill 01 60 E 1

4.4 The different grades of the rails that used in Transnet Freight Rail are given inTable 1.

4.5 There must be an approved works procedure for the different types of welding machines. The procedure must be submitted to Transnet Freight Rail's Principal Engineer (Pr. Eng.).

Table 1: Welding Identification of rail types (*BS EN 13674-1:2011+A1:2017 Railway*

applications — Track — Rail Part 1: Vignole railway rails 46 kg/m and above)

Steel grade [a]		Hardness range (HBW)	Description	Branding lines
Steel name	Steel number			
R200	1.0521	200 to 240	Non-alloy (C-Mn) Non heat treated	No branding lines
R220	1.0524	220 to 260	Non-alloy (C-Mn) Non heat treated	———
R260	1.0623	260 to 300	Non-alloy (C-Mn) Non heat treated	— ———
R260Mn	1.0624	260 to 300	Non-alloy (C-Mn) Non heat treated	——— ———
R320Cr	1.0915	320 to 360	Alloy (1 %Cr) Non heat treated	——— ——— ———
R350HT	1.0631	350 to 390 [b]	Non-alloy (C-Mn) Heat treated	— ——— ———
R350LHT	1.0632	350 to 390 [b]	Non-alloy (C-Mn) Heat treated	— ——— ——— —
R370CrHT	1.0992	370 to 410	Alloy (C-Mn) Heat treated	— ——— ——— ———
R400HT	1.1254	400 to 440	Non-alloy (C-Mn) Heat treated	——— ——— ———

PART 1: FLASH- BUTT WELDING OF VIGNOLE RAILS

1.0 PREPARATION OF RAILS FOR WELDING

1.1 DETECTION OF DEFECTS: No obvious surface defects shall be present after preparation and prior to welding.

1.2 CLEANING OF RAIL ENDS: The crown, the underside of the flange and the face of the rail (in case of the mobile flash butt welding machine, the web) shall be de-rusted and descaled using a shot blast cleaning method, or if not available, a grinding method. A minimum of 500 mm from the rail end shall be cleaned.

1.3 ROLLING MARKS: Care should be taken to ensure that all the rolling marks of the rails lie on the same side of the welded string.

1.4 No arcing during welding, due to insufficient contact between the rail and contact block, shall be permitted. All **arced joints** are to be **cut out** immediately.

2.0 FLASH BUTT WELDING.

2.1 Welding equipment to be used:

Only approved flash butt welding equipment shall be used. Transnet Freight Rail's Principal Engineer shall grant approval. Approval shall cease whenever a machine undergoes a major overhaul. The major overhaul shall be as defined in the supplier's equipment maintenance strategy.

Approval shall state:

- Machine identification.
- Type of rails that may be welded.
- Expiry date of certification.

2.2 There must be an approved work procedure for the different types of welding machines and an approval letter must be sent to Transnet Freight Rail's Principal Engineer before production welding can commence. The procedure must include all the welding parameters to be used by the machine.

2.3 Alignment of rails: Before flash butt welding of rails, rail ends must be aligned so that the crown and flange of both rail ends are in line.

2.4 Recording of welding parameters: The following flash butt welding parametersshall be recorded legibly and graphically for every joint made. The graphs shall be cross-

referenced to the actual joint and string number etc. These graphs shall be retained and easilyaccessible for a period of two years after the joint is welded. When the machine is not able to record parameters automatically an approved alternative way of recording should be implemented.

2.4.1 Primary welding current during each phase of the welding cycles.

2.4.2 Force applied in the longitudinal direction by the machine on the joint for eachphase of the welding cycle.

2.4.3 Movement of the non-fixed head of the flash butt welding machine during eachphase of the welding cycle.

2.4.4 The make and number of the flash butt welding machine.

2.4.5 The weld number of the joint.

2.4.6 Name and identification number of the machine operator and persons performing the controlled cooling of the joint, where applicable. The controlled cooling apparatus number shall be recorded in the local quality packet.

2.5 Numbering of joints:

2.5.1 Every flash butt joint shall be numbered uniquely.

2.5.2 This number shall be painted on the rail web within 300 mm of the joint. The letters shall be 75 mm high. The paint shall be of such a nature that it lasts “in the field” for a minimum of two years. Alternately the weld number may be punched on the field side of the crown with a punch. Care should be taken as not to introduce an initiation point for a crack.

2.6 Stripping of upset metal.

2.6.1 The stripping of the upset metal on the welded joint shall be automated to within thirty (30) seconds after completion of the welding cycle without any residual flashing material.

2.6.2 Delay before stripping the upset metal: The upset metal must be stripped within 30seconds after the welding cycle.

2.6.3 Amount of upset metal to be removed: The stripping system shall remove the maximum amount of upset metal without causing hollows in the rail profile. The stripper blades must be maintained in a good condition to eliminate stress

raisers.

3.0 CONTROL COOLING

3.1 All chrome manganese rails shall be post heated using approved equipment, procedures and operators as approved by Transnet Freight Rail's Principal Engineer or his authorized representative.

3.2 No control cooling procedures are to be used for the head hardened rails.

4.0 ROUGH GRINDING AND STRAIGHTENING OF WELDED JOINTS

4.1 All grinding shall be done by use of a suitable angle grinder using a conical grinding stone. All Flash Butt welded joints shall be straightened by means of a straightening press.

4.2 The joint shall not be straightenedbefore the temperature of the joint has dropped to below 50 degrees centigrade.

4.3 All flash butt joints shall be straightened to the tolerancesspecified in Part 1, clause 5.0

4.4 All Flash butt welds shall be tested by pressing downwards by 4mm and repressing back to correct alignment irrespective of the straightness. Any weld that fails shall be formally reported to Transnet Freight Rail's Principal Engineer.

4.5 No joint in excess of Table *2*alignment deviation shall be straightened. All such joints shall be rejected (See Figure 7).

Table 2: Permitted alignment deviations (*BS EN 14587-1:2018 Railway applications - Infrastructure - Flash butt welding of new rails, Part 01)*

Position of Steps on the rail	Maximum permitted step (in millimeters)
Vertically on the longitudinal centerline of the running surface	0,5
Horizontally on the aligned face or edge (14±1) mm below the running surface	0,5
Horizontally on the edge of the rail foot	2,0

5.0 FINISH GRINDING OF FLASH BUTT WELDED JOINTS

Alignment of flash butt joints after straightening and grinding. All flash butt welded joints shall be straightened and ground on the top and sides the crown to the tolerances specified below:

5.1 Position for measuring the alignment. Figure1 shows the position for measuring the vertical and horizontal alignment using the 1m and 100 mm straight edges.

5.2 Vertical alignment over 1 meter: On the running surface of the rail a 0.2 mm thick feeler gauge shall not enter at any point of a 1-meter straight edge placed centrally across the joint. Only a gradual sweep is permitted from the ends to the center of the straight edge. Alternately, the weld may be proud by allowing a 0.3 mm feeler gauge in at the higher end of the straight edge (See figures 2 &3). Vertical alignment over 100 mm: On the running surface of the rail, a 0.1mm thick feeler gauge shall not enter at any point over a 100-mm long straight edge placed centrally across the joint (See Figure 5).

5.3 Horizontal alignment over 1 meter: On both sides of the crown of the rail a 0.3 mm thick feeler gauge shall not enter at any point over a 1.0m straight edge placed centrally across the joint (See figure 4).

5.4 Horizontal alignment over 100 mm: On both sides of the crown of the rail, a 0.2 mm thick feeler gauge shall not enter at any point over a 100mm straight edge placed centrally across the joint (See figure 6).

5.5 Finishing rails with unequal crown widths: During the setting up of rails withunequal crown widths, due to rolling tolerances, the difference in crown widths shall be halved and the resulting steps, after welding, shall be ground out not steeper than 1:500 gradient on both sides of the rail (See Figure 8).

5.6 Rails welded out of alignment: When the sides of the rails are welded out of alignment up to a maximum of 0.5 mm, and the joint shall be ground back to a gradient not steeper than 1:500 (i.e., 400 mm) on the two diagonally opposite sides away from the line of the joint (See figure 9).

5.7 All Areas of the flash butt welded joint are to be ground smooth: The upper sides, under surfaces and the edges of theflanges shall be ground smooth. The edges of the flange shall be rounded to avoid damage to the elastic rail pads and to eliminate stress raisers. The crown ofthe rail joint shall be ground so that the rail-running surface is smooth, and the crown is of the correct rail contour.

5.8 Finish grinding of welded joints: After rough grinding the rail joint, the crown at the joint shall be finally ground to the tolerances specified in clause 9 . 0 .

5.9 Polishing the crown of the rail joint after grinding: After final grinding of the joint, the crown of the rail shall be polished with a disk or a belt sander to remove deep grinding marks.

5.10 Overheating during grinding and polishing: All welds with blue discoloration shall

be rejected (cut out), including on the heat affected zone of the weld.

6.0 GENERAL QUALITY OF FINISH ON FLASH BUTT WELDED JOINTS.

6.1 Stripping of the weld upset metal: The chiseled or machine stripped joint shall not be hollow. If any form of hollowing is present, the joint will be identified as a cut out and should not be correctively ground.

6.2 Finish of the weld: Undercutting or chiseled gouge marks in the vicinity of the weldand adjacent metal shall not be permitted. If present the joint will be identified as a cut out and should not be correctively ground.

6.3 No obvious surface defects shall be present after preparation and welding processes.

7.0 CUTTING OUT DEFECTIVE JOINTS

7.1 All defective welds shall be cut out using a cold saw or a portable disc cutter. Care shall be taken that the ends are not overheated. Flame cutting shall not be permitted. These cuts will also ensure that the entire defect and HAZ of the joint is removed. The cut should be done at a distance of at least 150 mm on either side measured from the edge of the weld collar.

8.0 NUMBER OF JOINTS PER LENGTH OF RAIL

8.1 For all grade of rails supplied, the number of flash butt joints per welded rail string shall not exceed the limits as in Table 2:

Table 3: Number of Flash But welds per welded rail string

INITIAL RAIL LENGHT	FINAL LENGTH METRE	MAXIMUM NUMBER OF JOINTS PER RAIL
18m	36	2 *
18m	216	16 **
36m	216	5 **
60m	240	3 ***
VARIOUS	108	8 **

* Minimum length of rail to be used is 12 meters.

** Any length from 5 and 36 meters, with one 2m length at one end only.

*** Welds are to be 60m apart. No variations will be permitted.

8.2 The maximum number of joints may be increased with special permission fromthe Transnet Freight Rail Principal Engineer (Pr. Eng.).

9.0 TOLERANCES ON RAIL LENGTH

9.1 The length of all welded rails shall be within the tolerances as given in Table *4*

Table 4: Rail string tolerances:

TOTAL LENGTH METER	LENGTH TOLERANCE (MILLIMETER)	
36	+0	-70
216	+1 000	-1 200
240	+0	-1 200

9.2 Other lengths shall be treated as specials and length tolerances shall be given bythe TFR Principal Engineer.

10.0 INSPECTION OF FLASH BUTT WELDED JOINTS.

10.1 A quality control plan should be in place assuring all aspects of the flash butt specification.

10.2 Every completed joint shall be inspected by the contractor. The following information shall berecorded and made readily available:

- Name and signature of operator
- Joint number
- Date of inspection
- Maximum gap size between the straight edge and the top and side of the railcrown (Horizontal and vertical alignment measurements).
- Number of joints per length of rail.
- Reasons for rejecting joints.
- Type of corrective action implemented

11.0 WELDS FAILING IN THE STRAIGHTENING PRESS.

11.1 Refer to part 4 clauses 1.0.

12.0 NON-DESTRUCTIVE TESTING

12.1 After final inspection of the welds for straightness, all welds are to be subjected to an ultrasonic inspection according to Transnet Freight Rail: **BBF 9298 Procedure for the ultrasonic testing of flash butt welded joints for quality control purposes**", dated April 2013.

12.2 Magnetic Particle inspection methods can be used to detect defects in the foot.

12.3 Radiography may be used as a substitute.

12.4 The flash butt welded joints shall not have any detected indications of defects. Should any indications be found, the flash butt welded joint shall be rejected (cut out).

PART 2: TESTING OF WELDS FOR THE PURPOSE OF APPROVAL OF THE EQUIPMENT AND FOR QUALITY CONTROL

1.0 PURPOSE AND NATURE OF TESTS

1.1 Bend tests and metallurgical tests, as specified in clauses 2.0 and 3.0arerequired under the following conditions:

1.1.1 When commissioning the flash butt welding machine for the first time

1.1.2 When welding a rail size or type not previously welded on a particular flash buttwelding machine.

1.1.3 After a major overhaul on a flash butt welding machine

1.1.4 Every three months of continuous welding on each machine

1.1.5 As requested by the Principal Engineer of Transnet Freight Rail, or his appointedrepresentative.

1.1.6 Two metallurgical test samples and three bend test samples must be submitted to a laboratory (TFR laboratory or bidders' choice of accredited laboratory) forapproval testing.

2.0 BEND TEST

2.1 The three test welds in the as welded condition shall be subjected to the bend testing as follows; the loading force shall be applied in the middle of the joint to achieve a deflection rate of 20 mm per minute.

2.2 The bend test shall continue until fracture or be terminated when the force limit of the machine is reached, provided that the bend test values have reached the minimum required values. If not, the weld shall be notched to ensure that fracture occurs in the welding zone, and the test weld shall be fractured.

2.3 Where a bend test is to be conducted out of track, a minimum length of track of 1.2m is required with the joint in the center.

2.4 Table 6 shows the minimum bend test requirement for approval.

Table 6: Bend test loads and deflection requirements

Rail Profile	Minimum bend Test deflection(mm)			Minimum Bend test Force (kN) for approval and production
Grade	R260	R350HT and R350LHT	R400HT	
60E1	20	20	15	1600
SAR57	20	20	15	1330
SAR48	30	25	15	1050

2.5 Appearance of the fractured face: The fracture face of the broken flash butt joint shall be free of oxidized metal, craters, and areas with lack of fusion, porosity and embrittled metal.

2.6 Records to be kept: The contractor shall keep the following information of all bend tests performed for a period of 5 years:

2.6.1 Name of welding workshop.

2.6.2 Type and number of welding machine.

2.6.3 Date of test.

2.6.4 The Quality Controller's name and signature.

2.6.5 Rail type and size

2.6.6 Load and deflection graphs.

3.0 METALLURGICAL TEST OF FLASH BUTT WELDED JOINTS.

3.1 Standard metallurgical testing methods shall be used toexamine flash butt welds for acceptance.

3.2 A letter stating the purpose of the test, the welding cycle graphs and the welding parameters, shall accompany the two test samples sent for approval.

3.3 Metallurgical requirements:

3.3.1 The macroscopical examination samples shall be sectioned in the longitudinal direction of the rail, prepared, and etched with ammonium per sulphate solution.

3.3.2 The setting of the flash butt welding machine and the method of controlled cooling shall be set so that the requirements set out in Part 3 clauses 2.4 and 3.4are met, and also so that excessive soft metal in the spheroidized zone and excessive hard metal in the coarse grain zone, as well as excessive enlargement of these zones or a "Widmannstaten" structure, is avoided.

3.3.4 Three microscopical examination samples shall be sectioned from each test weld, one from the crown on either side of the fusion line as well as from the flange andthe third samples shall be sectioned from the spheroidized zone. The samples shall be prepared and etched with 2% Nital and there shall be no evidence of martensite or bainite at 200 X magnification in the heat affected zone and on the fusion line.

3.4 Hardness limits:

3.4.1 Table *5* reflects the hardness limits for the spherodized and the coarse-grained zones.

Table 5: Minimum and maximum rail hardness

TYPE OF RAIL	MINIMUM HARDNESS VALUE (Hv30)	MAXIMUM HARDNESS VALUE (Hv30)
R260	Parent Rail Hardness - 30 Hv_{30}	Parent Rail Hardness + 60 Hv_{30}
R350LHT	325	410
R400HT	350	440

3.4.2 The hardness profile shall be measured on a longitudinal macroscopic (Macro etched) sample section through the weld. The profile shall be measured between 3 and 5 mm below the running surface 2 mm apart and 10 mm from the spheroidized

zone on either side of the weld. The variation in the hardness profile shall not exceed 15% of the rail hardness.

PART 3: WELDS FAILING IN PRODUCTION AND DURING QUALITY CONTROL

1.0 WELDS FAILING IN THE STRAIGHTENING PRESS.

1.1 Welds failing in the straightening press shall be examined for reasons for failure and the following information shall be recorded:

1.1.1 Rail type and size, joint number, and straightening direction information.

1.1.2 Contract number and welding machine number and welding parameters.

1.1.3 Cause of failure.

1.1.4 Steps followed for remedial action

1.2 The failed rail shall be cut out and forwarded to the Track Testing Centre, Rail Metallurgy section. For handling purposes, the length of the cut-out section forwarded to Track Testing Centre, Rail Metallurgy section shall be as short as practical, but not shorter than 300 mm with the weld centrally located.

1.3 If the rail failure was because of a rail defect, then the defective rail section shallbe removed completely.

1.4 The welding contractor shall be responsible for re-welding all failed flash butt welded joints.

2.0 RAILS FAILING A BEND TEST

2.1 If a joint has failed the bend test, inspect the rails slip marks. If slip marks are found, several joints prior to the failed joint must also be inspected for slip marks. Any joints on which slip marks are found are to be cut out and re-welded.

2.2 If no slip marks are present, the machine settings must be checked. If the settings are found to be incorrect, the settings must be corrected, and a test piece is welded and retested. Over and above this correction, the additional testing according to clause 2.4of part 4 below shall be done.

2.3 If the machine settings are correct. Re-weld a test sample and test. If the weld passes, the additional testing according to clause 2.4of part 4 shall still be done to ensure that the welding process is acceptable. If the weld fails, then stop production and find the fault. This still implies that the additional testing according to clause 2.4 must be done.

2.4 The welds, prior to the weld break, are to be broken up to the point where three consecutive welds are encountered that conforms to the specification. The failed

welds are to be sent for metallurgical evaluation.

3.0 RAILS FAILING THE METALLURGICAL TESTS

3.1 The remedial or corrective action shall be negotiated with the client.

Part 4: INFORMATION FOR CONTROL PURPOSES

(APPLICABLE TO TRANSNET FREIGHT RAIL ORDERS ONLY)

1.0 On the first of each calendar month a report on the quality tests of the previous month shall be compiled. The welding depot manager shall be familiar with the contents of the report. Distribution to and by the dates specified shall be as per Table *6*.

2. The following information shall be contained in the report:

2.1 A summary of all bend tests performed or in the case of no bend test performed a statement and explanation. If the rail failed below a specified minimum value, the reason shall be provided.

2.2 A summary of samples of flash butt welds sent for metallurgical tests and the report number.

2.3 The number of rails welded, including the machine identification number, the rail profile and type and the number of welds of each type.

2.4 Summary of the adjustments made on the machine settings for each rail size and type.

2.5 Summary of the recorded straightness profile and all non-destructive tests performed.

Table 6: Details of the designated person

CLAUSE	RECEIVER	DATE REQUIRED	METHOD OF TRANSMISSION
2.1 TO 2.5	Track Technology Management 1000 Bluegum Avenue Koedoespoort Pretoria 0186	Upon request by Transnet Freight Rail	Post summary e-mail (Contents can also be shared via email and drive)

APPENDIX A

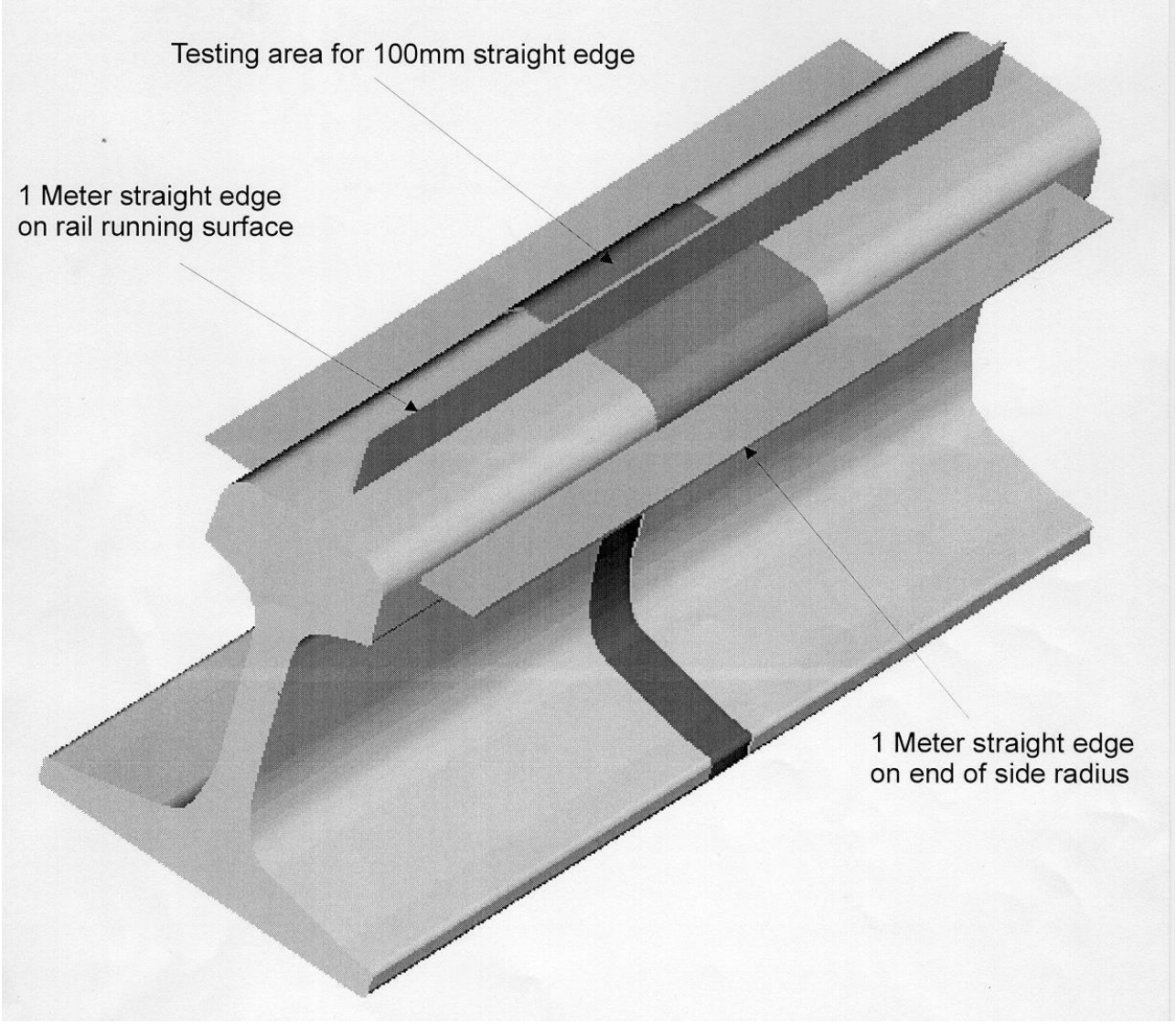

Figure 1: Position of straight edge for measuring horizontal and vertical alignment

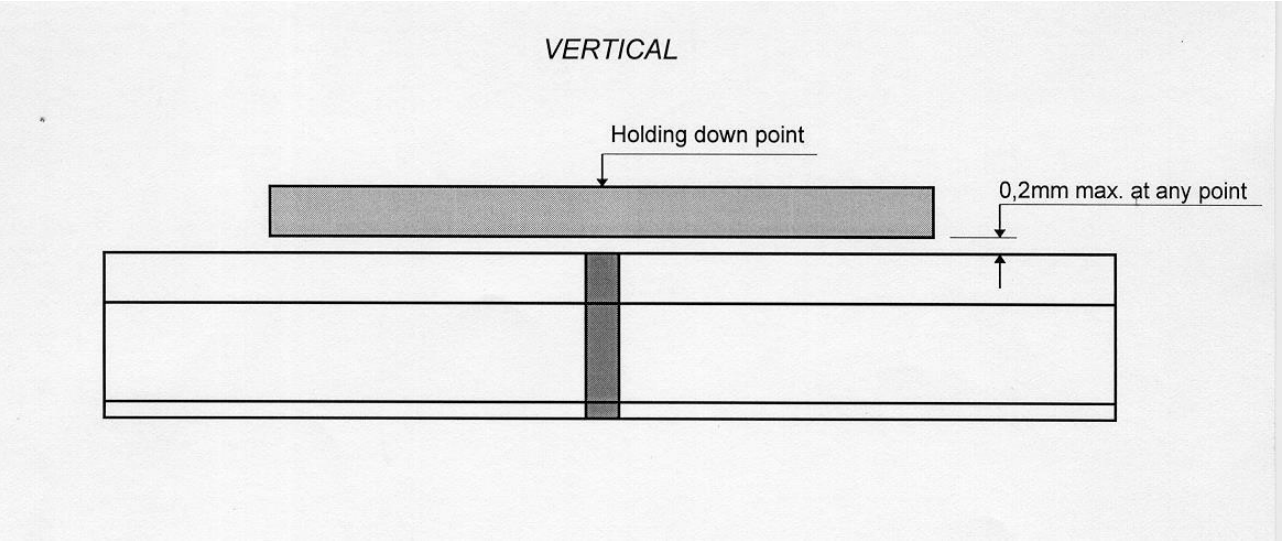

Figure 2: Straightness of flash butt joints after press and grinding using a 1m straight edge

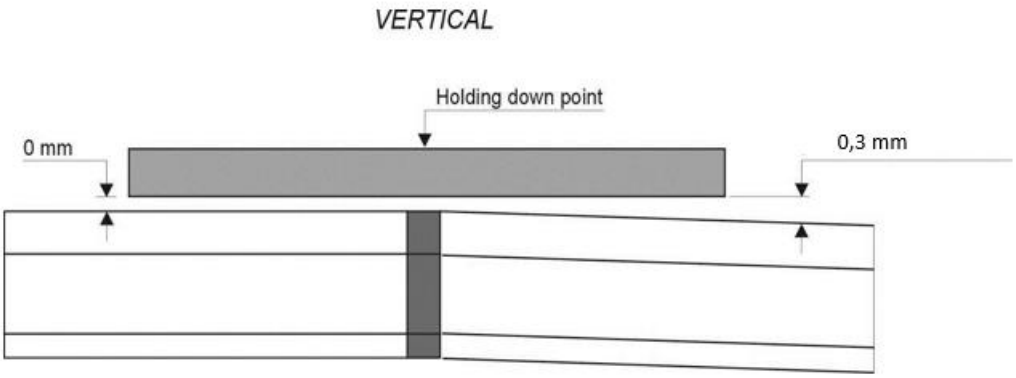

Figure 3: Measurement of Straightness of flash butt joints after press and grinding using a 1m straight edge

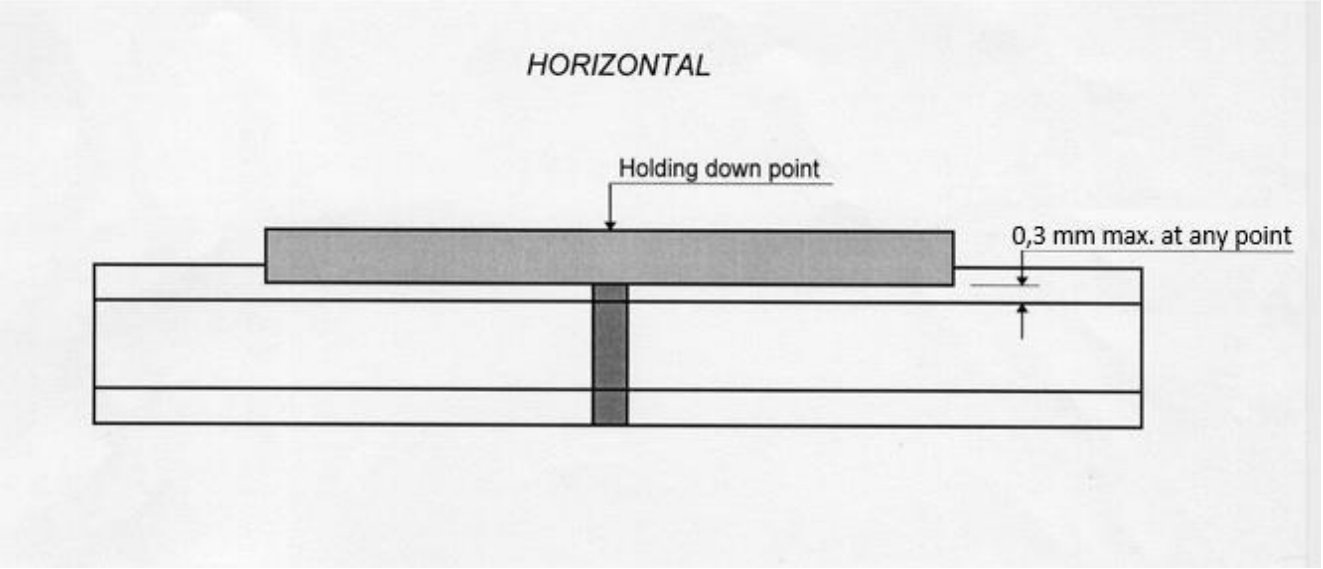

Figure 4: Straightness of flash butt joints after press and grinding using a 1m straight edge

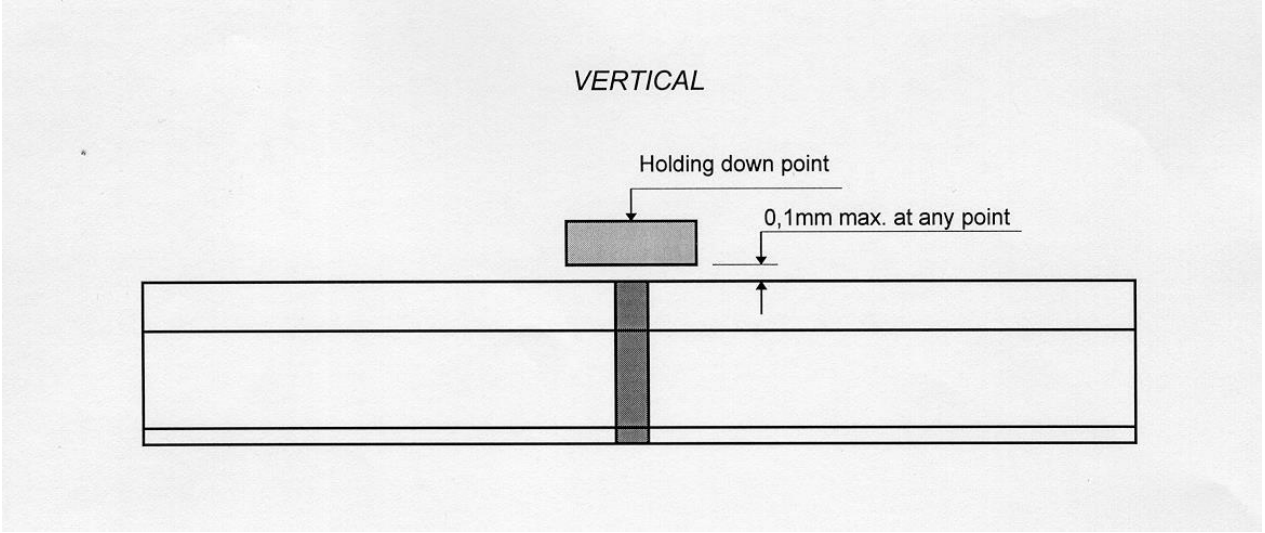

Figure 5 : Straightness of flash butt joints after press and grinding using 100mm straight edge

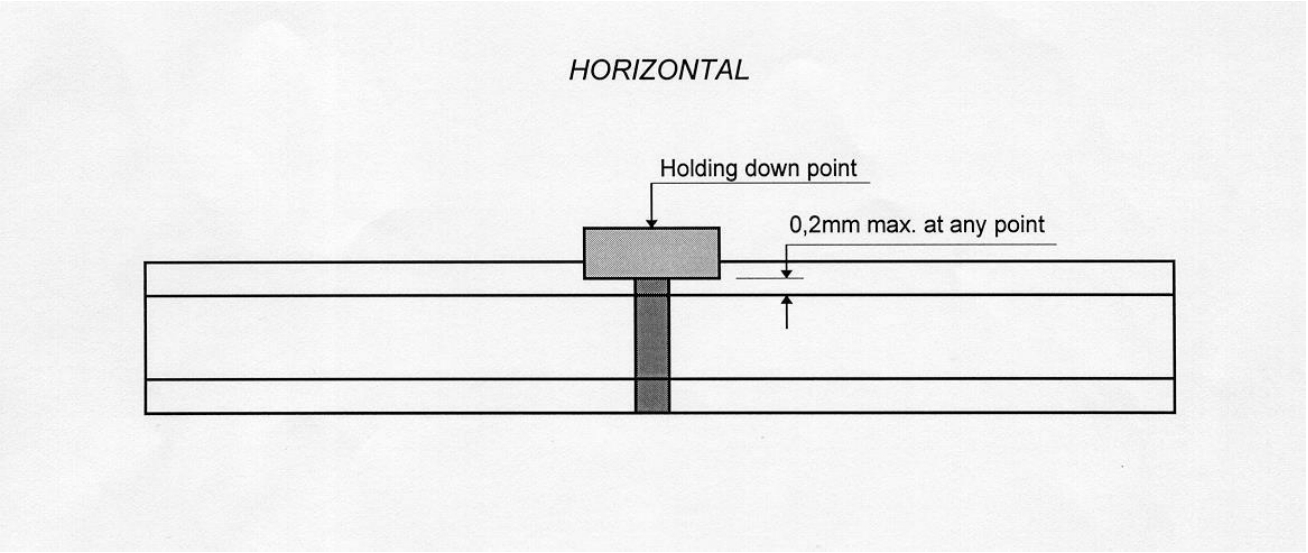

Figure 6: Straightness of flash butt joints after press and grinding using a 100 mm straight edge

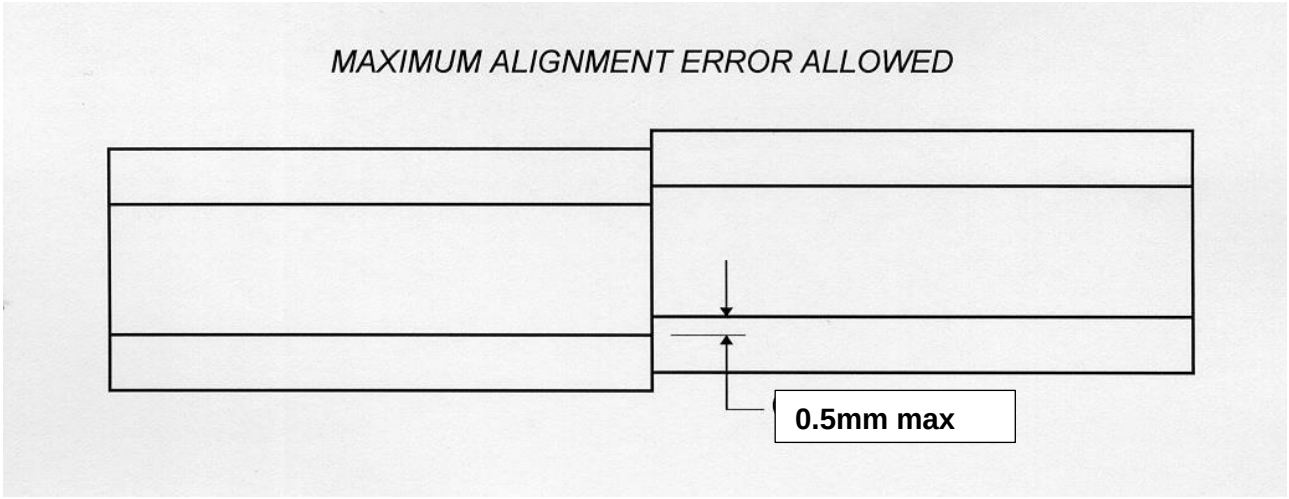

Figure 7: Maximum alignment error allowed

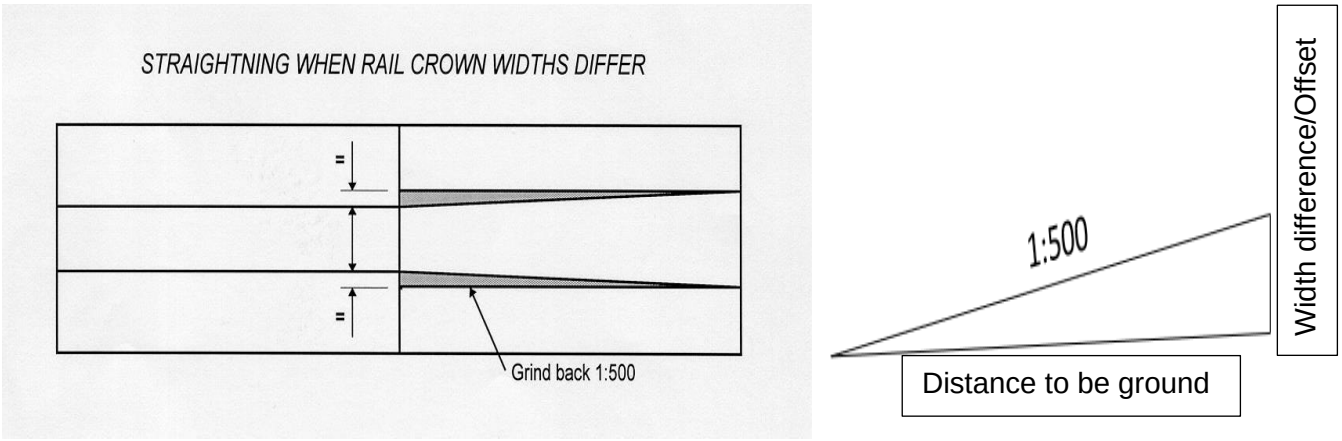

Figure 8: Straightening when rail crown width differs

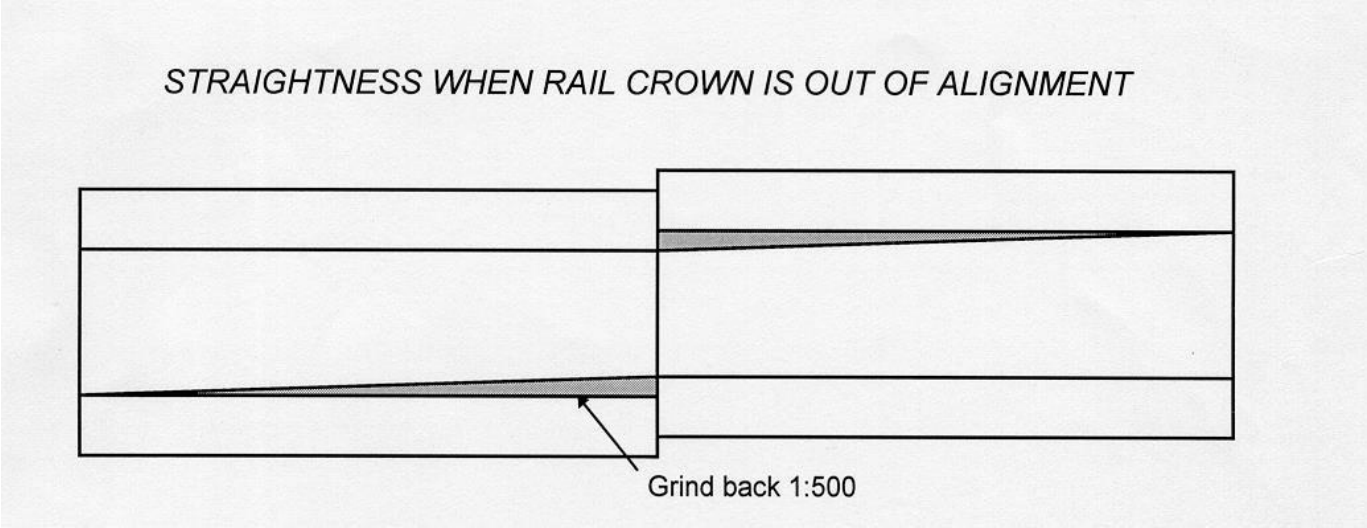

Figure 9: Straightness when rail crown is out of alignment