Approval of welding process according EN 14730-1:2009 and RFI TCAR SF AR 07005B

Process Changes - Rail 60E1, Grade R260, Gap 23

Process Changes - Rail 60E1, Grade R260, Gap 47 / 53

Grade Extension – Rail 60E1, Grade R200, Gap 23 / 27

Fatigue Test - Rail 60E1, Grade R260, Gap 23 / 27

Report Nr. TM83429T

Commissioned from Thermit Italiana s.r.l.

Graz, 01.12.2010

1 General

Purpose of this report is the approval of the welding process according to the EN 14730-1:2009 and the technical specification RFI TCAR SF AR 07005B. The tests were conducted in accordance to these standard and specification.

In chapter 3 are listed in detail which tests were conducted and theirs results.

Object of the approvals are the following

Process changes

- Rail 60E1, Grade R260, Gap 23 (see chapter 3.1);
- Rail 60E1, Grade R260, Gap 47 / 53 (see chapter 3.2)

Grade extension

- Rail 60E1, Grade R200, Gap 23 / 27 (see chapter 3.3)

Fatigue tests

- Rail 60E1, Grade R260, Gap 23 / 27 (see chapter 3.4)

According to the RFI TCAR SF AR 07005B, for the fatigue tests the Past-the-Post testing method has been applied. These tests were performed at the "Schweißtechnische Lehr- und Versuchsanstalt Halle GmbH". The slow bend tests were performed by the TÜV SÜD Rail laboratory in Görlitz and all other tests listed in the tables under chapter 3 by the TÜV SÜD laboratory in Munich.

2 List of Documents

List of documents		
Doc. Number.	Title	Date
[1]	Centerline hardness test protocol - Elektro Thermit	11.08.2010
[2]	Visible heat affected zone	20.10.2010
[3]	Slow bend test protocol	28.10.2010
[4]	Ultrasonic test protocol	13.10.2010
[5]	Fusion zone test protocol	17.11.2010
[6]	Heat softened zone width test protocol	16.11.2010
[7]	Visible heat affected zone	28.07.2010
[8]	Slow bend test protocol	09/12.04.2010
[9]	Ultrasonic test protocol	08.06.2010
[10]	Fusion zone test protocol	26.07.2010
[11]	Heat softened zone width test protocol	05.07.2010
[12]	Centerline hardness test protocol - Elektro Thermit	12.08.2010
[13]	Visible heat affected zone	20.10.2010
[14]	Slow bend test protocol	28.10.2010
[15.1]	Chemical analysis test protocol	02.11.2010
[15.2]	Product data sheet LLC – Elektro Thermit	05.03.2010
[16]	Heat softened zone width test protocol	17.11.2010
[17.1]	Microstructure test protocol	18.11.2010
[17.2]	Structure definition by Elektro-Thermit	26.11.2010
[18]	Ultrasonic test protocol	12-13.10.2010
[19]	Fatigue test – Examination report - SLV	20.10.2010
[20]	Slow bend test protocol	28.10.2010

Table 1: List of documents

3 Test activities

3.1 Process Changes - Rail 60E1, Grade R260, Gap 23

The tests were performed in accordance to the following table issued by Thermit.

Reference to 14730-1	**EN 14730-1: Table 3 test 6.1.6**		
Test	Number of welds	Rail nr.	Test conducted by
A - Centreline Hardness	6	W0489 – W0490 – W0491 – W0492 – W0493 – W0494	Elektro Thermit
B - Surface examination - Visual	10	W0489 – W0490 – W0491 – W0492 – W0493 – W0494 - W0495 – W0496 – W0497 – W0498	TÜV SÜD Rail
C - Visible HAZ	1	W0495	Laboratory TÜV SÜD I.S.
D - Slow bend test	6	W0489 – W0490 – W0491 – W0492 – W0493 – W0494	Laboratory TÜV SÜD Rail
F - Fatigue test	-		
G - Weld soundness 7.4.1	4	W0495 – W0496 – W0497 – W0498	Laboratory TÜV SÜD I.S.
G - Weld soundness 7.4.1.5	6	W0489 – W0490 – W0491 – W0492 – W0493 – W0494	TÜV SÜD Rail
H - Fusion width	4	W0495 – W0496 – W0497 – W0498	Laboratory TÜV SÜD I.S.
I - Chemical analysis	-		
J - HAZ hardness	2	W0497 – W0498	Laboratory TÜV SÜD I.S.
K - Structure	-		
L - UT inspection	-		
Total	10		
Rail	60E1		
Grade	R260		
Gap [mm]	23		
Crucible	SUC		

Table 2: Rail 60E1, Grade R260, Gap 23 [mm]

TÜV SÜD Statement: TÜV SÜD Rail supervised the welding of all samples by the company Elektro-Thermit in Halle.

3.1.1 Centerline hardness

Centerline hardness – Rail 60E1, Grade R260, Gap 23 [mm]						
Samples	Unit	Centerline			Average of the 3 hardness values	Tolerance acc. RFI 300 ± 20 HBW
		1 (Running Edge)	2 (Center)	3		
W0489	HBW	300	306	304	303	280 – 320 HBW
W0490	HBW	297	299	305	300	280 – 320 HBW
W0491	HBW	300	303	301	301	280 – 320 HBW
W0492	HBW	299	313	304	305	280 – 320 HBW
W0493	HBW	303	304	309	305	280 – 320 HBW
W0494	HBW	290	303	293	295	280 – 320 HBW

Table 3: Centerline hardness – samples W0489, W0490, W0491, W0492, W0493, W0494

TÜV SÜD Statement: All the values measured are inside the given tolerances (table 2 of the RFI TCAR SF AR 07 005 B). The test results are summarized in [1].

3.1.2 Surface examination

Surface examination – Rail 60E1, Grade R260, Gap 23 [mm]							
Samples	Unit	7.1.1 As cast weld surface			7.1.2 Ground weld surface		
		Cracks	Pores	Slag and sand inclusions	Cracks	Defects	Ground collar surface
		Tolerance: < 2mm	Tolerance: < 3mm (between 2-3mm max. 3. Pores)	Tolerance: acc. RFI table 3	Tolerances: No cracks allowed	Tolerance: acc. RFI table 3, no defects allowed	Tolerance: acc. RFI table 2, no defects allowed
W0489	mm	√	√	√	√	√	√
W0490	mm	√	√	√	√	√	√
W0491	mm	√	√	√	√	√	√
W0492	mm	√	√	√	√	√	√
W0493	mm	√	√	√	√	√	√
W0494	mm	√	√	√	√	√	√
W0495	mm	√	√	√	√	√	√
W0496	mm	√	√	√	√	√	√
W0497	mm	√	√	√	√	√	√
W0498	mm	√	√	√	√	√	√

Table 4: Surface examination – samples W0489, W0490, W0491, W0492, W0493, W0494, W0495, W0496, W0497, W0498

TÜV SÜD Statement: The results of the surface examination fulfill the requirements of table 2 and 3 of the RFI TCAR SF AR 07 005 B and point 7.1.1 and 7.1.2 of the EN 14730-1.

3.1.3 Visible heat affected zone

Visible HAZ – Rail 60E1, Grade R260, Gap 23 [mm]				
Sample	Unit	Centerline HAZ left	Centerline HAZ right	Tolerance RFI: 40 mm
W0495	mm	16	15	40

Table 5: Visible heat affected zone – samples W0495

TÜV SÜD Statement: The heat affected zone of the sample is according to the tolerance range from table 2 of RFI TCAR SF AR 07 005 B. The results are summarized in [2].

3.1.4 Slow bend test

Slow bend test - Rail 60E1, Grade R260, Gap 23 [mm]	
Samples	Minimum fracture load 1200 [KN]
W0489	√
W0490	√
W0491	√
W0492	√
W0493	√
W0494	√

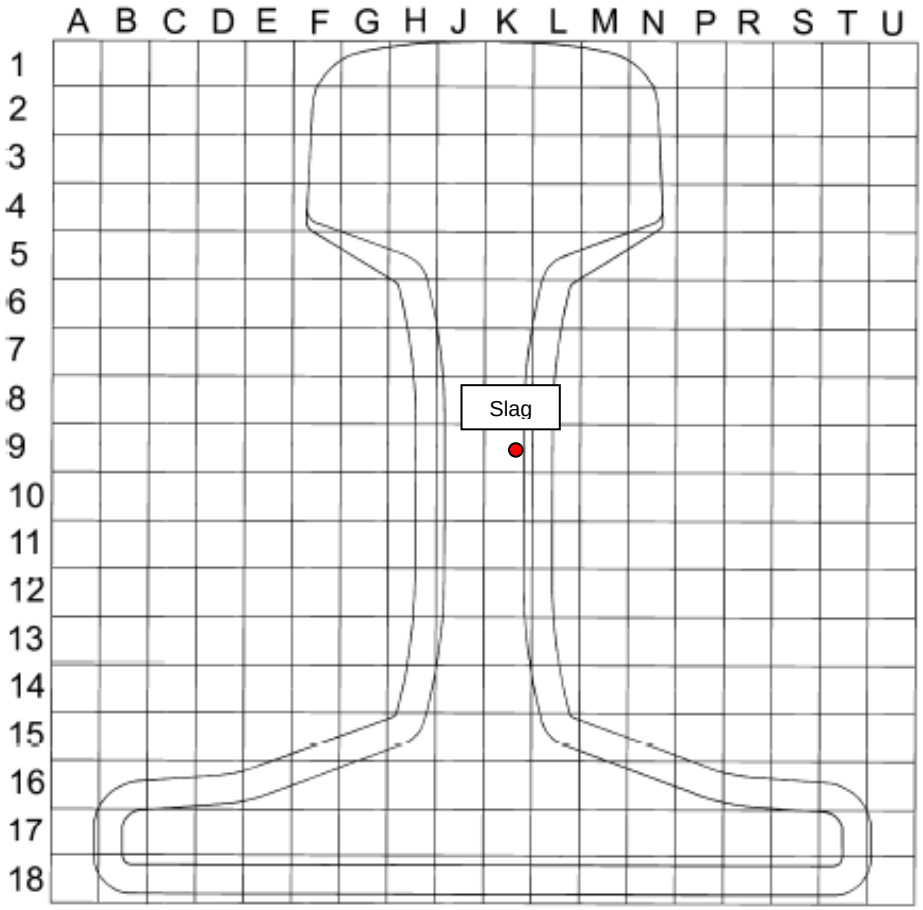
Table 6: Slow bend test – samples W0489, W0490, W0491, W0492, W0493, W0494

TÜV SÜD Statement: The 6 samples reached the minimum fracture load of 1200 [KN] according the EN 14730-1 point 7.3. The results are summarized in [3].

3.1.5 Fracture face defects

After the slow bend test the fracture face defects were recorded by TÜV SÜD Rail acc. to point 7.4.1.5 and Annex G.

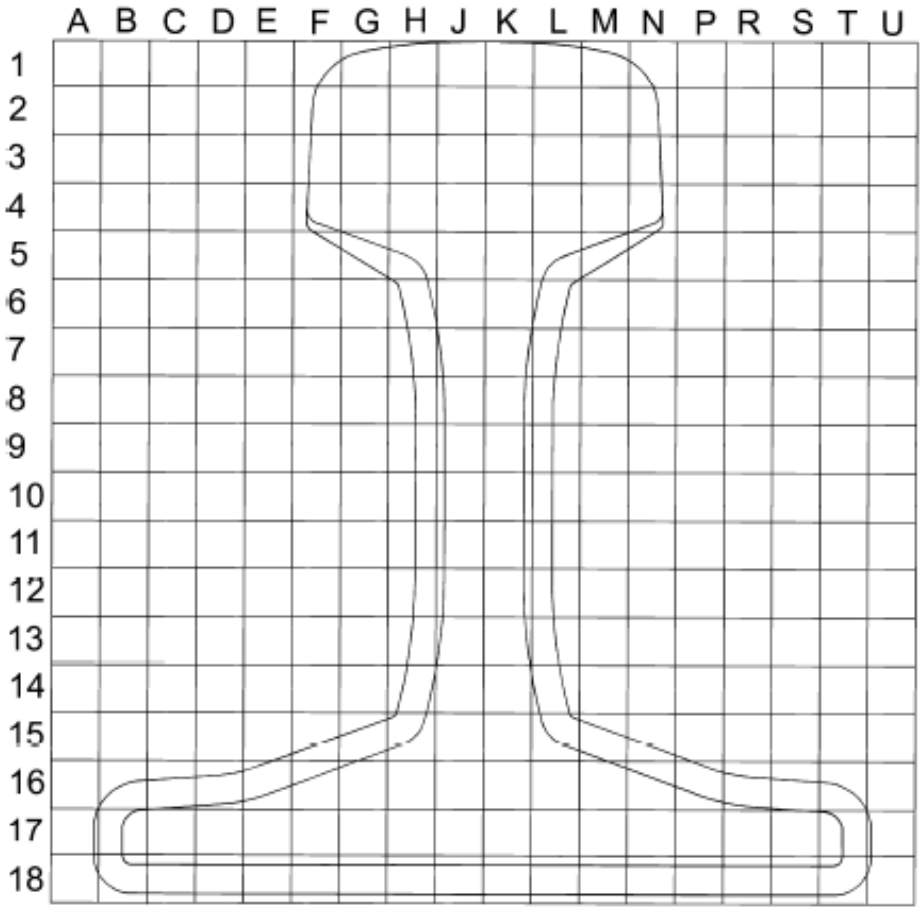
3.1.5.1 Sample Nr. W0489



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0489	Slag	Ø 0,5	Round	K9	-	Not broken	√		

Table 7: Fracture face defects - sample W0489

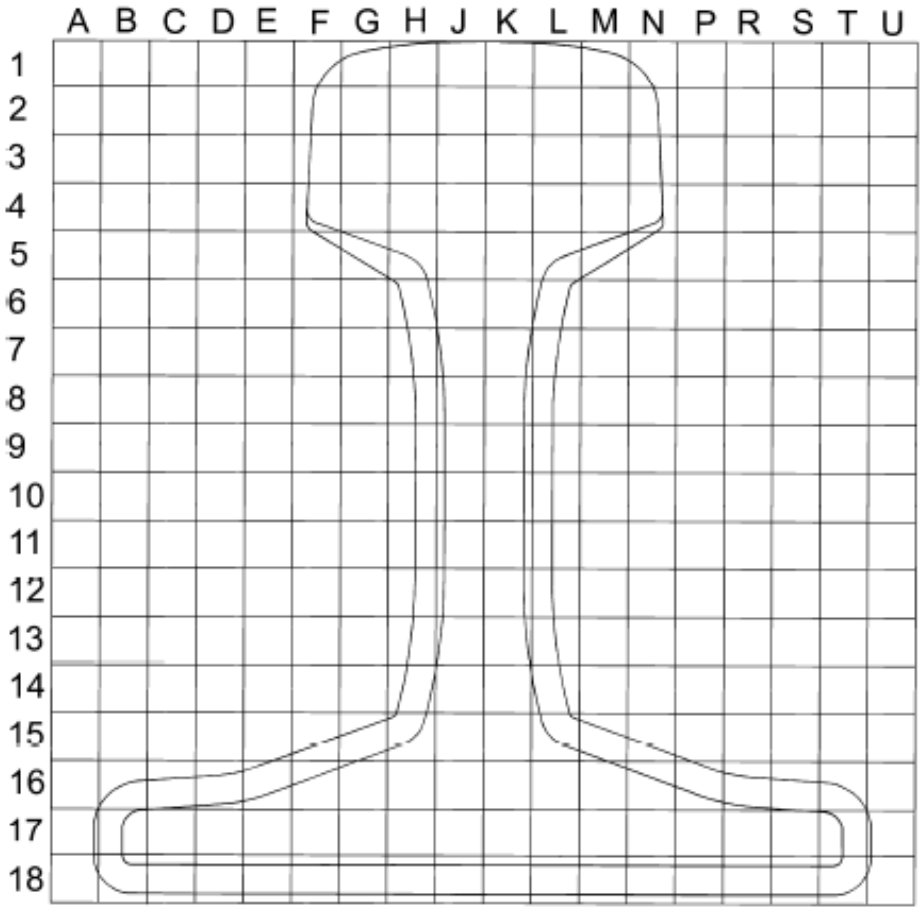
3.1.5.2 Sample Nr. W0490



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0490	-	-	-	-	-	-	√		√

Table 8: Fracture face defects – sample W0490

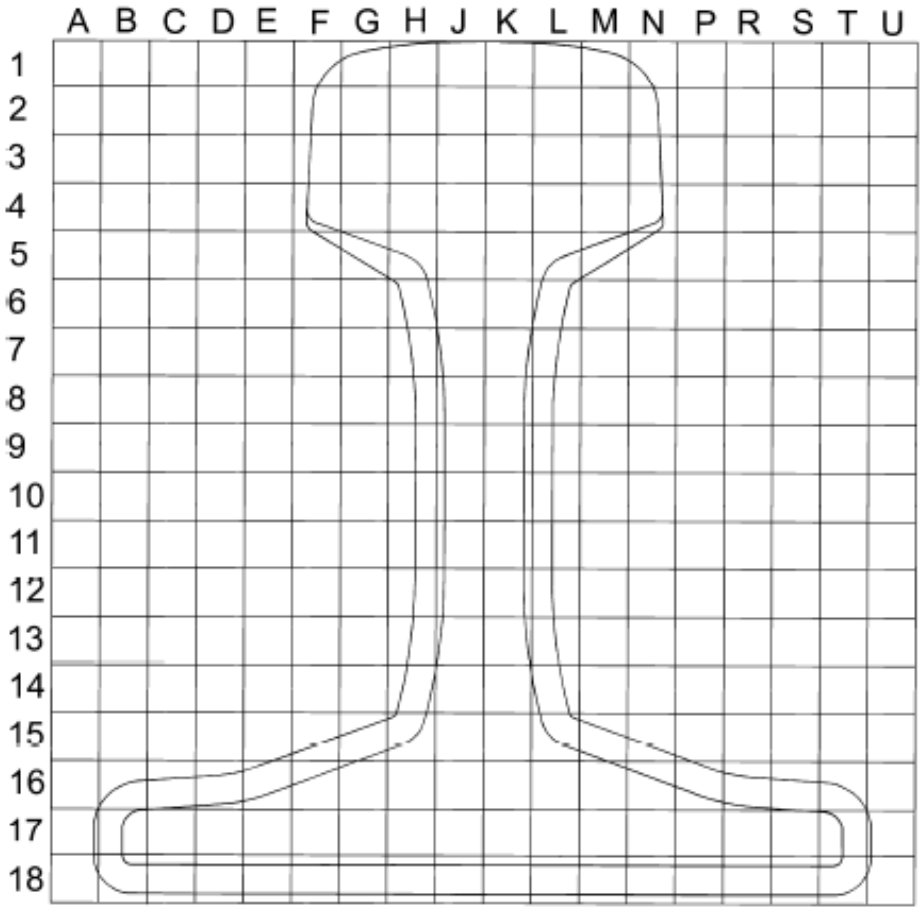
3.1.5.3 Sample Nr. W0491



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0491	-	-	-	-	-	-	√		√

Table 9: Fracture face defects – sample W0491

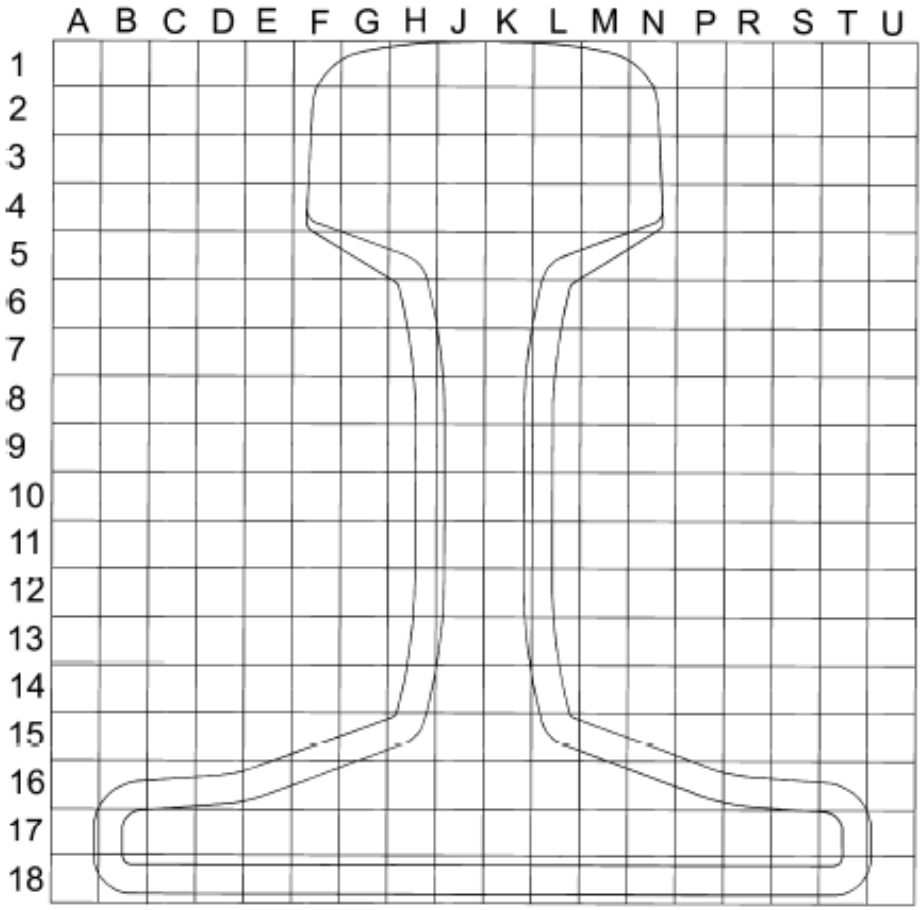
3.1.5.4 Sample Nr. W0492



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0492	-	-	-	-	-	-	√		√

Table 10: Fracture face defects – sample W0492

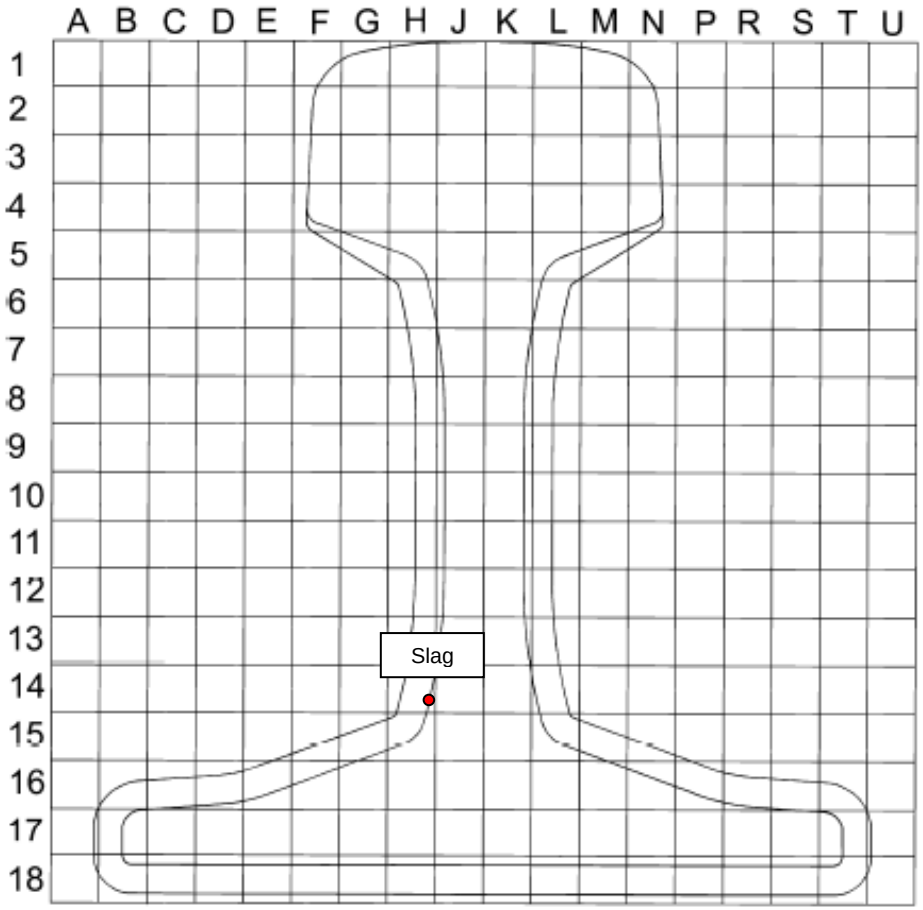
3.1.5.5 Sample Nr. W0493



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0493	-	-	-	-	-	-	√		√

Table 11: Fracture face defects - sample W0493

3.1.5.6 Sample Nr. W0494



Fracture face defects - Rail 60E1, Grade R260, Gap 23 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0494	Slag	Ø 1,9	Round	H14	-	Not broken	√		

Table 12: Fracture face defects - sample W0494

3.1.6 Internal examination

In the following table are summarized the results of the fracture face defects checked acc. to EN 14730-1 point 7.4.1.4.

Internal examination - Rail 60E1, Grade R260, Gap 23 [mm]				
Samples	Head (1 defect > 2 [mm])	Web		Food
	O-1 [mm]	O-1 [mm]	1-2 [mm]	O-1 [mm]
W0489	-	0,5	-	-
W0490	-	-	-	-
W0491	-	-	-	
W0492	-	-	-	
W0493	-	-	-	-
W0494	-	-	1,9	-

Table 13: Internal examination – samples W0489, W0490, W0491, W0492, W0493, W0494

TÜV SÜD Statement: No defects in the head area have been found

3.1.7 Weld soundness

The following samples were ultrasonically tested according to EN 14730-1 point 7.4.1 and annex H.

Wels soundness - Rail 60E1, Grade R260, Gap 23 [mm]			
Samples	Head	Web	Food
W0495	√	√	√
W0496	√	√	√
W0497	√	√	√
W0498	√	√	√

Table 14: Weld soundness – samples W0495, W0496, W0497, W0498

TÜV SÜD Statement: No "lack-of-fusion" defects, large gas pores and "hot tears" in the rail head, web and food have been found. The results are summarized in [4].

3.1.8 Fusion zone - shape and dimension

Fusion zone - shape and dimension - Rail 60E1, Grade R260, Gap 23 [mm]			
Samples	Longitudinal vertical section on centre line	Longitudinal vertical section of foot tip	Longitudinal vertical section of foot tip
	Cut 1	Cut 2.1	Cut 2.2
W0495	√	√	√
W0496	√	√	√
W0497	√	√	√
W0498	√	√	√

Table 15: Fusion zone – sample W0495, W0496, W0497, W0498

TÜV SÜD Statement: The minimum distance X between the parent rail end before welding and the fusion line was greater than 3 mm. Therefore the results fullfile the requirement of the EN 14730-1 point 7.4.2.2.

No "lack of fusion" or an unwelded weld collar's edge with the rail surface was recorded, reason while the requirements of EN 14730-1 pt. 7.4.1.3 are met. The results are summarized in [5].

3.1.9 Heat softened zone width

Heat softened zone width - Rail 60E1, Grade R260, Gap 23 [mm]				
Samples	Unit	Width between A1 – B1	Width between A2 – B2	Tolerance acc. RFI: ≤ 30 [mm]
W0497	mm	4,3	1,3	30 mm
W0498	mm	3,0	< 0,8	30 mm

Table 16: Heat softened zone width – sample W0497, W0498

TÜV SÜD Statement: The heat softened zone on either side of the weld had less than 30 mm, reason while the requirements of the RFI TCAR SF AR 07 005 are met. The results are summarized in [6].

3.2 Process Changes - Rail 60E1, Grade R260, Gap 47 / 53

The tests were performed in accordance to the following table issued by Thermit.

Reference to 14730-1	**EN 14730-1: Table 3 test 6.1.6**			
Test	Number of welds		Rail nr.	Test conducted by
A - Centreline Hardness	6		10 - 11 - 12 -14 - 16 - 17	Thermit Italiana
B - Surface examination - Visual	-			
C - Visible HAZ	1		38	Laboratory TÜV SÜD I.S.
D - Slow bend test	6		10 - 11 - 12 -14 - 16 - 17	Laboratory TÜV SÜD Rail
F - Fatigue test	-			
G - Weld soundness 7.4.1	4		04 - 18 - 38 - 39	Laboratory TÜV SÜD I.S.
G - Weld soundness 7.4.1.5	6		10 - 11 - 12 -14 - 16 - 17	TÜV SÜD Rail
H - Fusion width	4		04 - 18 - 38 - 39	Laboratory TÜV SÜD I.S.
I - Chemical analysis	-			
J - HAZ hardness	2		04 - 18	Laboratory TÜV SÜD I.S.
K - Structure	-			
L - UT inspection	-			
Total	5	5		
Rail	60E1	60E1		
Grade	R260	R260		
Gap [mm]	47	53		
Crucible	LLC	LLC		

Table 17: Rail 60E1, Grade R260, Gap 47 / 53 [mm]

TÜV SÜD Statement: TÜV SÜD Rail wasn't present during the welding of the samples. They were supervised by Mr. Lanna from RFI.

3.2.1 Centerline hardness

Centerline hardness – Rail 60E1, Grade R260, Gap 47 / 53 [mm]						
Samples	Unit	Centerline			Average of the 3 hardness values	Tolerance acc. RFI 300 ± 20 HBW
		1 (Running Edge)	2 (Center)	3		
10	HBW	306,5	306,5	302	305	280 – 320 HBW
11	HBW	293	293	302	296	280 – 320 HBW
12	HBW	311	311	311	311	280 – 320 HBW
14	HBW	297,5	302	306,5	302	280 – 320 HBW
16	HBW	297,5	302	297,5	299	280 – 320 HBW
17	HBW	297,5	293,5	293,5	295	280 – 320 HBW

Table 18: centerline hardness- samples 10, 11, 12, 14, 16, 17

TÜV SÜD Statement: All the values measured are inside the given tolerances (table 2 of the RFI TCAR SF AR 07 005 B).

3.2.2 Visible heat affected zone

Visible HAZ – Rail 60E1, Grade R260, Gap 47 / 53 [mm]				
Sample	Unit	Centerline HAZ left	Centerline HAZ right	Tolerance RFI: 40 mm
38	mm	15	13	40

Table 19: Visible heat affected zone- sample 38

TÜV SÜD Statement: The heat affected zone of the sample is according to the tolerance range from table 2 of the RFI TCAR SF AR 07 005 B. The results are summarized in [7].

3.2.3 Slow bend test

Slow bend test - Rail 60E1, Grade R260, Gap 47 / 53 [mm]	
Samples	Minimum fracture load 1200 [KN]
10	√
11	√
12	√
14	√
16	√
17	√

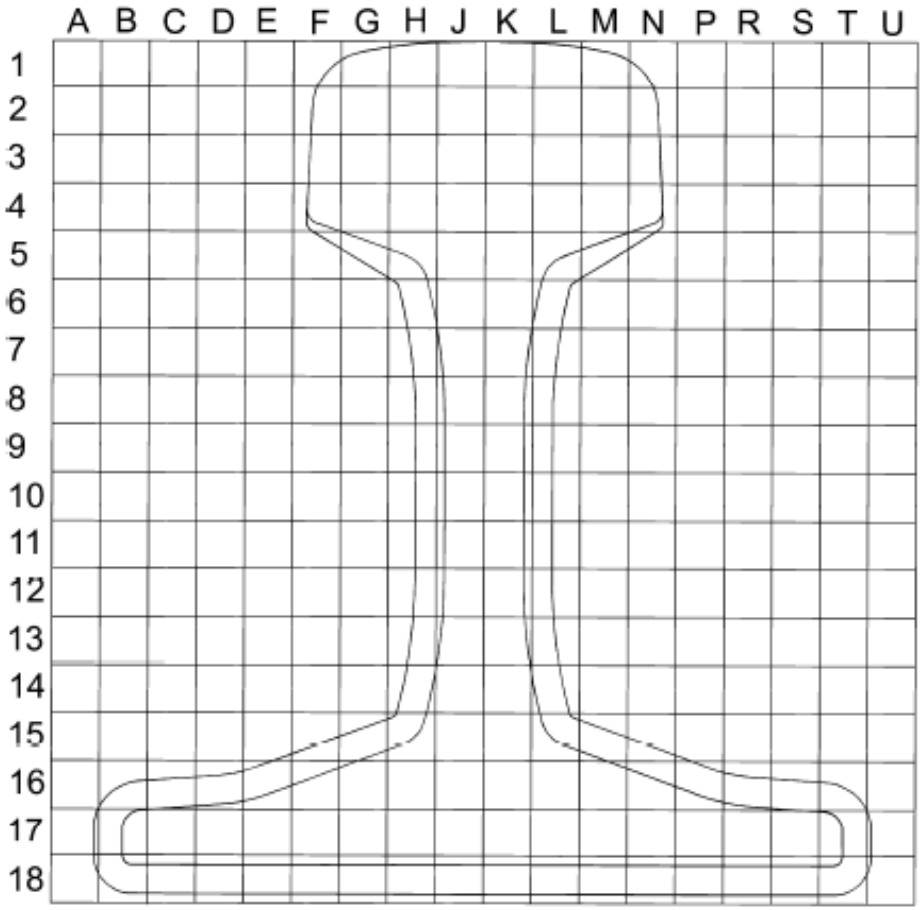
Table 20: Slow bend test- samples 10, 11, 12, 14, 16, 17

TÜV SÜD Statement: The 6 samples reached the minimum fracture load of 1200 [KN] according the EN 14730-1 point 7.3. All the results are summarized in [8].

3.2.4 Fracture face defects

After the slow bend test the fracture face defects were recorded by TÜV SÜD Rail acc. to point 7.4.1.5 and Annex G.

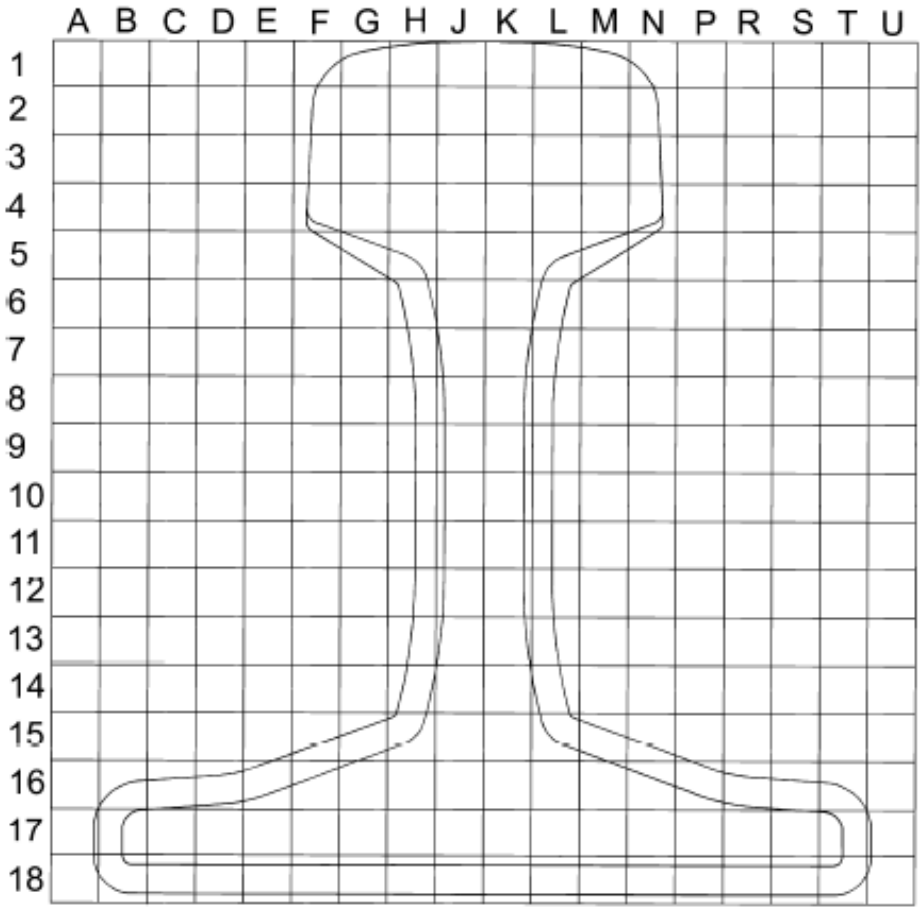
3.2.4.1 Sample Nr. 10



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
10	-	-	-	-	-	-	√		√

Table 21: Fracture face defects - sample 10

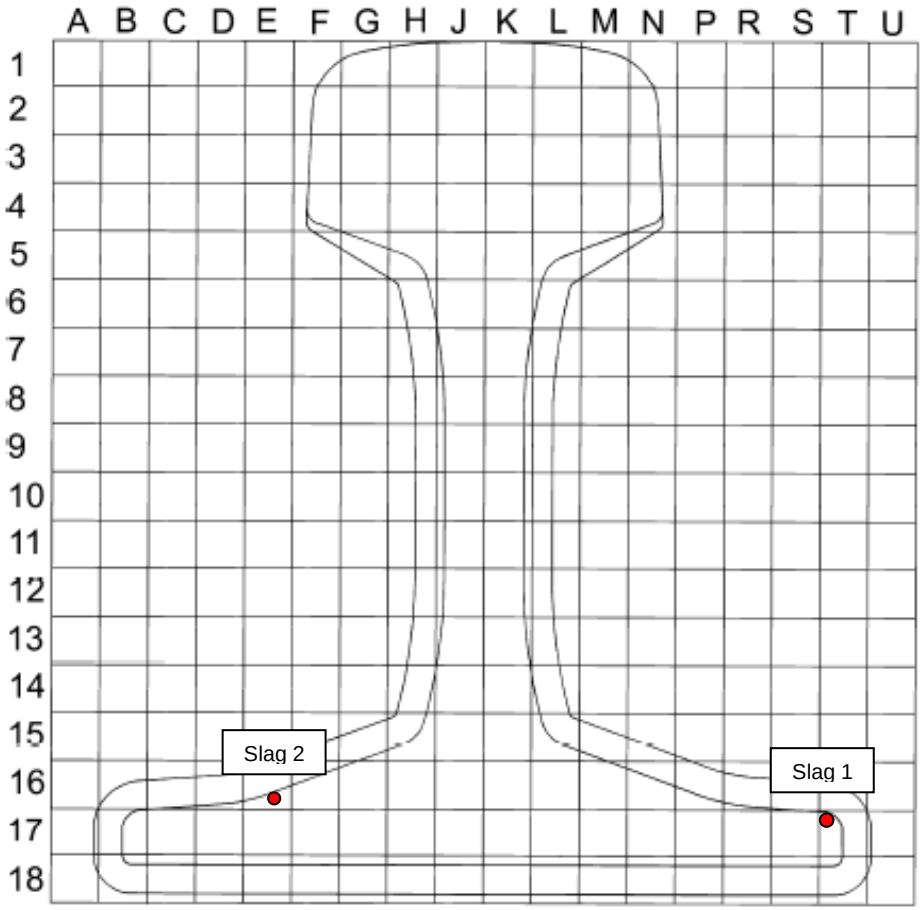
3.2.4.2 Sample Nr. 11



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
11	-	-	-	-	-	-	√		√

Table 22: Fracture face defects - sample 11

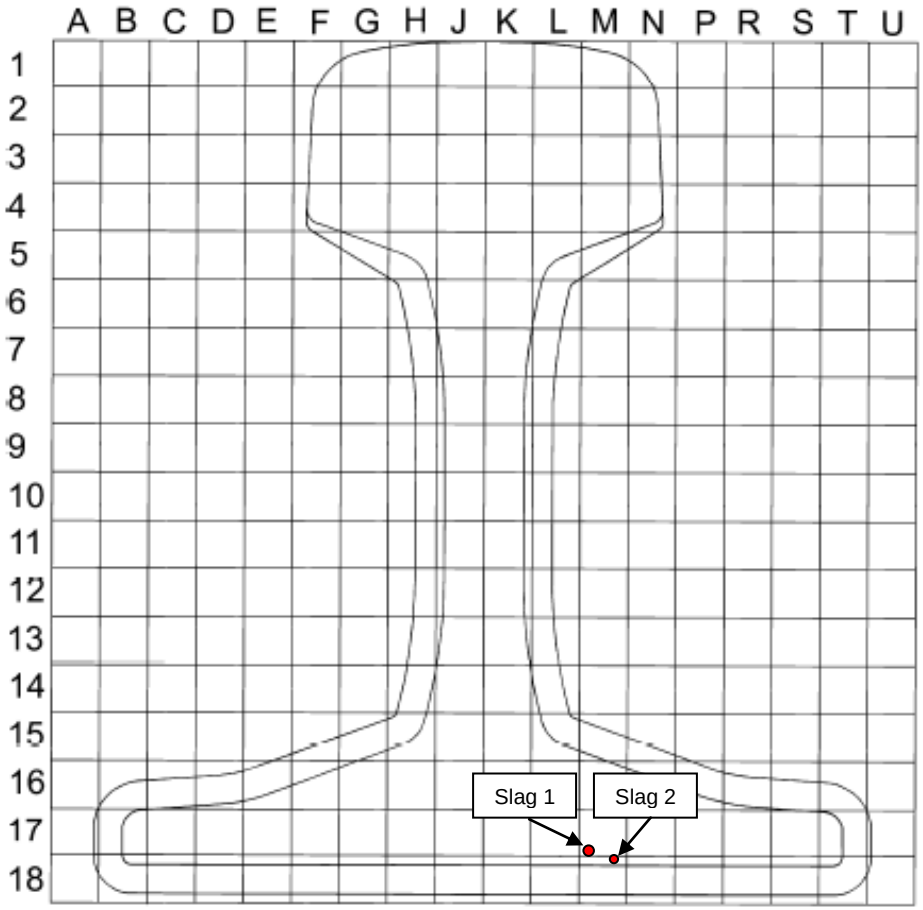
3.2.4.3 Sample Nr. 12



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
12	Slag 1	Ø 2,4	Round	T17	-	Not broken	√		
	Slag 2	Ø 0,8	Round	E16	-	Not broken			

Table 23: Fracture face defects - sample 12

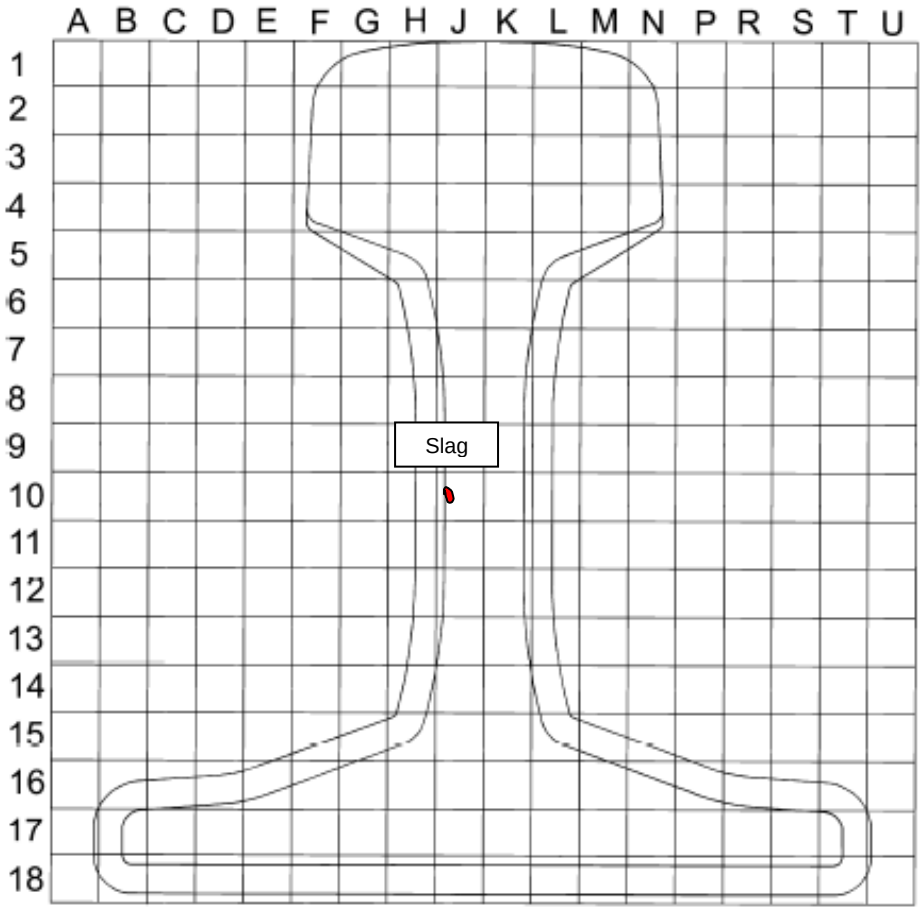
3.2.4.4 Sample Nr. 14



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
14	Slag 1	Ø 3,2	Round	M17	-	Not broken	√		
	Slag 2	Ø 2,1	Round	M18	-	Not broken			

Table 24: Fracture face defects - sample 14

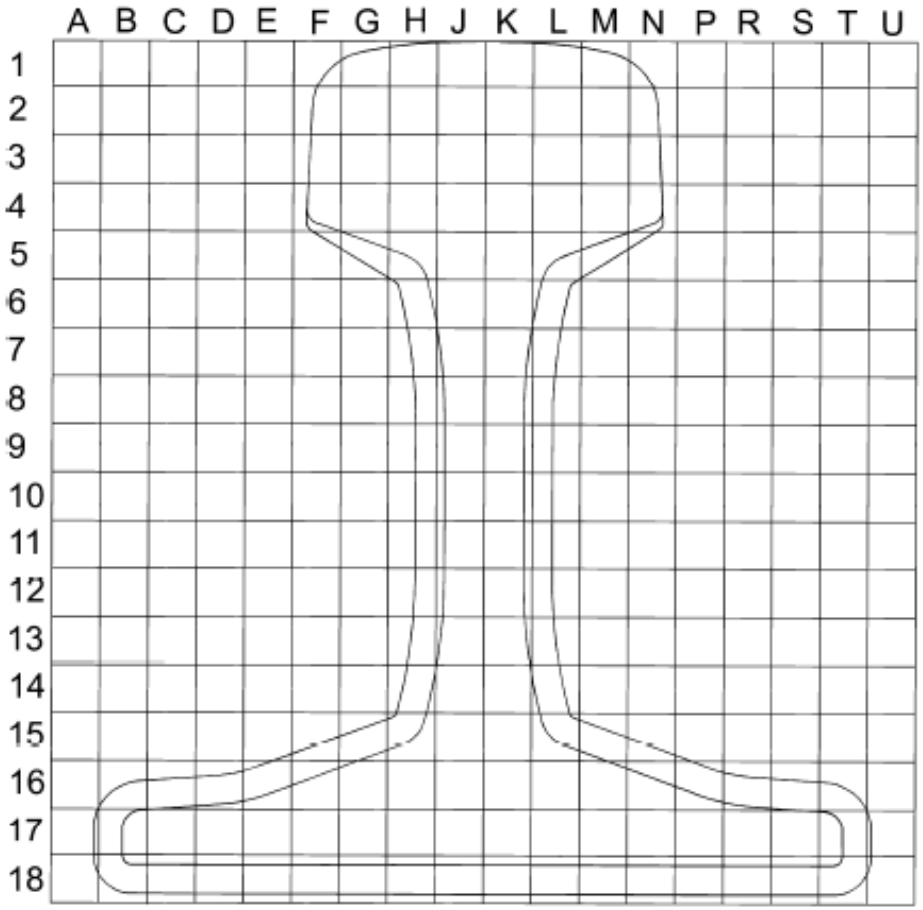
3.2.4.5 Sample Nr. 16



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
16	Slag	5,3 x 1,8	Oval	J10	-	Not broken	√		

Table 25: Fracture face defects - sample 16

3.2.4.6 Sample Nr. 17



Fracture face defects - Rail 60E1, Grade R260, Gap 47 / 53 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
17	-	-	-	-	-	-	√		√

Table 26: Fracture face defects - sample 17

3.2.5 Internal examination

In the following table are summarized the results of the fracture face defects checked acc. to EN 14730-1 point 7.4.1.4.

Internal examination - Rail 60E1, Grade R260, Gap 47 / 53 [mm]					
Samples	Head (1 defect > 2 [mm])	Web	Food		
	O-1 [mm]	5-6 [mm]	O-1 [mm]	2-3 [mm]	3-4 [mm]
10	-	-	-	-	-
11	-	-	-	-	-
12	-	-	0,8	2,4	-
14	-	-	-	2,1	3,2
16	-	5,3	-	-	-
17	-	-	-	-	-

Table 27: Internal examination - samples 10, 11, 12, 14, 16, 17

TÜV SÜD Statement: No defects in the head area have been found.

3.2.6 Weld soundness

The following samples were tested ultrasonically according to EN 14730-1 point 7.4.1 and annex H.

Wels soundness - Rail 60E1, Grade R260, Gap 47 / 53 [mm]			
Samples	Head	Web	Food
04	√	√	√
18	√	√	√
38	√	√	√
39	√	√	√

Table 28: Weld soundness- samples 04, 18, 38, 39

TÜV SÜD Statement: No "lack-of-fusion" defects, large gas pores and "hot tears" in the rail head, web and food have been found. All the results are summarized in [9].

3.2.7 Fusion zone - shape and dimension

Fusion zone - shape and dimension - Rail 60E1, Grade R260, Gap 47 / 53 [mm]			
Samples	Longitudinal vertical section on centre line	Longitudinal vertical section of foot tip	Longitudinal vertical section of foot tip
	Cut 1	Cut 2.1	Cut 2.2
04	√	√	√
18	√	√	√
38	√	√	√
39	√	√	√

Table 29: Fusion zone- samples 04, 18, 38, 39

TÜV SÜD Statement: All the requirements of EN 14730-1 pt. 7.4.2.2 are met. No "lack of fusion" or an unwelded weld collar's edge with the rail surface was recorded. All the results have been summarized in [10].

3.2.8 Heat softened zone width

Heat softened zone width - Rail 60E1, Grade R260, Gap 47 / 53 [mm]				
Samples	Unit	Width between A1 – B1	Width between A2 – B2	Tolerance acc. RFI: ≤ 30 [mm]
04	mm	5,5	5,5	30
18	mm	5,5	2,7	30

Table 30: Heat softened zone - samples 04, 18

TÜV SÜD Statement: The heat softened zone on either side of the weld had less than 30 mm, reason while the requirements of the RFI TCAR SF AR 07 005 are met. All the results are summarized in [11].

3.3 Grade Extension – Rail 60E1, Grade R200, Gap 23 / 27

The tests were performed in accordance to the following table issued by Thermit.

Reference to 14730-1	**EN 14730-1: Table 2 Category 3**			
Test	Number of welds		Rail nr.	Test conducted by
A - Centreline Hardness	6		W0502 – W0503 – W0504 – W0506 – W0507 – W0508	Elektro Thermit
B - Surface examination - Visual	8		W0502 – W0503 – W0504 – W0505 - W0506 – W0507 – W0508 – W0509	TÜV SÜD Rail
C - Visible HAZ	2		W0503 - W0508	Laboratory TÜV SÜD I.S.
D - Slow bend test	2		W0502 - W0509	Laboratory TÜV SÜD Rail
F - Fatigue test	-			
G - Weld soundness 7.4.1.5	2		W0502 - W0509	Laboratory TÜV SÜD I.S.
H - Fusion width	-			
I - Chemical analysis	3		W0503 – W0504 – W0508	Laboratory TÜV SÜD I.S.
J - HAZ hardness	2		W0505 - W0506	Laboratory TÜV SÜD I.S.
K - Structure	1^{α}	1^{β}	W0505 - W0506	Laboratory TÜV SÜD I.S.
L - UT inspection	8		W0502 – W0503 – W0504 – W0505 - W0506 – W0507 – W0508 – W0509	Laboratory TÜV SÜD I.S.
Total	4	4		
Rail	60E1	60E1		
Grade	R200	R200		
Gap [mm]	23	27		
Crucible	LLC	LLC		

Table 31: Rail 60E1, Grade R200, Gap 23 / 27 [mm]

TÜV SÜD Statement: TÜV SÜD Rail supervised the welding of all samples by the company Elektro-Thermit in Halle.

3.3.1 Centerline hardness

Centerline hardness – Rail 60E1, Grade R200, Gap 23 / 27[mm]						
Samples	Unit	Centerline			Average of the 3 hardness values	Tolerance acc. RFI 230 ± 20 HBW
		1 (Running Edge)	2 (Center)	3		
W0502	HBW	234	238	236	236	210 – 250 HBW
W0503	HBW	230	231	233	231	210 – 250 HBW
W0504	HBW	224	225	227	225	210 – 250 HBW
W0506	HBW	230	232	231	231	210 – 250 HBW
W0507	HBW	223	223	224	223	210 – 250 HBW
W0508	HBW	225	230	223	226	210 – 250 HBW

Table 32: Centerline hardness – samples W0502, W0503, W0504, W0506, W0507, W0508

TÜV SÜD Statement: All the values measured are inside the given tolerances of table 5 of the EN 14730-1. All results are summarized in [12].

3.3.2 Surface examination

Surface examination – Rail 60E1, Grade R200, Gap 23 / 27[mm]							
Samples	Unit	7.1.1 As cast weld surface			7.1.2 Ground weld surface		
		Cracks	Pores	Slag and sand inclusions	Cracks	Defects	Ground collar surface
		Tolerance: < 2mm	Tolerance: < 3mm (between 2-3mm max. 3. Pores)	Tolerance: RFI table 3	Tolerances: No cracks allowed	Tolerance: RFI table 3, no defects allowed	Tolerance: RFI table 2, no defects allowed
W0502	mm	√	√	√	√	√	√
W0503	mm	√	√	√	√	√	√
W0504	mm	√	√	√	√	√	√
W0505	mm	√	√	√	√	√	√
W0506	mm	√	√	√	√	√	√
W0507	mm	√	√	√	√	√	√
W0508	mm	√	√	√	√	√	√
W0509	mm	√	√	√	√	√	√

Table 33: Surface examination - samples W0502, W0503, W0504, W0505, W0506, W0507, W0508, W0509

TÜV SÜD Statement: The results of the surface examination fulfill the requirements of table 2 and 3 of the RFI TCAR SF AR 07 005 B and point 7.1.1 and 7.1.2 of the EN 14730-1.

3.3.3 Visible heat affected zone

Visible HAZ – Rail 60E1, Grade R200, Gap 23 / 27[mm]				
Sample	Unit	Centerline HAZ left	Centerline HAZ right	Tolerance RFI: 40 mm
W0503	mm	18	18	40
W0508	mm	17	16	40

Table 34: Visible heat affected zone - samples W0503 and W0508

TÜV SÜD Statement: The measured values fulfill the requirements of table 2 of the RFI TCAR SF AR 07 005 B. All the results are summarized in [13].

3.3.4 Slow bend test

Slow bend test - Rail 60E1, Grade R200, Gap 23 / 27 [mm]	
Samples	Minimum fracture load 1200 [KN]
W0502	√
W0509	√

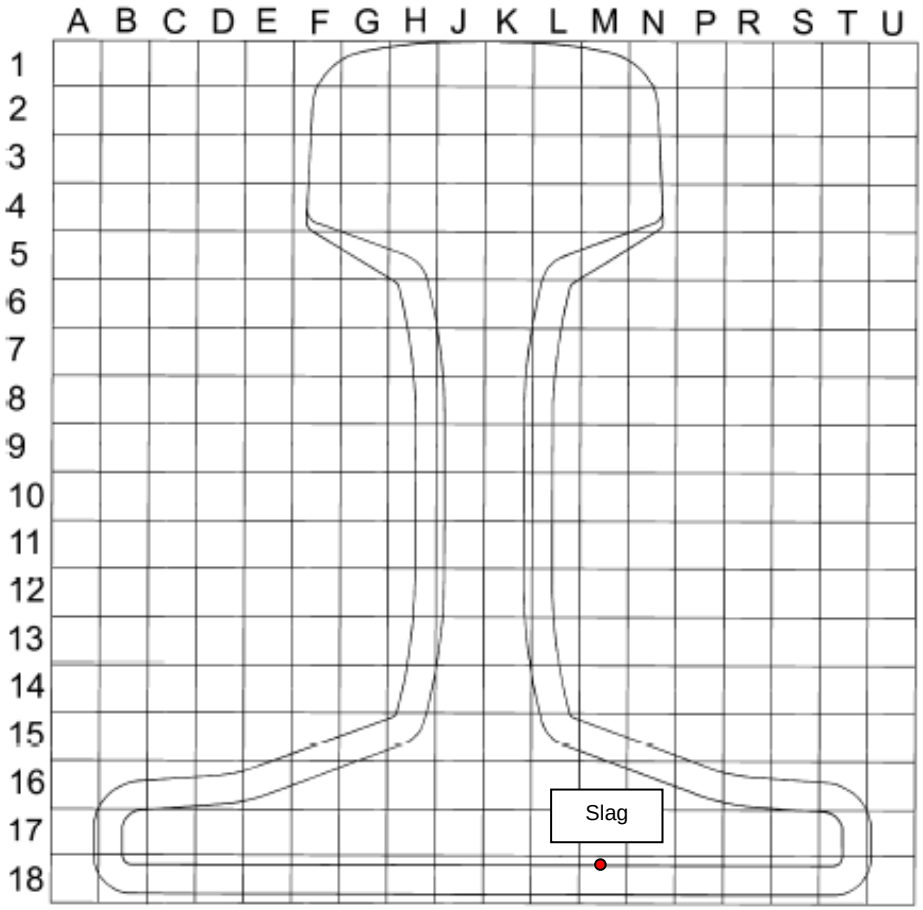
Table 35: slow bend test - samples W0502, W0509

TÜV SÜD Statement: The 2 samples reached the minimum fracture load of 1200 [KN] according the EN 14730-1 point 7.3. All the results are summarized in [14].

3.3.5 Fracture face defects

After the slow bend test the fracture face defects were recorded by TÜV SÜD Rail acc. to point 7.4.1.5 and Annex G.

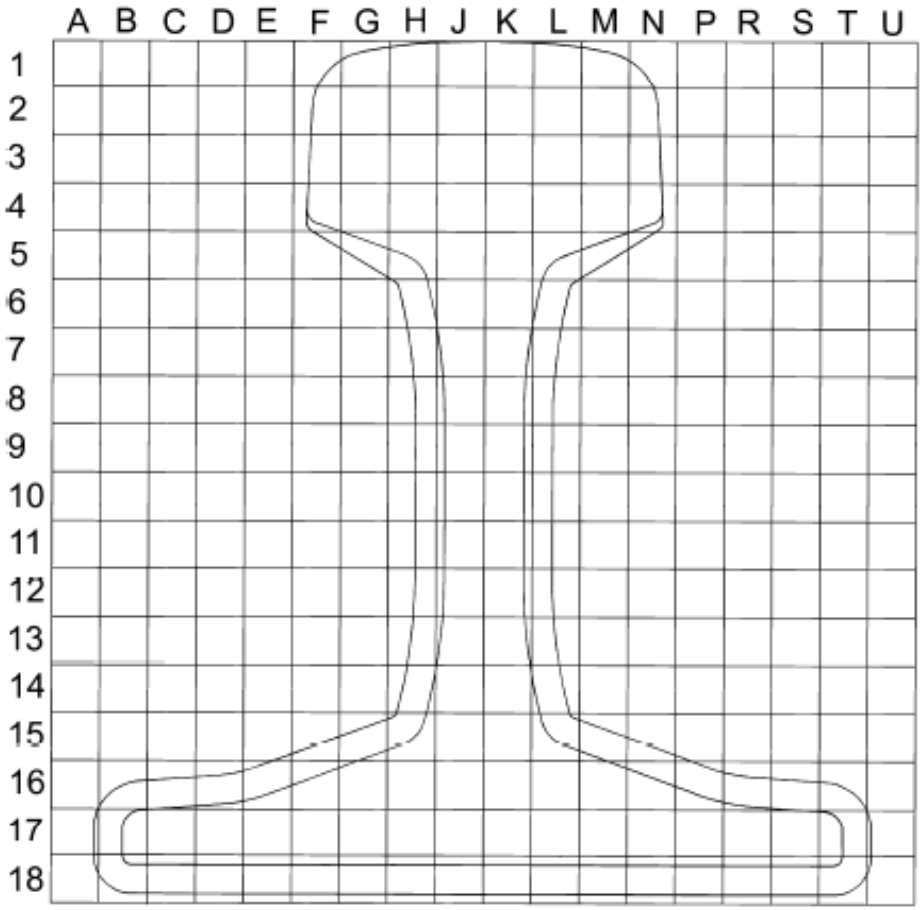
3.3.5.1 Sample Nr. W0502



Fracture face defects - Rail 60E1, Grade R200, Gap 23 / 27 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0502	Slag	Ø 1	Round	M18	-	Not broken	√		

Table 36: Fracture face defects - sample W0502

3.3.5.2 Sample Nr. W0509



Fracture face defects - Rail 60E1, Grade R200, Gap 23 / 27 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0509	-	-	-	-	-	-	√		√

Table 37: Fracture face defects - sample W0509

3.3.6 Internal examination

In the following table are summarized the results of the fracture face defects checked acc. to EN 14730-1 point 7.4.1.4.

Internal examination - Rail 60E1, Grade R200, Gap 23 / 27 [mm]			
Samples	Head (1 defect > 2 [mm])	Web	Food
	O-1 [mm]	O-1 [mm]	O-1 [mm]
W0502	-	-	1
W0509	-	-	-

Table 38: Internal examination - samples W0502, W0509

TÜV SÜD Statement: No defects in the head area have been found.

3.3.7 Chemical analysis

Chemical analysis - Rail 60E1, Grade R200, Gap 23 / 27 [mm]							
Element	Permitted range (%)				Samples - Measurements (%)		
	Minimum	Maximum	Mean value	Working range	W0503	W0504	W0508
Carbon	0,30*	0,54*	0,42**	+/- 0,12	0,36	0,35	0,36
Silicon	0,30*	0,80*	0,55**	+/- 0,25	0,51	0,50	0,51
Manganese	0,60*	1,00*	0,80**	+/- 0,20	0,84	0,89	0,90
Phosphorus	0,00	0,035	-	-	0,030	0,028	0,30
Sulphur	0,00	0,035	-	-	0,004	0,005	0,003
Chromium	0,00	0,20	-	-	0,15	0,14	0,14
Molybdenum	0,00	0,10	-	-	0,03	0,03	0,03
Nickel	0,00	0,10	-	-	0,05	0,05	0,05
Aluminium	0,020	0,420	0,22**	+/- 0,20	0,08	0,14	0,13
Copper	0,00	0,20	-	-	0,04	0,04	0,04
Tin	0,00	0,02	-	-	***	***	***
Antimony	0,00	0,02	-	-	***	***	***
Titanum	0,00	0,05	-	-	0,002	0,003	0,003
Niobium	0,00	0,01	-	-	0,05	0,05	0,05
Vanadium	0,00	0,25	-	-	0,02	0,02	0,01

Table 39: Chemical analysis - Rail 60E1, Grade R200, Gap 23 / 27 [mm]

* Specified values by Elektro-Thermit see [15.2]

** Mean value specified by Elektro- Thermit

*** Below the detection limit

TÜV SÜD Statement: The actual values of the analyzed elements taken from 3 samples were within the permitted range. All analyzed elements, where no working range is given fit in the permitted range (EN 14730-1 point 7.6 table 7). The elements Tin and Antimony are below the detection limit. The results are summarized in [15.1].

3.3.8 Microscopic examination

Microscopic examination - Rail 60E1, Grade R200, Gap 23 / 27 [mm]				
Samples	Head		Food	
	Visible heat affected zone - Containing no bainite and martensite	Fusion zone - Containing no bainite and martensite	Visible heat affected zone - Containing no bainite and martensite	Fusion zone - Containing no bainite and martensite
W0505	√	√	√	√
W0506	√	√	√*	√

Table 40: Microscopic examination - samples W0505 and W0506

TÜV SÜD Statement: The examined samples contained no bainite and martensite. The structure of the fusion zone conforms to that defined by the supplier.

* Sample W0506 had in the food near the fusion line slag inclusions which are conditional of manufacturing in the rails. All the results are summarized in [17.1].

In the document [17.2] Elektro-Thermit defined the microstructure of the welding.

3.3.9 Ultrasonic inspection

Ultrasonic inspection - Rail 60E1, Grade R200, Gap 23 / 27 [mm]						
Samples	Test of head for non-planar defects	Test of heat for planar defects	Test of web for planar defects	Test of middle of food	Test of ankles	Test of toes
	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 5 mm diame-ter flat-bottomed hole.	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 10 mm diameter flat-bottomed hole.	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 10 mm diameter flat-bottomed hole.	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 10 mm diameter flat-bottomed hole.	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 5 mm diame-ter flat-bottomed hole.	Acceptance criteria: Reject level – any defect signals ≥ the signal from a 5 mm diame-ter flat-bottomed hole.
W0502	√	√	√	√	√	√
W0503	√	√	√	√	√	√
W0504	√	√	√	√	√	√
W0505	√	√	√	√	√	√
W0506	√	√	√	√	√	√
W0507	√	√	√	√	√	√
W0508	√	√	√	√	√	√
W0509	√	√	√	√	√	√

Table 41: Ultrasonic inspection - samples W0502, W0503, W0504, W0505, W0506, W0507, W0508, W0509

TÜV SÜD Statement: All samples were tested ultrasonically according to EN 14730-1 Annex C and the results were inside the acceptance criteria. All the results are summarized in [18].

3.4 Fatigue Test - Rail 60E1, Grade R260, Gap 23 / 27

The fatigue tests where required by RFI and were conducted in accordance to the following table issued by Thermit.

Required from RFI				
Test	Number of welds		Rail nr.	Test conducted by
A - Centreline Hardness	-			
B - Surface examination - Visual	3		W0499 – W0500 – W0501	TÜV SÜD Rail
C - Visible HAZ	-			
D - Slow bend test	-		W0499 – W0500 – W0501	Laboratory TÜV SÜD Rail
F - Fatigue test	3		W0499 – W0500 – W0501	Laboratory SLV
G - Weld soundness 7.5.3	3		W0499 – W0500 – W0501	TÜV SÜD Rail
H - Fusion width	-			
I - Chemical analysis	-			
J - HAZ hardness	-			
K - Structure	-			
L - UT inspection	-			
Total	2	1		
Rail	60E1	60E1		
Grade	R260	R260		
Gap [mm]	23	27		
Crucible	SUC	SUC		

Table 42: Rail 60E1, Grade R260, Gap 23 / 27 [mm]

TÜV SÜD Statement: TÜV SÜD Rail supervised the welding of all samples by the company Elektro-Thermit in Halle.

3.4.1 Surface examination

Surface examination – Rail 60E1, Grade R260, Gap 23 / 27 [mm]							
Samples	Unit	7.1.1 As cast weld surface			7.1.2 Ground weld surface		
		Cracks	Pores	Slag and sand inclusions	Cracks	Defects	Ground collar surface
		Tolerance: < 2mm	Tolerance: < 3mm (between 2-3mm max. 3. Pores)	Tolerance: acc. RFI table 3	Tolerances: No cracks allowed	Tolerance: acc. RFI table 3, no defects allowed	Tolerance: acc. RFI table 2, no defects allowed
W0499	mm	√	√	√	√	√	√
W0500	mm	√	√	√	√	√	√
W0501	mm	√	√	√	√	√	√

Table 43: Surface examination-samples W0499, W0500, W0501

TÜV SÜD Statement: The measured values fulfill the requirements of table 2 and 3 of the RFI TCAR SF AR 07 005 B and point 7.1.1 and 7.1.2 of EN 14730-1.

3.4.2 Fatigue test

Fatigue test – Rail 60E1, Grade R260, Gap 23 / 27 [mm]	
Samples	5 million cycles
W0499	"run – out"
W0500	"run – out"
W0501	"run – out"

Table 44: Fatigue test- samples W0499, W0500, W0501

TÜV SÜD Statement: The 3 samples reached the cycle of 5 million without any break in that way they fulfill Annex K.1 of the EN 14730-1. All the results are summarized in [19].

3.4.3 Slow bend test

Slow bend test - Rail 60E1, Grade R260, Gap 23 / 27 [mm]	
Samples	Minimum fracture load 1200 [KN]
W0499	√
W0500	√
W0501	√

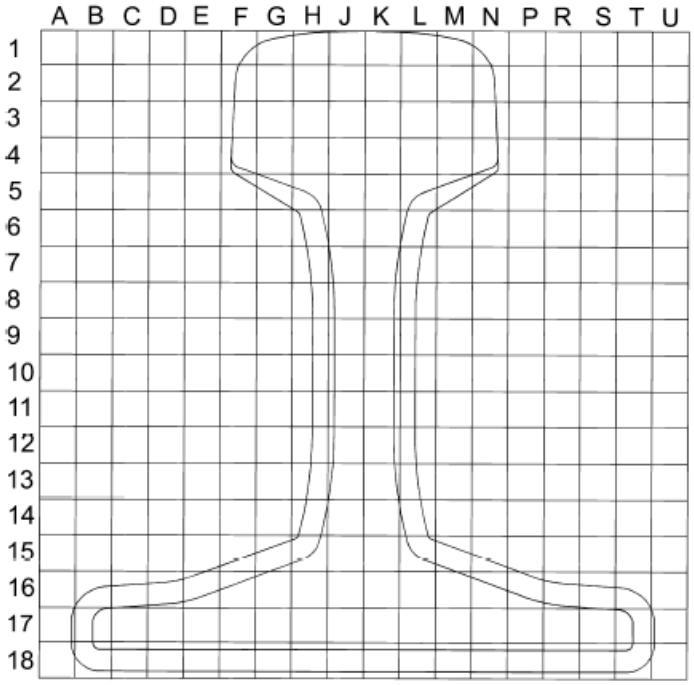
Table 45: Slow bend test - samples W0499, W0500, W0501

TÜV SÜD Statement: The 3 samples reached the minimum fracture load of 1200 [KN] according to EN 14730-1 point 7.3. All the results have been summarized in [20].

3.4.4 Fracture face defects

After the slow bend test the fracture face defects were tested acc. to point 7.4.1.5 and Annex G.

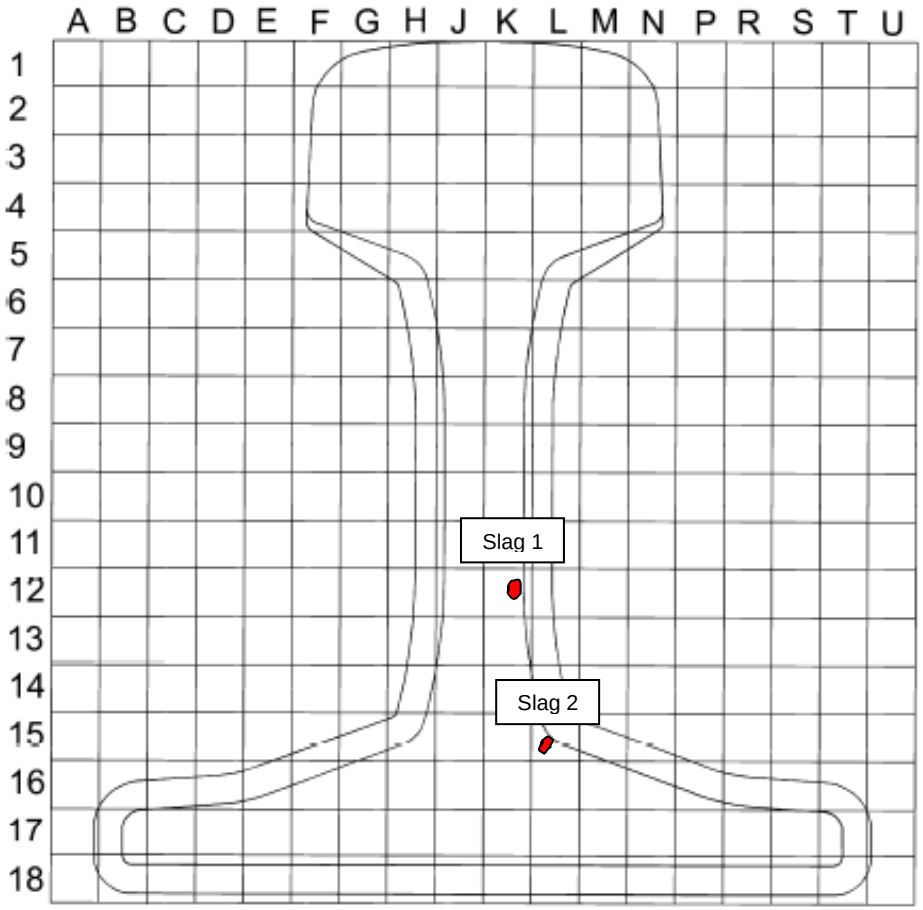
3.4.4.1 Sample Nr. W0499



Fracture face defects - Rail 60E1, Grade R260, Gap 23 / 27 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0499	-	-	-	-	-	-		√	√

Table 46: Fracture face defects - sample W0499

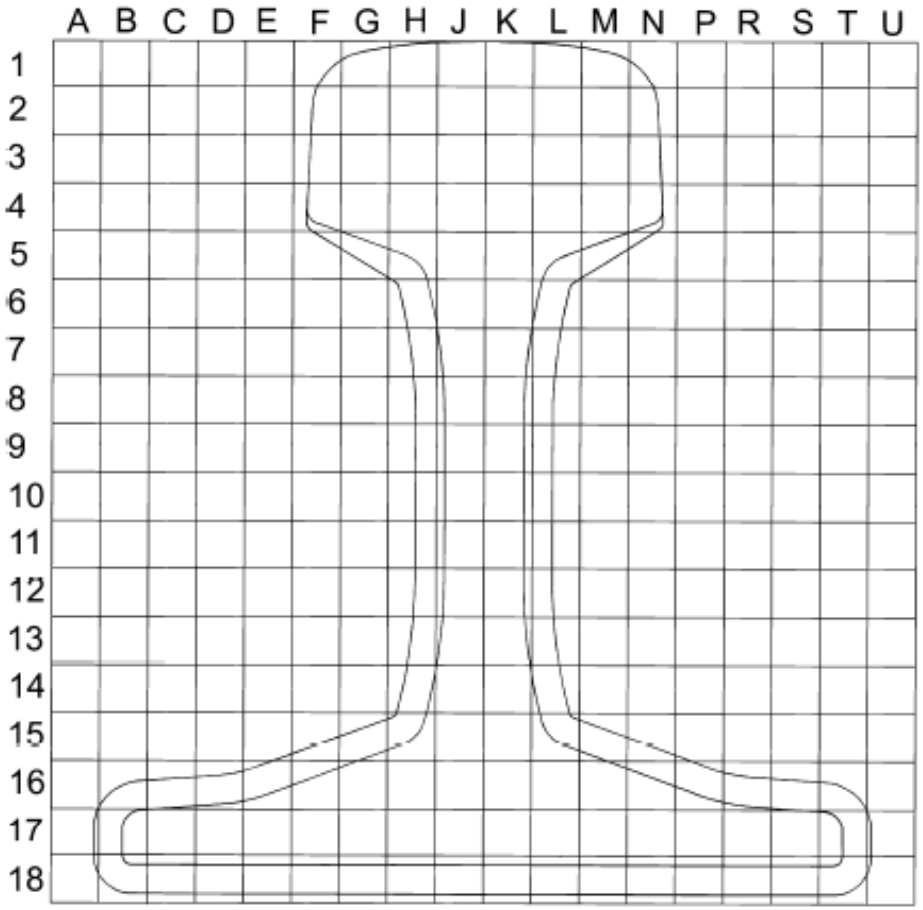
3.4.4.2 Sample Nr. W0500



Fracture face defects - Rail 60E1, Grade R260, Gap 23 / 27 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0500	Slag 1	4,5 x 3,5	Oval	K12	-	Not broken		√	
	Slag 2	4,5 x 1,8	Oval	L15	-	Not broken			

Table 47: Fracture face defects - sample W0500

3.4.4.3 Sample Nr. W0501



Fracture face defects - Rail 60E1, Grade R260, Gap 23 / 27 [mm]									
Sample	Type of defect (pores, slag, sand inclusion, metal beads)	Surface dimension (diameter or length x width) [mm]	Shape [round, oval, etc.]	Location	Depth of pores [mm]	Whether surface breaking	Sample: Slow bend test	Sample: Fatigue test	No visible defects
W0501	-	-	-	-	-	-		√	√

Table 48: Fracture face defects - sample W0501

3.4.5 Internal examination

In the following table are summarized the results of the fracture face defects checked acc. to EN 14730-1 point 7.4.1.4.

Internal examination - Rail 60E1, Grade R260, Gap 23 / 27 [mm]			
Samples	Head (1 defect > 2 [mm])	Web	Food
	O-1 [mm]	4-5 [mm]	4-5 [mm]
W0499	-	-	-
W0500	-	4,5	4,5
W0501	-	-	-

Table 49: Internal examination – samples W0499, W0500, W0501

TÜV SÜD Statement: No defects in the head area have been found.

3.5 Conclusion

For the

Process changes

- Rail 60E1, Grade R260, Gap 23 (see chapter 3.1);
- Rail 60E1, Grade R260, Gap 47 / 53 (see chapter 3.2)

Grade extension

- Rail 60E1, Grade R200, Gap 23 / 27 (see chapter 3.3)

Fatigue tests

- Rail 60E1, Grade R260, Gap 23 / 27 (see chapter 3.4)

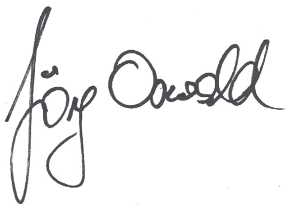
have been conducted the tests in accordance to the EN 14730-1:2009 and the technical specification RFI TCAR SF AR 07005B. All performed tests gave positive results and fulfill the requirements of the EN 14730-1:2009 and the technical specification RFI TCAR SF AR 07005B.

TÜV SÜD Rail

Graz 01.12.2010



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