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INNOTRACK

D 4.6.5 Gas Pressure Welding – Quality of Test Welds

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Glossary

B.C.G.A.	British Compressed Gases Association
Clamping Pressure :	Pressure Applied to fasten the welding machine to the workpieces (rails)
H.A.Z.	Heat Affected Zone
Hv30	Vickers Hardness Value with 30kg indentor
MPa:	Mega Pascal
M.P.I.	Magnetic Particle Inspection
G.P.W.	Gas Pressure Weld or Welding
G.T.G.	The Thermit Goldschmidt Group
GT-C	Goldschmidt Thermit - China
Staircase Method:	Approved method of determining the minimum number of tests required to assess the fatigue strength of a component
Тое	The outer foot tip of the rail profile
Weld Upset	The excess rail material remaining around the periphery of the rail after the weld has been mechanically trimmed

1. Executive Summary

Following the presentation release of gas pressure welding report no 1⁽¹⁾ at the working group meeting held in December 2006 at the Goldschmidt Thermit offices in Halle, representatives from the track authorities expressed reservations as to the suitability of the technology for track trials. The working group agreed to amend the work programme to include laboratory analysis of GPW welds manufactured in the workshop, using propriety welding equipment. The welds were to be procured through the services of GTG -Thermit China for laboratory testing, at the GTG Research and Development facilities in Halle. The report on the tests undertaken to assess weld quality were to be reported in the present report – Deliverable D4.6.5.

The merged Innotrack Deliverable D4.6.3 / D4.6.4 ⁽²⁾ provided recommendations for the application of established European standards for the approval of flash butt and aluminothermic welds to gas pressure welds, with boundary acceptance criteria. The welds produced in China have therefore been examined using the test process recommended in the report, with specific attention to the presence of foot tip lack of bond defects evident in the earlier studies.

In this report, the information provided from the tests demonstrates the potential of the gas pressure welding process for use as an alternative to site based flash butt welding. The process required further development to improve joint alignment but mechanical and metallurgical properties of the welded joint compare favourable with those of flash butt welds. The long-term resistance to preferential wear remains in question due the greater length of heat affected zone on the running surface as compared to flash welds⁽³⁾. Therefore further laboratory wear tests may be required before installation in heavy use track. The process will also require development for application with heat treated or alloyed rails.

2. Introduction

To date the Gas Pressure Welding (GPW) process has not seen use in Europe, however, in the UK the opening of the railway infrastructure maintenance business to private contractors has lead to the renewed interest in innovative rail maintenance methods which either reduce costs, or track possession times – or both.

Gas Pressure Welding forms a work package in the Innotrack project. The first progress report ⁽¹⁾ summarised the introduction of the process, original acceptance tests undertaken in the UK and deficiencies that were identified. A report issued under the merged deliverable D 4.6.3 and 4.6.4 ⁽²⁾ reviewed the operating parameters for the process with recommendations for improving equipment performance and quality control. The report also included a summary of established standards for welding process approval with adaption to Gas Pressure welds.

One of the key properties of any weld is its reaction to impact and wear – differential wear across the weld and heat affected zone arising from the change in metallurgy, leading to localised batter or wear, which in addition to increasing impact forces has been linked to the initiation of corrugations and squats. The work in Deliverable D 4.6.1 has been considering the potential of novel welding processes and procedures to restrict preferential wear with attention to Aluminothermic and Flash welding methods. The results from this work package⁽³⁾ have therefore been used as a comparison when assessing the mechanical and metallurgical properties of the Gas Pressure welds.

2.1 Approval Protocol – Testing Conditions

As no specific specifications for Gas Pressure Weld quality were available, the laboratory assessment used criteria contained in two technical standards for the closest equivalent welding method (Flash butt welding) were selected as the model for defining a process approval protocol:

- EU Standard: EN 12587-1⁽⁴⁾ Flash Butt welding of rails pt 1 220 & 260 grade rails in fixed plant
- Network Rail: RT/CE/S/001⁽⁵⁾ Joining of Rails by Flash Welding (now NR/TRK/S/001)

In addition reference has been taken to Innotrack reports issued under work packages D $4.6.1^{(3)}$ and D4.6.4^{(2)}

These standards include provision for mobile welding plant but the core technical requirements for process approval are common.

3. Results of the Test Programme

3.1 Manufacture of Test Welds

Lengths of new 60E1 rail grade 260 were provided by Corus. The test welds were manufactured by the process supplier in collaboration with the Goldschmidt Thermit China Company (GT C). A total of 14 welds were ultimately provided for testing – these were transported to the GTG Research and Development division at Elektro-Thermit GmbH in Halle for mechanical and Metallurgical examination.

The report from GT China covering the manufacture of the test welds is provided in **Annex 3-1**. Welding conditions remained unchanged during production, and rail end preparation, welding, and finishing (trimming) was in accordance with the process requirements. All the welds were left in the "as trimmed" condition for measurement of the upset and as trimmed straightness.

The welding parameters provided by the manufacturer are shown in **Annex 1-1**.

On arrival at GTG, the welds were visually examined, and straightness measurements taken using the GT electronic straightedge (Annex 3.2)

After the measurement of weld upset and as-welded joint alignment, welds were profile ground to before final straightness measurements.

3.2 Inspection and Joint alignment

3.2.1 Visual examination and Non destructive Testing (NDT)

All the welds were examined for visual defects and then photographed. No surface cracks were identified. Photographs of the as trimmed welds are shown in **Annex 2.1-14**.

Three welds were selected at random and the trimmed surfaces were tested using magnetic particle inspection methods (MPI). Particular attention was given to the foot tip areas to detect any presence of small trimming tears. No evidence of tears was found.

3.2.2 Weld Trimming Quality.

The weld upset was inspected for surface finish (no score marks, notches on the exit of the trimming blades, undercut) and the closeness of the trimmed upset to the rail profile measured using the GT electronic straightedge. The measurements of upset dimensions are provided in **Annex 1. 2**, and summarised below:

Trimming Upset	En 14587 pt 1		Test weld - max thickness	
location	maximum thickness - mm		range (mm)	avg (mm)
Aligned surfaces – head, gauge face	1.0 mm		0.25 – 1.1 0.15 – 1.4	0.65 0.64
Upper and underside of the foot foot tips	1.0 mm		2.75 – 4.45 0 - 4.05	3.74 2.52

Trimming Upset	En 14587 pt 1		Test weld - max	x thickness
location	maximum thickness - mm		range (mm)	avg (mm)
Fishing surface –underside of head	2.5 mm		not measured	
All other surfaces	2.0 mm		0.55 - 3.10	1.89

3.2.3 Joint Misalignment

The step across the joint in the as-welded condition was measured at 100mm either side of the centreline. These results are presented in **Annex 1.3** and summarised below:

Step across the weld interface	En 14587 pt 1		test weld	
			range	avg
Vertically -on the running surface	0.5mm		0.3 – 6.65	4.17
Horizontally – on the aligned face	0.5mm		0. – 2.8	0.58
Horizontally –across the foot tip	2.0mm		not measured	

3.2.4 Joint Straightness

Limits on straightness are measured over a 1.0m span with the weld central. Straightness tolerances are normally linked to line speed – in the case of GPW weld acceptance the highest line speed (90mph and above) was selected. Straightness measurements along the running surface and one aligned gauge face were taken after the joints had been profile ground.

The results are shown graphically in **Annex 2 .15-17**, and the values 100mm either side of the weld interface are presented in **Annex 1.4** and summarised below:

Joint straightness –over 1.0m span	En 14587 pt 1 (class 1)		test welds	
			range	avg
Vertically –on the running surface	0 - 0.3 mm		0 - 0.6	0.19
Horizontally – on the aligned face	0 - +/- 0.3mm		0 - 0.15	0.04
Horizontally –across the foot tip	1.5		not measured	

3.2.5 Flatness

Flatness is a measurement of the performance of the profile grinding – usually measured over a 200 mm straightedge. The maximum gap between the straightedge and the finish ground rail surface must be less than 0.2mm.

The results of the flatness measurements are provided in **Annex 1.5**.



3.3 Mechanical Testing

3.3.1 Bend Testing

Bend testing on full rail section welds is undertaken using the arrangement shown in Appendix III. All tests are completed to failure of the joint or up to a pre determined maximum load. A record is maintained of the load at failure, with an option to also record deflection. 5 welds were selected at random for testing, and the results are shown in Annex 1.6 and 2.18, and summarised below:

Bend test – minimum load	En 14587 pt 1		GPW test welds	
			range	avg
56E1 – grade 220	1230			
56E1 – grade 260	1330			
60E1 – grade 220	1500			
60E1 – grade 260	1600		1809 - 1856	1830

3.3.2 Fatigue Tests

The common form of fatigue test is to establish the fatigue strength of the weld at a life of 5,000,000 cycles. This is usually evaluated using the "Staircase "method, and a minimum of 8 welds would be allocated for testing. For this project the fatigue testing procedure was amended with a reduced life of 2,000,000 cycles. The results are recorded below and compared with archive data on aluminothermic welds, Gas Pressure welds, and Flash butt welds in **Annex 1.7** and **2.19**.

Fatigue Strength -	En 14587 pt 1		Test data		
Weld I.D.	stress range	life (cycles)	stress range	life (cycles)	
flash weld	215 MPa	5,000,000			
gas pressure:				*	
396			216Mpa	> 2,000,000	
401			216Mpa	> 2,000,000	
402			216 MPa	> 2,000,000	

3.4 Metallurgical Examination

Prior to the metallurgical examination, the hardness of the base rail material and its chemical composition was measured. The results are provided in **Annex1.8**.

3.4.1 Macro Examination

Two welds were sectioned and prepared for macro examination in order to determine the dimensions of the heat-affected zone (HAZ), HAZ symmetry and the presence of any weld interface defects.

The sections are normally prepared from the vertical centreline of the full rail section, with additional sections from each side of the foot, 10mm inboard of the foot tip.

Photographs of the two welds are shown in **Annex 2.20 & 2.21**. The weld interface is not distinguishable from the heat affected zone, but the approximate bond line was examined for presence of defects down the centreline and foot tip. No evidence of cracks or voids was recorded.

After preparation and etching with Fry's reagent, the weld heat affected zone dimensions along the centreline and foot tip was measured. (Annex 2.20 & 2.21). The dimensions are compared with Aluminothermic, Flash butt welds, and previous Gas Pressure welds in Annex 1.9.

Macro Examination HAZ	En 14587 pt 1		GPW	
Minimum width	25m		74mm	
Maximum width	45 mm		82mm	
Maximum variation	10 mm		15mm	

3.4.2 Hardness Testing

The hardness variation through the heat-affected zone has to be measured at a position not less than 5mm below the running surface. The Vickers method of hardness testing is used as the default in compliance with EN ISO 6507. The hardness variation measured across weld 391 is recorded in Annex 2. 22

HAZ Hardness Variation - Hv30	En 14587 pt 1		GPW weld 391	
			rail 1	rail 2
parent rail			275 -295	260 – 275
HAZ minimum hardness			238	235
HAZ Maximum Hardness			275 -300	
variation as specified :				
Minimum hardness	P - 30 Hv 30kg		235 - 265	230 – 245
Maximum hardness width	P + 60 Hv 30kg		335 - 355	310 - 335
(P = avg hardness of parent rail steel)				

3.4.3 Micro Examination

Micro examination of the samples from the prepared sections from the head and each side of the foot are prepared and etched (2-4% Nital) for Micro examination. The weld interface and heat affected zone in the

head and foot was examined for micro defects and cracks, and to confirm that there was no evidence of y Martensite or Bainite at 100x magnification. Micrographs of the two sections are shown in Annex 2.23

3.4.4 Foot defects

The main problem with previous test welds manufactured using Gas Pressure welding process was the propensity to form planar lack of bond defects in the foot tip $^{(1,2)}$ (Annex 2.24)

Samples of the test welds from this project were examined in the foot tip sections to determine whether similar defects could be identified. Magnetic particle inspection and subsequent sectioning demonstrated that there was no evidence of similar defects in this series of tests.

3.5 Wear Tests

By agreement with the working group twin disc wear tests on test pieces machined from two Gas pressure welds have been undertaken by Corus Rail technology. The test discs were machined from the rail head in the horizontal orientation, so that the disc contact surface was in the heat affected zone of the welded joint., The results are summarised below with comparative data provided by Corus for R 260 grade rail:

Comparative wear data								
Weld I.D.	Hardness (HB)	Contact Stress (MPa)	Rail Wear (mg/m of slip)	Wheel wear (mg/m of slip)				
GPW Weld 1	283	560	36.7	56.4				
GPW weld 2:	297	560	33.4	54.9				
R260 rail	266	560	63.6	67.3				

4. Compliance with Flash Weld Technical Standards

A summary of the test requirements for approval of a process based on the EN 14587 protocol for flash butt welds is provided in **Appendix III**. The closest equivalent "solid phase" welding process deployed to weld rail is the Flash Butt welding method, therefore the criteria for acceptance of mobile flash welding equipment has been used as the basis for comparison. The criteria and tolerances for this assessment has been described in previous Innotrack reports for work package 4.5.4 and reproduced below. The highlighted data is outside the specified range for the flash butt weld.

			GP Weld data	Flash weld	GPW weld
			from first series (ref 1,2)	criteria	current series
2.2.1	Excess upset	Head	<mark>1.25 - 1.65mm</mark>	1.0mm	0.25 – 1.0
		Foot	0.7 - <mark>2.8</mark>	2.0mm	<mark>2.75 – 4.45</mark>
		Other surfaces	<mark>1.6 -1.8</mark>	1.0mm	<mark>0.55 - 3.1</mark>
2.2.2	Step across the weld	Vertical – surface	0 - 0.32	0.5mm	0.3 – <mark>6.6</mark>
		Horizontal	0 – 0.39	0.5mm	0.0 – <mark>2.8</mark>
2.2.3	straightness	Running surface	<mark>0.09</mark>	0-0.4mm	0.0 - <mark>0.6</mark>
		Running edge	<mark>0-0.66</mark>	+/-0.4mm	0.0 - <mark>1.5</mark>
2.2.4	Flatness	200mm span	< 0.2mm	0.2mm max	< 0.2
2.3.1	Bend test	Min load	1348	1320 KN	1809 – 1886
		Deflection	30	n/a	
2.3.2	Fatigue test	Min @5m cycles	230MpA	215MpA	216Mpa
					(2,000,000 cycles)
2.4.1	Macro examination	Min HAZ width	<mark>115mm</mark>	20mm	<mark>74mm</mark>
		Max HAZ width	<mark>154mm</mark>	56mm	<mark>82mm</mark>
		HAZ variation	<mark>39mm</mark>	20mm	15mm
2.4.2	Hardness - HAZ	Rail avg	264Hv30	275 Hv30	275mm
		Min HAZ	230	245	<mark>238</mark>
		Max HAZ	295	335	300
2.2.3	Micro examination	Weld interface	Foot tip defects identified		no defects
		HAZ	Fully pearlitic		fully pearlitic.

4.1 Non Compliance

4.1.1 Alignment

Trimming was variable – excess upset remaining around the foot. This may be a result of the available trimming tooling not being adapted to match the 60E1 rail profile.

The step at the interface and vertical misalignment was variable. Additional support, alignment devices will be required if the Flash butt welding standard is to be achieved.

4.1.2 Heat Affected Zone:

The welding method produces a heat affected zone with a different metallurgy to that of Flash butt welds – the peak temperature and temperature gradient across the HAZ results in a relatively wide heat affected zone, but the metallurgical transformations within it reflect the relatively low temperature with limited grain growth, with a consequent small variation in HAZ hardness. The welds in this series show a significantly reduced HAZ width compared with the previous series produced by the TGP5 machine,

A better comparison could be made with an Aluminothermic weld, where the total "heat affected area" – including the weld metal, is greater than that produced in this series of Gas Pressure welds.

5. Concluding Comments

- 1) A series of Gas Pressure welds, manufactured out of track in 60 E1 260 grade rail, have been subject to testing using the procedure and criteria specified for depot based flash butt welds.
- 2) The principal divergence from the standard was the variation in as trimmed alignment. As with flash butt welds, the use of additional aligning equipment, supported by final adjustment and profile grinding should enable joints in Gas Pressure welds to be manufactured to the straightness standard required for installation in track.
- 3) The metallurgical and mechanical properties and characteristics of the Gas Pressure weld show distinct differences from the Flash butt weld, however, the combination of post weld treatment and control of the forging process has produced a heat affected zone in the joint showing minimal hardness variation and no abnormal transformation.
- 4) A brief assessment of the wear resistance by twin disc wear tests was undertaken at late notice by Corus Rail Technology. The data indicated that the heat-affected zone of the gas pressure has a slightly higher resistance to wear than the parent rail. Based on this data there should be little risk of preferential wear across the welded joint.
- 5) The results of these tests indicate that the weld quality is sufficiently high to support further work to confirm consistency and develop on site procedures for rail alignment and post weld straightening.

6. Bibliography

6.1 Acknowledgements

The author wishes to acknowledge the input of Corus Rail Technologies for the provision and shipment of the rail, and for the laboratory wear tests completed at their Swinden laboratories, U.K.

The welding and weld records were provided by Goldschmidt Thermit China.

All testing was undertaken by Dr R Gerhmann and Mrs Jinling Yang ant the GTG R& D laboratories at ElektroThermit GMBH, in Halle, Germany. Additional metallurgical examination was undertaken by Thermit Welding (GB) ltd .

6.2 References

1	R.S. Johnson	Gas Pressure Welding - Innotrack WP4.6 Progress report no 1 Thermit Welding (GB) Itd Technical Report TR 0607 –Nov 2006
2	Innotrack Report	D4.6.3 and D4.6.4 - Analysis of Equipment design and Optimisation of parameters for Gas Pressure Welding INT-SP4.6 – 13 – Gas Pressure Welding – D1 – Aug 2008
3	Innotrack Report	D4.6.1 – The influence of working procedures on the formation and shape of the HAZ of flash butt and aluminothermic welds in Rails D461-F3P-Influence on Formation and shape of HAZ – Nov 2007
4	EN 14587-1 (2007)	Railway Applications – Track – Flash Butt welding of track Pt 1: New 220 & 260 grades of rail in fixed plant
5	Network Rail NR/SP/TRK/111	Joining of Rails by Flash Butt Welding in a fixed depot Network Rail Technical Standard– Aug 2003

7. Annexes

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7.3 Annex 3 – Appendix 1 - 3

APPENDIX I -	GPW Welding Process – Procedure (Provided by GT C)
APPENDIX II –	Description of GT SE Straightedge
APPENDIX III –	Summary of Testing Protocol for Process Approval

ANNEX 1

TABLE 1 – Weld Parameters – GPW Test welds

			Alignm	ent Inspe	ection (mr	n)	oxyger	ı	acetyle	ene	Heating 1	Heating Time/Pump pressure		Forging	Normalizing Heat Treatme		at Treatment	comments
Weld	Date	Air T	rail			joint	Pres	Flow	Pres	Flow	stage			Dist	temp			
NO.		(°C)	Head	End	Foot	Gap	Мра	m³/h	Мра	m³/h	1	2	3		Start	fin	Time (ms)	
1	29.08.08	29	0.1	0.12	0.3	0.15	0.5	3.6	0.15	3.9	3m20s/ 18	5m00s/ 10	5m16s/ 36	30mm	450° C	900° C	2m00s	U-Slot bending test->broken surface inspection (passed)->Re- welded
2	29.08.08	28	0.1	0	0.2	0.2	0.5	3.6	0.15	3.9	3m12s/ 18	4m57s/ 10	5m18s/ 36	30mm	450° C	900° C	2m09s	
3	29.08.08	28	0.2	0.1	0.2	0.28	0.5	3.6	0.15	3.85	3m10s/ 18	5m00s/ 10	5m20s/ 35	30mm	440° C	890° C	2m15s	Slight higher joint gap at a fool side
4	31.08.08	27	0.2	0.1	0.2	0.15	0.5	3.6	0.15	3.8	3m12s/ 18	5m00s/ 10	5m14s/ 35	31mm	440° C	880° C	2m10s	
5	31.08.08	28	0.3	0.4	0.25	0.15	0.5	3.6	0.15	3.9	3m17s/ 18	4m48s/ 8	5m09s/ 34	32mm	450° C	890° C	2m05s	Shearing not completed, re- sheared by normalisation, slight dent at joint foot.
6	31.08.08	28	0.2	0.35	0.3	0.2	0.5	3.6	0.15	3.9	3m09s/ 20	4m55s/ 8	5m12s/ 34	32mm	450° C	900° C	2m15s	Slight Stagger of level direction in joint top (<2mm)
7	31.08.08	26	0.1	0.1	0.2	0.15	0.5	3.6	0.15	3.85	3m15s/ 18	4m56s/ 8	5m12s/ 32	32mm	450° C	900° C	2m15s	
8	01.09.08	27	0.1	0.2	0.2	0.15	0.5	3.6		3.9	3m08s/ 18	4m50s/ 8	5m12s/ 32	31mm	450° C	900° C	2m15s	
9	01.09.08	29	0.3	0.1	0.2	0.2	0.5	3.6	0.15	3.9	3m20s/ 18	4m29s/ 8	5m00s/ 35	32mm	450° C	900° C	2m19s	
10	01.09.08	29	0.2	0.1	0.3	0.15	0.5	3.6	0.15	3.9	3m17s/ 18	4m56s/ 8	5m05s/ 35	32mm	450° C	900° C	2m16s	
11	01.09.08	30	0.1	0.2	0.2	0.16	0.5	3.7	0.15	4	3m20s/ 20	4m55s/ 10	5m10s/ 35	32mm	450° C	900° C	2m15s	
12	01.09.08	29	0.1	0.1	0.3	0.15	0.5	3.7	0.15	3.9	3m30s/ 20	4m55s/ 10	5m12s/ 37	32mm	450° C	900° C	2m15s	
13	02.09.08	29	0.2	0.1	0.3	0.15	0.5	3.7	0.15	3.9	3m20s/ 18	5m00s/ 8	5m15s/ 36	31mm	450° C	900° C	2m15s	
14	02.09.08	30	0.1	0.1	0.2	0.2	0.5	3.7	0.15	3.9	3m20s/ 18	5m00s/ 8	5m17s/ 36	30mm	450° C	900° C	2m17s	

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					Pos	sition									
Weld No.		He	ad		N	/eb		Fo	oot						
	sur	face	gaug	je face	mi	ddle	1	Гір	Underside						
	Width [mm]	Thickness [mm]													
W0391	55,01	0,15	64,38	0,45	42,79	2,60	40,96	3,30	44,62	3,75					
W0392	60,64	0,25	62,23	0,65	36,35	1,15	42,45	2,45	41,71	4,65					
W0393	63,62	0,90	64,92	0,45	47,65	0,75	48,58	2,25	44,49	3,65					
W0394	65,05	0,90	54,10	0,50	31,06	5,55	38,83	0,00	44,05	3,45					
W0395	62,39	0,35	63,67	1,40	34,46	1,25	43,45	2,15	43,18	4,05					
W0396	55,13	1,10	57,46	0,65	44,37	1,05	42,57	1,90	42,20	3,65					
W0397	47,78	0,75	59,75	1,05	42,32	1,40	41,60	2,85	42,95	3,75					
W0398	55,29	1,05	58,67	1,15	40,10	2,25	38,33	3,05	41,13	3,10					
W0399	61,15	0,70	60,69	0,35	39,34	1,45	39,08	2,35	42,90	4,45					
W0400	60,05	0,25	60,79	0,15	38,08	2,35	35,36	4,05	42,39	2,75					
W0401	59,78	0,35	61,58	0,25	40,18	0,55	36,07	1,40	43,99	3,85					
W0402	56,44	0,95	53,46	0,70	38,38	1,35	43,73	2,45	41,79	3,55					
W0403	64,01	0,75	62,16	0,25	41,16	1,65	38,56	3,70	44,11	3,80					
W0404	60,45	0,70	58,11	0,95	35,47	3,10	36,80	3,35	41,17	3,95					

TABLE 2 Measurement of trimmed upset width and Thickness

TABLE 3 – Joint Alignment – before profile Grinding

Wold No.		Position										
Weld NO.	R	unning surface [m	m]		Gauge face [mm]							
	Side 1 (R)	Side 2 (L)	Step	Side 1 (R)	Side 2 (L)	Step						
W0391	6,90	1,40	5,50	0,05	2,80	2,85						
W0392	3,50	4,90	1,40	0,40	0,60	0,20						
W0393	6,70	0,05	6,65	0,75	0,85	0,10						
W0394	0,05	6,60	6,55	0,05	0,10	0,05						
W0395	2,30	4,20	1,90	0,05	0,10	0,05						
W0396	0,10	7,30	7,20	0,60	0,90	0,30						
W0397	0,05	6,20	6,15	0,45	1,75	1,30						
W0398	2,30	2,00	0,30	0,05	0,05	0,00						
W0399	0,05	2,70	2,65	1,40	1,80	0,40						
W0400	5,00	0,00	5,00	0,20	0,15	0,05						
W0401	2,80	1,20	1,60	0,20	0,10	0,10						
W0402	7,40	0,90	6,50	2,10	0,40	1,70						
W0403	0,00	6,20	6,20	1,20	2,30	1,10						
W0404	2,50	3,30	0,80	0,00	0,00	0,00						

TABLE 4 – Joint Alignment – After Profile Grinding

Wold No.			Pos	ition						
weld NO.	R	unning surface[mn	n]		Gauge face					
	Side 1	Side 2	Step	Side 1	Side 2	Step				
W0391	0,25	0,60	0,35	0,00	0,05	0,05				
W0392	0,40	0,20	0,20	0,05	0,00	0,05				
W0393	0,05	0,05	0,00	0,00	0,10	0,10				
W0394	0,25	0,15	0,10	0,00	0,00	0,00				
W0395	0,20	0,25	0,05	0,00	0,00	0,00				
W0396	0,25	0,25	0,00	0,00	0,05	0,05				
W0397	0,20	0,20	0,00	0,00	0,10	0,10				
W0398	0,15	0,10	0,05	0,00	0,00	0,00				
W0399	0,00	0,15	0,15	0,00	0,00	0,00				
W0400	0,20	0,25	0,05	0,00	0,00	0,00				
W0401	0,05	0,10	0,05	0,10	0,10	0,00				
W0402	0,20	0,25	0,05	0,05	0,00	0,05				
W0403	0,05	0,05	0,00	0,00	0,00	0,00				
W0404	0,10	0,10	0,00	0,00 0,00		0,15				

TABLE 5Measurement of surface flatness (over 200mm)

Weld No			Pos	ition		
weld No.	Ā	Running surface[mr	n]		Gauge face	
	Side 1	Side 2	Step	Side 1	Side 2	Step
W0391	0,00	0,00	0,00	0,05	0,10	0,05
W0392	0,10	0,00	0,10	0,15	0,10	0,05
W0393	0,00	0,00	0,00	0,40	0,05	0,35
W0394	0,25	0,20	0,05	0,15	0,05	0,10
W0395	0,15	0,15	0,00	0,10	0,15	0,05
W0396	0,10	0,15	0,05	0,10	0,05	0,05
W0397	0,15	0,20	0,05	0,15	0,20	0,05
W0398	0,15	0,15	0,00	0,05	0,00	0,05
W0399	0,00	0,15	0,15	0,00	0,00	0,00
W0400	0,00	0,05	0,05	0,35	0,25	0,10
W0401	0,15	0,15	0,00	0,00	0,00	0,00
W0402	0,10	0,05	0,05	0,00	0,15	0,15
W0403	0,10	0,05	0,05	0,10	0,15	0,05
W0404	0,10	0,15	0,05	0,00	0,15	0,15

TABLE 6: Comparison of Bend Test Data – 60E1 rail Profile

	WELD I.D	Load (kN)	deflection	Comments
GPW welds	392	1856	54.4	
	393	1824	48.7	
	394	1809	49.2	
	400	1814	47.33	
	403	1848	60.63	
comparison data				
Gas Pressure welds (ref 1)	GP3	1680	37	
(JIS 60 profile)	GP5	1680	40	
Aluminothermic Weld	EN 14730-1	1200	not specified	
	SkV-E process	1300 -1470	10 - 17.5	Typical
	HPW (3)	1440 - 1475	13 – 19.5	
Flash butt welds				standard for approval – fixed plant
Narrow HAZ (ref 3)	std	1675	34	not fractured.
	narrow HAZ (3)	1825 - 2010	35-60	not fractured

TABLE 7 Comparison of fatigue test data - 60E1 Rail profile

	WELD I.D	Stress Range mPa)	Cycles	Comments
	396	216	2,000,000+	run-out - no failure
	401	216	2,000,000+	run out – no failure
	402	216	2,000,000+	run out – no failure
comparison data				
Gas Pressure welds (ref 1)	GP1,A4,A5	230	5 x 10 ⁶ +	Run Out
Fully ground	GP2,A7	250	5 x 10 ⁶	Run Out – GP2 retest at higher load
	GP2-2	270 5 x 10 ⁶ Run Out		Run Out
Gas Pressure welds (ref 1)	GP4, GP5, T16	230	5 x 10 ⁶	Run out - GP2 retest at higher load
As trimmed	GP4-2	250	1.58 x 10 ⁶	
	GP6	250	0.76 x 10 ⁶	
Flash butt welds		215	5,000,000 +	standard for approval – fixed plant
SkV-E Thermit Weld		210	5,000,000 +	Data from approval tests

Weld no.	Hardness on the weld [HB]	chemical analysis										
		С	Si	Mn	V	Cr	Ti	Р	S	AI		
W0392	298	0,755	0,27	1,014	0,002	0,026	0,002	0,012	0,018	0,001		
W0393	301	0,764	0,255	0,99	0,001	0,025	0,001	0,015	0,023	0,001		
W0394	295	0,75	0,253	0,992	0,001	0,025	0,001	0,015	0,021	0,001		
W0400	294	0,779	0,261	1,001	0,001	0,025	0,002	0,015	0,02	0,001		
W0403	290	0,787	0,262	1,007	0,001	0,026	0,002	0,015	0,019	0,001		

TABLE 8Chemical Composition of the 260 grade rail.

TABLE 9Weld Heat affected Zone dimensions (mm) – Centreline.

	distance	GPW test	UK	Thermit weld*	Flash weld		
	below surface	weld	gpw weld		EN 14587	standard	narrow gap
ref			(1)	(1)	(4)	(1) (3)	(3)
surface	0	82	120	88-110		35 - 37	26
	30 mm	67	118	81 – 90	25 – 45	26 – 35	21
	60 mm	78	126	83 – 95	(10 mm max variation)	27 – 35	
	100 mm	78	146	75 – 85		30 – 35	23
	145 mm	74	123	70 - 80		31 - 38	20
base	170 mm	76	112			33 - 38	23
foot tip		72 - 73		70 – 80		32-36	24

(* includes the width of the Thermit Weld metal)

ANNEX 2

Figure 1: As trimmed weld no 391



Figure 2: As trimmed weld no 392





Figure 3: As trimmed weld no 393



Figure 4: As trimmed weld no 394



Figure 5: As trimmed weld no 395



Figure 6: As trimmed weld no 396



Figure 7: As trimmed weld no 397



Figure 8: As trimmed weld no 398



Figure 9: As trimmed weld no 399



Figure 10: As trimmed weld no 400



Figure 11: As trimmed weld no 401



Figure 12: As trimmed weld no 402



Figure 13: As trimmed weld no 403



Figure 14: As trimmed weld no 404















Figure 16: Joint Straightness - Running surface and Gauge face - Welds 398,399,400,401



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FIGURE 18: Bend test load/ deflection records for 4 GPW welds

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FIGURE 19 – Comparison of Fatigue Data – Gas Pressure, Aluminothermic and Flash welds



FIGURE 20 a – Heat affected zone dimensions –GPW weld



FIGURE 20b – Heat affected zone - –GPW weld foot tip (measured as 72mm, and 73mm.)



FIGURE 21 – Weld ref 391



FIGURE 22 – Hardness Variation across the GP Weld





FIGURE 23 – Micro photographs of the Heat Affected Zone.



na il	tra ns itio n	ta nsitio n	<i>"</i> w eld "
	na il / HAZ	HAZ/ <i>"</i> ,w eld "	



n il

transition rail/HAZ

transition HAZ/"weld" "w**eld**"

Fig 24 – Examination for foot tip defects

Fig 24a – example of lack of bond defect – from report ref 1 and 2.





Fig 24b – examples of foot tip from two welds



ANNEX 3

APPENDIX I - Report from GT China – Manufacture of GP test welds

Thermit China Co., Ltd.



A Member of the Goldschmidt-Thermit-Group

Gas Pressure Welding (GPW) Process and Operating Instructions

1. Welding Principle

The gas pressure welding (GPW) is a welding method that heats the metal parts into plasticity state and then exerts certain pressure to combine the metal parts into one. The basic principle is that two metal surfaces joint closely under high temperature, the intermetallic atoms inter-diffuse and then the recrystallization is achieved, so that the two metal parts combine into one.

The welding of rail joints adopting GPW technique is to make the clean end faces of the two rails closely and

heats the rail end joint equally along the rail profile. When the temperature reaches 1200 C1250 C, the metal of the rail joint is at plastic state, the metal molecules of rail joint own adequate activation energy, then the metal molecules of the two rail ends penetrate through the interface, inter-diffuse and combine with each other, the molecular linkage is achieved and recrystallizing again, so the object of welding the two rails is achieved.

Following is the operating instructions on the basics of physic of GPW.

2. Welding Process Chart



3. Operation procedure and process parameters

3.1. Rail end grinding

3.1.1. Coarse grinding

3.1.1.1. Clean the metal rust within 200mm from rail ends with wire brush and clean the dirt such as oil and dust with tetrachloride carbon.

3.1.1.2. If there are steel seals on the corresponding rail locking position of the welder wedge at the ends of the rail, grind the steel seals away with portable grinder, this shall be favorable for the straightness of the welding rail.

3.1.1.3. Lock the rail end grinder on the rail, set the feed nut to initial position, try to swing the lever handle, start the motor, rotate the feed nut and grind the rail end. Control the grinding less than 0.08mm by each feed to avoid burning the rail end faces.

3.1.1.4. Inspection standard of coarse grinding: measure the rail end face and rail head verticality with a square along the vertical direction, the rail head regarded as the reference, the verticality shall be less than 0.12mm. Regard the rail head side and rail foot side as the reference, measure the verticality of the rail end face, rail head side and rail foot side along level direction, the verticality shall be less than 0.12mm (Figure 1 and Figure 2).

Notes:

A. The rotation direction of grinding wheel shall be same with the direction of the mark on the rail end grinder.

B. The operator must wear goggles during grinding!



Figure 1 and 2:

Verticality of rail end face: max: 0.12mm Lateral squareness max 0.12mm across the foot

3.1.2. Treating the rail end accurately

3.1.2.1. Choose the 450mm flat rasp, the new rasp must be cleaned to removing oil by tetrachloride carbon or gasoline. It could be used only until it becomes dry.

3.1.2.2. The file-pressing hand should not wear the glove when filing the rail end (figue 3). Keep the hands off from the rail end face.

3.1.2.3. Inspection standard of the treated rail ends: The verticality of the rail end face along the vertical and level direction shall be less than 0.08mm (measuring method as mentioned earlier). Protect the rail corner carefully when filing the rail end face, the 2 rail feet shall joint to the square when inspect the rail end face verticality with a square.

Figure 3:

The file-pressing hand should not wear the glove while filing the rail end

Notes:

A. Rail foot is the weak position during rail welding, i.e. the welding defects emerge at the rail foot mostly, so protect the rail foot during the entire process of the welding.

B. Protect the rail end faces after being accurately filed.

3.2. Installation of Welder



The two long rails shall be straight (inspection standard as mentioned earlier). Lay the welder on the rails waiting for welding, place the shearing machine and pad plate beside the primary wedge base, draw the two blades on the waist of the shearing machine outward and pull out the blade on the bottom of the shearing machine. Inspect and be sure that the oil pipe of the high pressure oil pump connects well: the welder oil cylinder connects with the connector of the keeping pressure reversing valve of oil pump (the handle end of the keeping pressure reversing valve is a red ball), and the shearing machine connects with the connector of the traditional reversing valve (the handle end is a black ball). Start the oil pump, reposit the welder oil cylinder (enlarge the distance between primary and secondary wedge bases, cylinder moving distance 155mm), and then reposit the oil cylinder of the shearing machine (cylinder rod retracts, oil cylinder moving distance 114mm).

3.2.1. Adjust the relative position between the welder and rail end joint, and the distance from the welder primary wedge base to the rail ends joint is 375mm (Figure 4).

Figure 4:

The distance from the primary wedge base to the rail ends joint is 375mm.



3.2.2. Put on the rail bottom bolts & its nuts.

3.2.3. Inspect the straightness of the two rails, tighten the rail head bolts with special wrench and make the rail foot lean against the rail foot bolts.

3.2.4. Tighten the wedge

Notes: The operators must wear goggles!

Knock at the wedge with red copper hammer.

3.2.5. Tighten the rail foot bolts with special wrench.

3.2.6. Start the high pressure oil pump, adjust valve handle to increase the pressure then the rail gap between the two rails folds. Keep the oil pump pressure at 20Mpa (Figure 5) which is the first stage of welding pressure.

3.2.7. Adjust the welding feed-in staff (Figure 6) for the distance of 30+-2mm.



Figure 5 Keep the fist stage rail pressure at 20Mpa.



Figure 6: Welding feed-in staff

3.3. Heater installation

3.3.1. Place the heater on the welder cylinder rod and connect it with the swing mechanism of the welder.**3.3.2.** Adjust the elevating mechanism of the heater and keep the distance from heater fire holes to rail at 25mm.

3.3.3. Adjust the swing mechanism of the welder and keep the heater fire holes vertical to the rail. **3.3.4.** Connect the cooling water hose to the heater, start the pump and inspect the cycle water, connect the oxygen and acetylene hose to the heater. Swing the welder swing mechanism with the lever, keep the heater at the down wind position to the rail ends joint to avoid polluting the joint when the heater is ignited.

<u>Notes</u>: A. Before welding test the fire of the heater and inspect whether the fire hole meets the requirements.

B. Testing the cooling water, keep the water away from the rail end joint.

3.4. Ignition and Heating

3.4.1. In order to avoid polluting the rail end face, refile the rail end face finely. Welding must be done within 20 minutes after refile.

3.4.2. Open the oxygen value of the gas controller slowly, adjust the oxygen rotameter to ensure that the oxygen flow is 0.1 to 0.2 $\frac{3}{4}$ (b lower than the working flow, open the cost days of gas controller clowly.

oxygen flow is 0.1 to 0.2 M /h lower than the working flow, open the acetylene valve of gas controller slowly, and adjust the acetylene rotameter to ensure that the acetylene accords with the working parameter. In order to avoid excessive mixed gas around the heater causing the blast during igniting, the operation of gas controller shall be fast and accurate, generally completed within 10 seconds.

3.4.3. Oxygen and acetylene control parameters of gas controller

Oxygen flow $3.4 - 3.8 \text{ M /h}_{3}$ Acetylene flow 3.8 - 4.4 M /h

Igniting the heater, adjust the oxygen rotameter of gas controller, the flame of the heat shall be miniature reducing flame (also called the weak carburizing flame): the flame core is bright blue-white conical shape, the length of the flame core is shorter than the carburizing flame and longer than the oxidizing flame (Figure 7). The ratio of acetylene gas to oxygen of the miniature reducing flame is about 1.2.



Figure 7 - Miniature de-oxidising flame

3.4.4. After adjusting the heater flame, push swing lever, move the heater to the rail end joint and swing the lever constantly for heating, keep the rail end joint as the center, so the internal and external temperatures to be equal. When the rails joint temperature within the pressing volume range (less than 35mm) reaches the welding temperature, the welding is completed.

3.4.4.1. Swing distance of the heater

As the heater has just ignited, the rail ends joint temperature is low, in order to increase its temperature rapidly, the heater shall be swung in a little range, then increase the swing range at the later period of heating.

During heating process, if the 2 rail feet at the rail end joint is not heated excessively and the rail temperature at the sides of the rail end joint rises equally, keep the swing range as a little as possible, so the rail foot shapes well, no collapse, the rail weld are straight, this shall be favorable for the shearing.

The following table lists the relation between the swing distance and swing frequency of the heater during heating (Table 1).

Table 1: Heater swing distance and swing frequency

Heating time	About 0 - 4'30"	About 4'30" - 5'	About 5' - 5'30"
Swing distance	6 - 10mm	15 - 25mm	About 30mm
Swing frequency	About 60 times/min.		About 80 times/min.

3.5. Three-stage pressure welding process

During the heating, the pressure (oil pump pressure) exerted by the welder on the rail joint should be closely adjusted to the 3 stages of the heating time (see table 2)

Table 2 : Heating time and oil pump pressure

Heating time	0 - 3′30″	3'30" - 4'50"	4′50″ - 5′20″
Oil pump pressure	20 Mpa	6 - 10Mpa	35 - 38Mpa

As mentioned before, the GPW technique is to make two clean rail end faces welding together under high temperature and pressure. So the 3 necessary conditions of GPW are: clean rail end face, plasticity temperature (about1200-1300C) and the pressure (about 35-38 Mpa).

Stage 1: The welder tightens on the rails, start the high pressure oil pump, adjusting valve handle increases the pressure so the two rails move together and by now the oil pump pressure is about 20 Mpa. When the rail ends touch each other, keep the pressure at 20 Mpa to ensure the rail joint closely and avoid polluting the rail end faces.

Stage 2: When the rails have been heated for 3'30", the rail surface has produced mini bulges (the rail temperature is about 1000C), now decrease the pump pressure to 6-10 Mpa and maintaining this pressure from 3'30" to 4'50" (Figure 8, figure 9).

Figure 8 and 9,

The oil pump pressure decreases to 10 Mpa when the rail temperature is about 1000.





In this stage, the temperature at the rail joint increases continually, but the mini bulges does not increase. Stage 3: When the rails have been heated for more than 4'50", the rail surface temperature has reached 1250—1300C and the rail core temperature is about 1250C, the metal molecules of the two rail end faces own adequate activation energy, then increase the pump pressure to 35-38 Mpa rapidly (Figure 10), thus to press the weld joint moving together for 30mm and to finish the welding. This is the 3rd stage of the welding process. During this stage of process, the rail end face oxidation films breaks and the welding defects are squeezed out of the rail effective section (Figure 11).





Figure 10: The oil pump pressure increases rapidly to 35-38Mpa when the rail core temperature is about 1250

Figure 11: During the welding process, the rail end face oxidation films break and the welding defects are squeezed out of the rail effective section.

3.6. Shearing

3.6.1. Hang the pad plate on the inner lateral of the welder primary wedge base before the pressing procedure of the welding.

3.6.2. When the rail pressing achieves prescribed value, the oil cylinder of the welder is keeping the pressure of 20 Mpa, separate the heater away from the swing mechanism of the welder, put out the heater and move it to the secondary wedge base.

3.6.3. Lay the shearing machine on the rail head promptly, the shearing machine cylinder rod shall enter into groove of the pad plate, propel the blade on the waist of shearing machine and insert the blade at the bottom of shearing machine.

3.6.4. Move the traditional reversing valve handle of the oil pump from the centre to position A, adjusting valve handle to increase the pressure and the shearing machine advances, until the shearing is completed.

<u>Notes</u>: Remove shearing blades instantly after shearing to avoid the high temperature damaging to the blades. Repair the blunt blade in time to reduce shearing resistance and keep the rail weld shaped smooth and flat.

3.6.5. Adjusting valve of the oil pump relieves to zero.

3.6.6. Move the traditional reversing valve handle of the oil pump from position A to B, the oil pump adjusting valve pressurizes (15 Mpa), the shearing machine retreats and the oil cylinder of shearing machine restores, remove the shearing machine.

3.6.7. Draw out the blades at the bottom and the waist of shearing machine, remove shearing machine and the pad plate.

3.6.8. Remove the welder, move the pressure maintaining reversing valve handle of the oil pump from midposition to position B, then the welder oil cylinder restores.

3.7. Normalization heat treatment

During the heating process, the metal grains grow with the rail temperature increasing and generate thick grain structure. So the normalization heat treatment must be carried out after welding, to reduce the grain size of the weld and the heat affected zone, to eliminate the internal stress, to improve the strength of the

weld, to decrease brittleness and increase the toughness.

3.7.1. Lay the reheating frame on the rail, measure the surface temperature of the weld. When the rail temperature deceases to 450-500C, start the normalization process.

3.7.2. Place the heater on the reheating frame, start the cooling water pump to cool the heater.

3.7.3. Make the heater swing by the swing lever. The relations between the heating time, the swing distance and the swing frequency are specified in the following table.

Heating time	0 - 1′50″	1′50″ - 2′20″	
Swing distance	40mm	70mm	
Swing frequency	40 – 50 /min.	30 – 40 /min.	

<u>Notes</u>: The prior period of reheating mainly heats the weld, when the weld has been heated for 1'50", the temperature has reached about 850, but the temperature of the heat affected zone at the laterals still low. In order to increase the temperature of the heat affected zone rapidly and to slow down the temperature rise of the weld, increase the swing distance at the late stage of reheating, meanwhile decrease the swing frequency of the heater.

3.7.4. After reheating for 2'20", the temperature reaches 870-920, stop the heating by taking the heater out of the rail, let the rail weld cooling in the air.

3.7.5. After the heat treatment, remove the sleeper pier when the rail temperature is below 400.

APPENDIX II – Description Of The GTG Sec Straightedge

(Extracted From GTG Literature)







Abb. I/ Fig. I

Geometrische Lineale Geometric Straightedges

SEC RC - Straightedge Compact

Ensotzgebiet

Des Gerodlinigkeitemezsperöt Straightedge Comport Rodio Controlled - SEC RC (Abb. 1) wird zur Vermessung der Geometrie des Schlenenkopfels eingesetzt. Im Vergleich zum SEC atelike aufere Weiterentwirdlung mit höherer Mezsgenzuigkeit und PDA. Hondrechner das Das Geröt arbeitet berührungslas nach dem Magnetprinzip und bietet die Möglichkeit der schnellen Vermezung und Dakumentstein der Dierfläche von Fahrflöche und Fahrkanze. In Leichtbouweise gefertigt, ist es begaert ut tragen. Das Geröt ist Weiterungsteständig.

Messmethode

Des Stroightedge Comport RC (Abb. 2) be steht aus einem Messhelken (1) mit Tragegriff (2) und einem PDA Rechner (Abb. 3), Messlänge ist 1 m. Die Messung erfolgt durch löngsteiliges Verfahren des im Messbalken integrierten Mognetne sakapfes, wobei der Abstond zwischen zu prüfender Oberfläche und Messkopf berührungslos erfasst wird. Der Messkopf wird mit Hilfeeines Motors ongetrieben. Die Stormversorgung wird durch wiederaufodbare Botterien, die im Messbalken untergebrocht sind, gewährleistet (4). Zwei Abstondshalter (5), die ebenfalls am Messbalken angebrocht sind, gewährleistet die konneke Pasifonierung des Limals auf der Schiene.

Messdurchführung

Vor der Durchführung der Messung können über die PDA-Oberfläche Informationen zum Messort, z. B. die Kilometrierung, eingegeben werden. Anschließend wird das Lineal mittels der Abstandshalter auf der Schiene positioniert. Die Messung wird über den PDA ausgelöst. Die Auswertung erfolgt automatisch direkt im Anschluss on die Messung

Dos Messergebnis wird ouf dens Display des Rechners grophisch und numerisch dargestellt (Abb. 4). Ablestar sind dos Linientöld, die charabieristischen Messwerte wie abere, untere und absolute Abweichung vom Nennmaß, sowie u. a. Messtemperatur und Batterielsdestatus.

Mittels Datentronsferzu einem PC konn das Messengebnis weiter ausgewertet und datumentiertwerden (Abb. 5,6) Die bedienerfreundliche Saftware ist einfach zu handhaben und ernöglicht die Archivierung und die schnelle Visualisierung der abgespeicherten Messengebnism.



Abb. 3/ Fig. 3

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SEC RC - Straighte dge Compact

- Mitte Iveilige Measung
 Measgenouigle it: ± 20 µm
 Fembedenbor Uter PCA
 Medum-waved measurem

- Measuring accuracy: ± 20 jam
 Remately controllable via FDA

General

The straightness-measuring device Straightedge Compact RC-SEC RC (Fig. 1) is used to survey the geometry of the railhead. In comparison to the SEC, it is further developed, possesses a higher accuracy and is equipped with a PDA hand-held computer. The device uses a magnetic principle for non-contact gouging to give fast measurements and documentation of the running surface and running edge. The SEC RCislightweight for easy portability and weather resistant.

Method of operation

The Straightedge Compact RC (Fig. 2) consists of a measuring beam (1) with handle (2) and a PDA computer (Fig. 3). The measurement is performed by the motor driven longitudinal movement of an internal magnetic probe in which the distance between the surface and probe is detected without contact. Power is supplied by rechargeable batteries (4). Two spacers (5) on the measuring beam allow the correct positioning of the straighte dge on the roil

Realization of measuring

Before the measurement, information about the measuring place, e.g. the section, con be entered. The straightedge is then positioned on the rail by means of the spocers. The measurement is initiated by the PDA. The evaluation follows outomatically just after the THE DALLINE THEMT.

The line scon and the characteristic measurement values like upper, lower and obsolute deviation from the mean plus other data such as the measurement temperature and the state of the battery charging are depicted graphically and numerically on the computer display (Fig. 4). The comparison of two line scans on the display e.g. Measurements before and after works, is also possible.

The measurement result can be elaborated by means of a data transfer to a PC (Fig 5, 6). The operator-friendly software is any to use and facilitates the archiving and the fast visualization of stored results.



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APPENDIX III – Summary of Testing Protocol for Process Approval

Weld condition

As Welded:	Welded and trimmed using the purpose built (integral) trimming equipment
Finished:	Welded and trimmed, followed by mechanical alignment, and profile grinding

	PR EN 14587-1		NR RT/CE/S/001	
Rail type	R220,260		R220,260	
Rail Profile	60E1		60 E1	
Total No test welds	10		10	As welded
	12		10	Welded and finished
Inspection				
Trimming quality	10	As welded	10	As welded
Alignment	10	As welded	10	As welded
Visual appearance	All		All	
NDE	All		10	finished
Bend testing	10	As welded	10	As welded
Fatigue testing	10 max	finished	10	finished
Macro examination	2	finished	2 (from fatigue test)	finished
Hardness testing	2 (from above)		2 (from above)	finished
Micro examination	2 (from above)			

Weld Parameters for test series - process approval - refer to Appendix III for test data