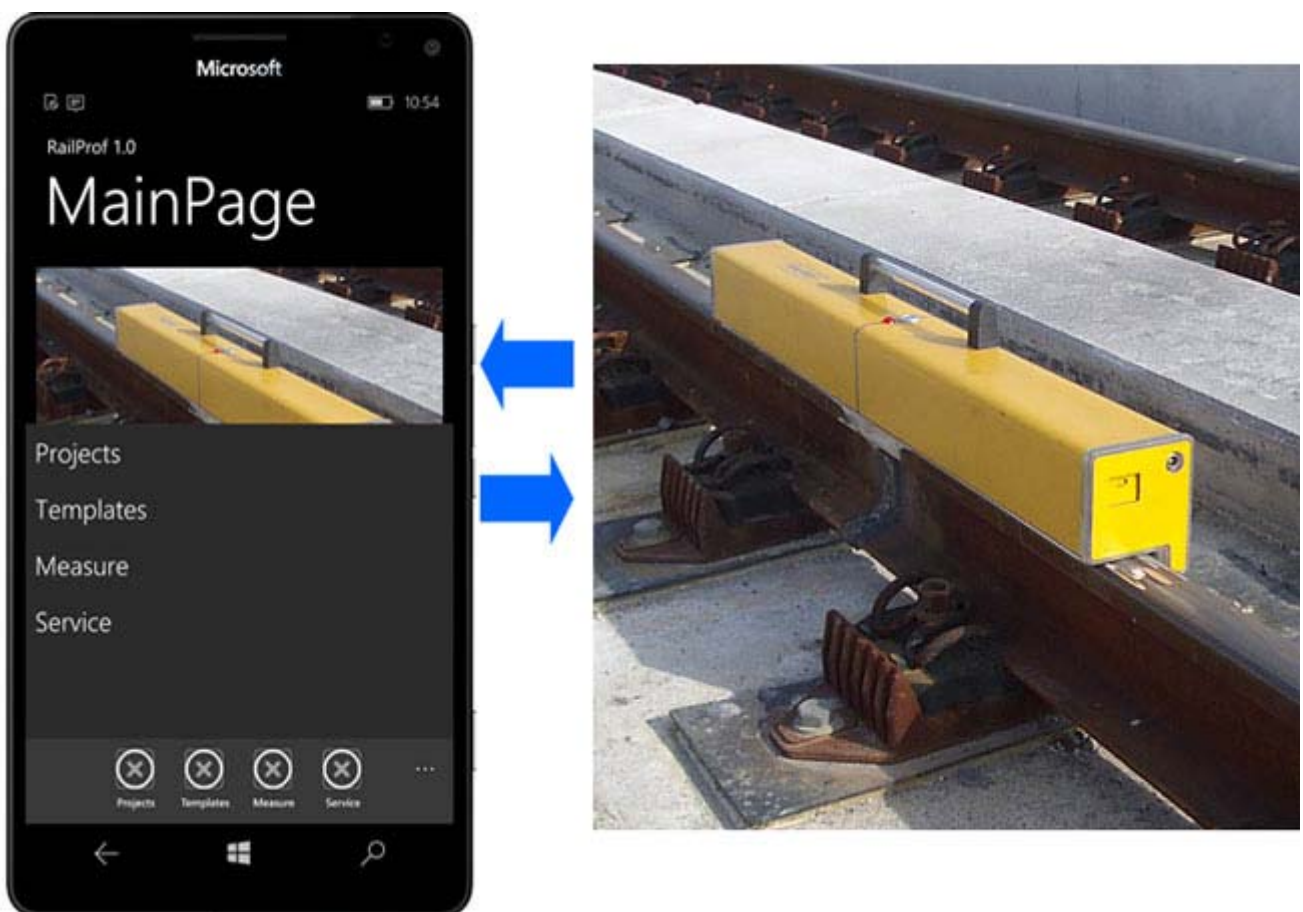


RAILPROF USER MANUAL



January 2017

1. INTRODUCTION

Since 2005 ProRail has introduced force-based weld geometry assessment standards. This requires determination of the first derivative (gradient) of the weld geometry, which is tested against speed-dependent standards. These calculations are efficiently performed in real-time with a Windows smartphone, which communicates wireless with the RAILPROF.

2. MAIN CHARACTERISTICS

The RAILPROF is a field instrument for accurately measuring longitudinal rail geometry -both vertical and lateral over a length of 1000 mm, at ambient temperatures between -5 °C and +40 °C. For detailed specifications please refer to Chapter 11.

The measurements are performed by two contact free, eddy current based sensors inside the housing of the RAILPROF, which are driven by a step motor. Each 5 mm a measurement is made. Measuring accuracy is +/- 0.02 mm at deviations up to 0.5 mm from a straight line between the first and last measuring point. Beyond that limit the accuracy is +/- 5 % of the measured value up to 1.5 mm deviation.



Figure 1 Picture of RAILPROF

The present RAILPROF configuration is controlled by a Windows Phone running on Windows 10. Based on research at TU Delft, in cooperation with the Dutch Infra Provider ProRail, force-based standards have been developed. The standards are expressed in terms of a quality index QI, which is directly related to the first derivative of the measured vertical rail geometry. The standards are presented in Chapter 6. Vertical and lateral geometry are measured simultaneously. The measuring results are automatically sent to the Smartphone, which carries out all the calculations like filtering and computing the first derivative of the vertical geometry, in accordance with the force-based weld standards of ProRail. Due to the additional speed classes in the lower speed range the standards are also applicable to metro and tram networks.

The RAILPROF will be kept awake if the operator is working in the measuring menu on the Smartphone, whereas otherwise the RAILPROF is switches off after 10 minutes of not being used.

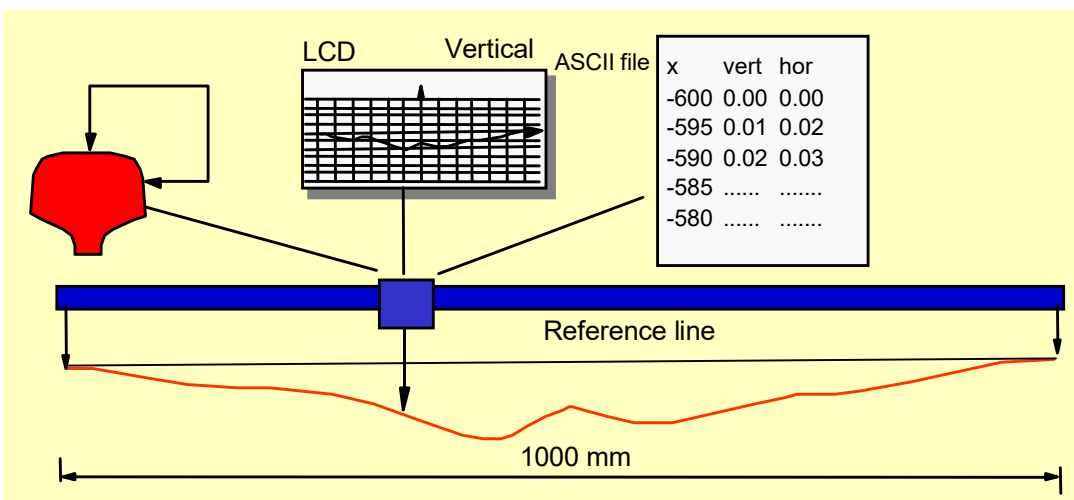


Figure 2 Measuring principle

The measurements are not influenced by moist, rust and dirt on the rail surface; the actual metal surface below these contaminations is measured, so cleaning of the rail track surface before a measurement is not necessary. Also the measurement result cannot be influenced by the operator.

Through the use of carbon fiber rods and its design, the RAILPROF is robust and shock resistant; it weighs less than 7 kg only in spite of its dimensions (1.16 m long), inevitable because of the measuring length of 1000 mm.

The RAILPROF is both easy and safe to operate. Due to the smartphone control all relevant input data can be provided beforehand via menus. The measurement can then be carried out remotely. Positioning of the RAILPROF onto the rail is easy because of its magnetic feet.

Measurement of top and horizontal geometry takes about 10 seconds. Data transmission to the smartphone and the performance of the calculations in the PDA takes about 6 seconds.

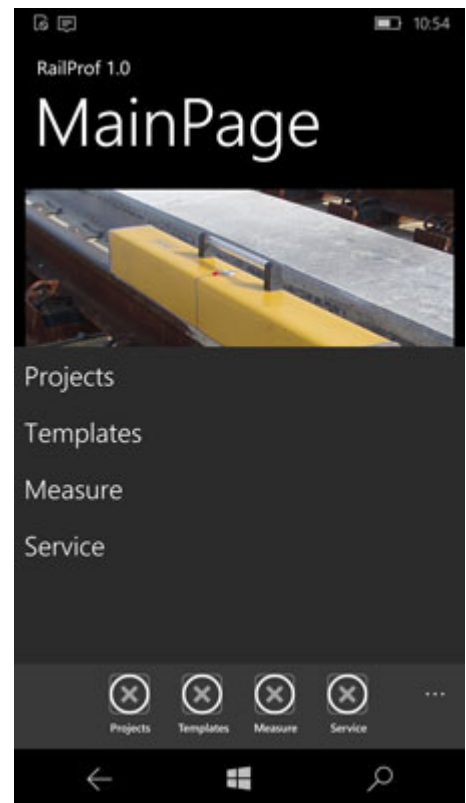
3. INSTALLING THE SOFTWARE

The Windows Phone comes with preinstalled software. If it should be necessary to reinstall the software the app Railprof should be installed from the Windows Store, or from www.railprof.com.

4. MAIN MENU

At the startup of the 'RAILPROF' program the main menu at the right hand side appears, in which the following choices are possible:

- Templates: creation of templates in which the data for a measurement can be stored in advance;
- Projects: measuring results;
- Measure: execution of a measurement;
- Service:
 - RP Status: status of the RAILPROF;
 - RP Off: switching off the RAILPROF (there is no hardware switch off button);



5. MEASURING

Before starting the measurement procedure first Bluetooth should be activated (icon at the bottom right). Next the 'RAILPROF' program on the PDA is started by pressing function key 5 (house). At 'Setup' so-called templates can be found in which data constant for that group of welds can be stored. The user can make new templates by changing an existing one and save it under a new name. The 'Active Template' is used for a new measurement.

Position RAILPROF at the weld and switch it on. The red lamp lights on. After 10 minutes of inactivity the RAILPROF automatically switches off. To continue measurements push the switch again.

Be sure that the right template is activated and tap 'Measure'. Now the active template appears and changes can be made if necessary.

Tap 'Measure' to start the measurement.

Bluetooth asks to choose a device. Tap the name of the RAILPROF (=serial number 'RPxxxx').

After completion of the measurement ('top' en 'horizontal' are measured in one go and stored in one record), which takes about 10 seconds, the results are transmitted to the PDA. The PDA performs all calculations such as filtering of short waves, trend, determination of the first derivative for 'Top' etc..

Via the menu bar at the bottom the results can be browsed. At 'Info' the template data are shown; almost all information can be modified, except speed, standards and measuring results. The file name is unique, ie contains the serial number (RP4175 in example), date and time. The extension is always xml.

After viewing the measurements tap OK. Now there is a choice of 'yes' or 'no' storing the record. Subsequently the choice is 'Measure new weld', 'Measure old weld again', 'Back', or 'Exit'. Moreover this screen shows the actual battery status.

If the weld should be measured again the program returns to the last screen before the new measurement was taken. In practice this will be mostly 'Top_Qual'. After the weld is approved tap OK to store the record.

At the next measurement the input data of the previous measurements are kept in memory (previous modified template), so that just the changed should be keyed in.

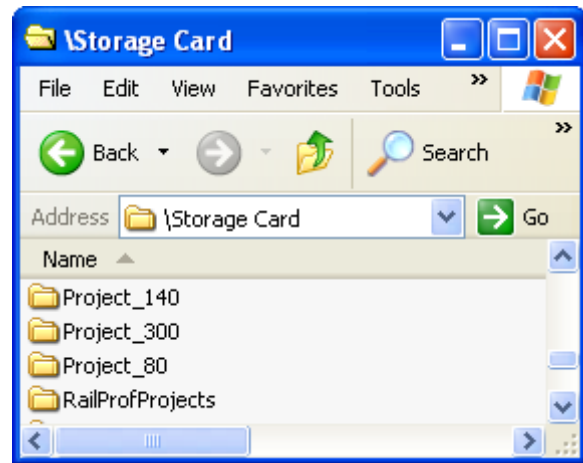
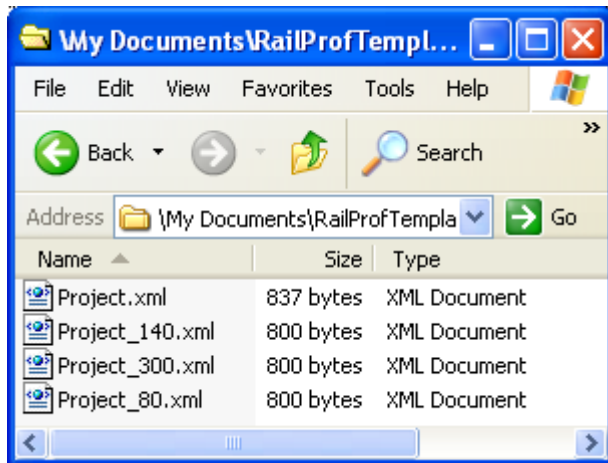
Templates can be created for each measuring job.

The values of the active template are used for the current measurement.

So you can create your own templates. Per template the measurement data are stored in a separate directory on the SD-card. In the example the following templates were created:

Project_80,
Project_140,
Project_300.

RailProfProjects is created by default for Project and is generated during installation of the software. Afterwards the input data can be modified if required, via the main menu and Projects.



6. PRORAIL STANDARDS FOR WELD GEOMETRY

The weld geometry standards applied in the smartphone software are based on a study of TU Delft. These standards have been in force at ProRail since 1 January 2005. The vertical weld geometry should comply to:

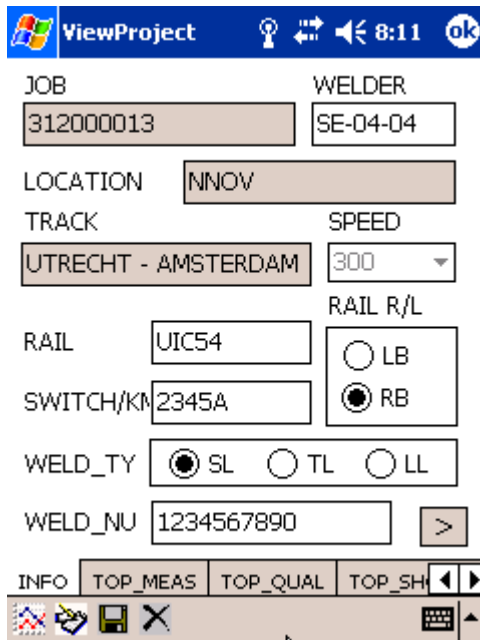
Standards vertical rail geometry	
Speed [km/h]	Inclination [mrad]
250 < V ≤ 300	≤ 1.0
200 < V ≤ 250	≤ 1.1
180 < V ≤ 200	≤ 1.3
160 < V ≤ 180	≤ 1.4
140 < V ≤ 160	≤ 1.6
120 < V ≤ 140	≤ 1.8
100 < V ≤ 120	≤ 2.0
90 < V ≤ 100	≤ 2.2
80 < V ≤ 90	≤ 2.3
70 < V ≤ 80	≤ 2.4
60 < V ≤ 70	≤ 2.6
50 < V ≤ 60	≤ 2.8
40 < V ≤ 50	≤ 3.0
V ≤ 40	≤ 3.2

Standards lateral rail geometry	
Speed [km/h]	Versine p [mm]
80 < V ≤ 300	-0.5 ≤ p ≤ 0.5
40 < V ≤ 80	-0.7 ≤ p ≤ 0.7
V ≤ 40	-1.0 ≤ p ≤ 1.0

$$QI = \frac{Inclination_{max}}{Inclination_{norm}} \leq 1 \rightarrow OK$$

7. MEASUREMENT RESULTS

After completion of a measurement the results can be browsed via the menu bar at the bottom of the screen. This can also be done afterwards via the main menu through 'Projects'. An example of the screens showing the results is presented below.



ViewProject 8:11

JOB: 312000013 WELDER: SE-04-04

LOCATION: NNOV

TRACK: UTRECHT - AMSTERDAM SPEED: 300

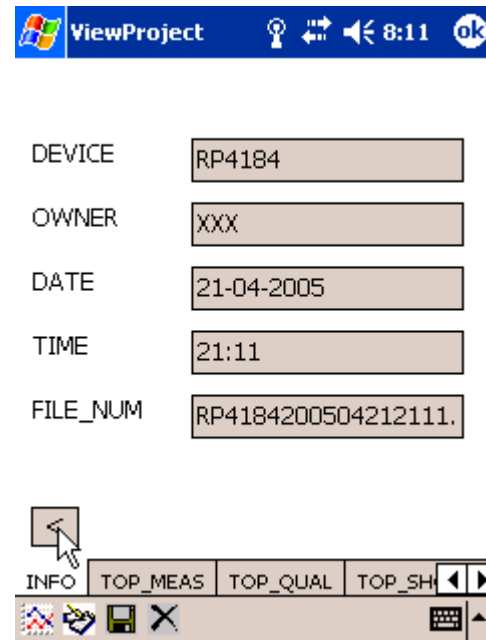
RAIL: UIC54 RAIL R/L: ☐ LB ☒ RB

SWITCH/KM: 2345A

WELD_TY: ☒ SL ☐ TL ☐ LL

WELD_NU: 1234567890

INFO TOP_MEAS TOP_QUAL TOP_SH



ViewProject 8:11

DEVICE: RP4184

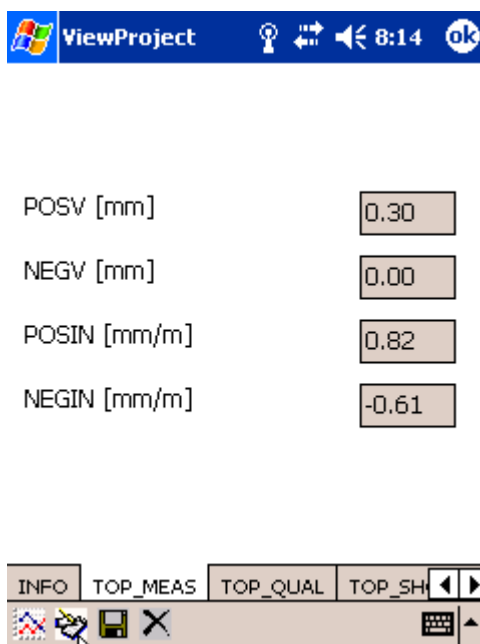
OWNER: XXX

DATE: 21-04-2005

TIME: 21:11

FILE_NUM: RP4184200504212111.

INFO TOP_MEAS TOP_QUAL TOP_SH



ViewProject 8:14

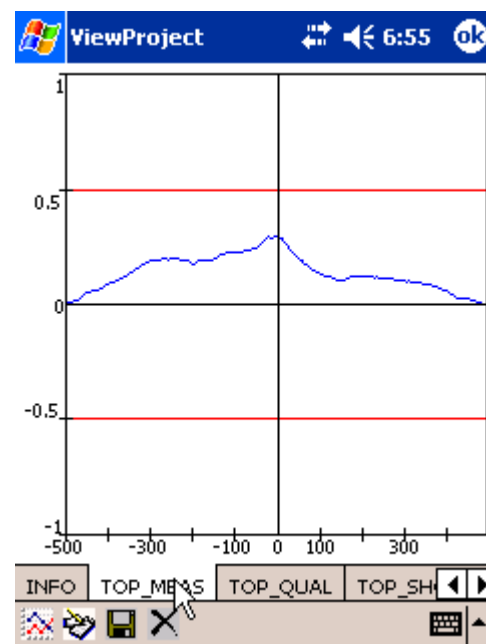
POSV [mm]: 0.30

NEGV [mm]: 0.00

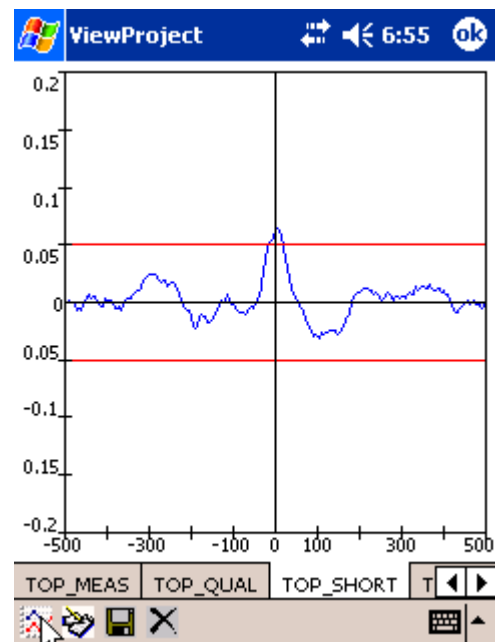
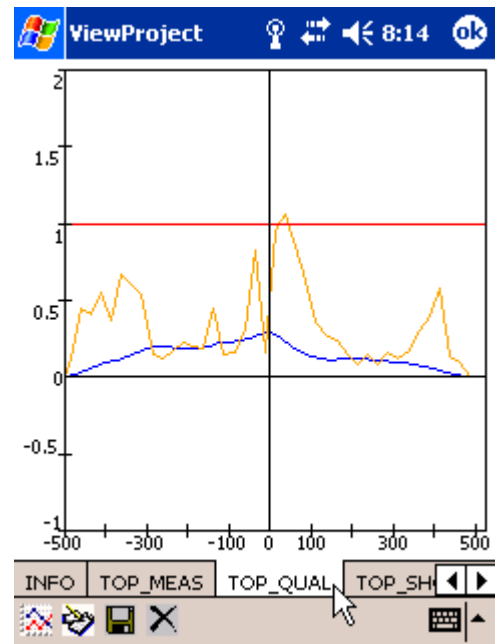
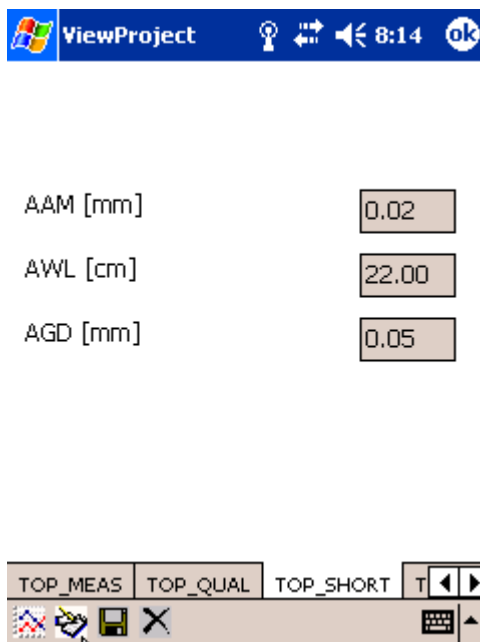
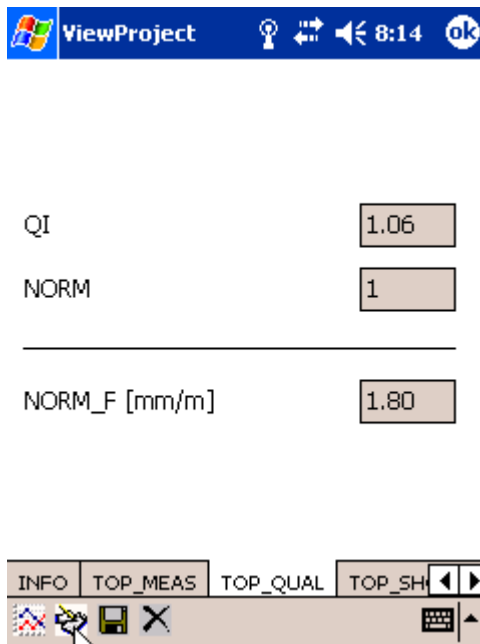
POSIN [mm/m]: 0.82

NEGIN [mm/m]: -0.61

INFO TOP_MEAS TOP_QUAL TOP_SH



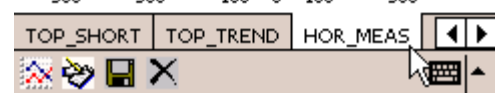
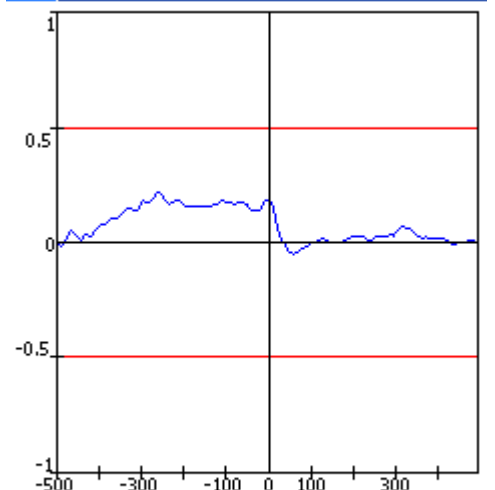
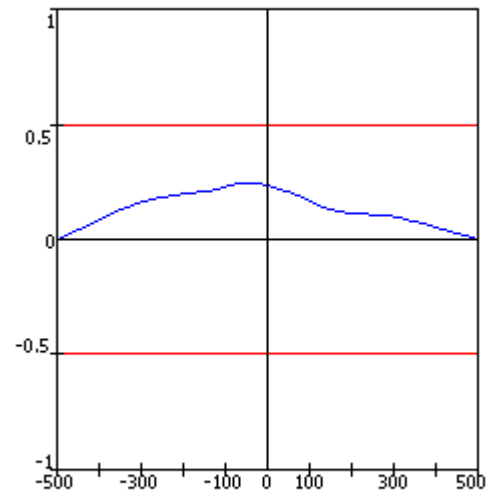
POSV = maximum positive versine, NEGV = maximum negative versine, POSIN = maximum positive inclination, NEGIN = maximum negative inclination (over 20 cm, based on the filtered signal).



QI = quality index according to Prorail norm (should be less than 1), absolute norm in mrad as a function of the speed. AAM = average amplitude waveband 0 – 20 cm, AWL = average wavelength, AGD = average grinding depth.



POSV [mm]	0.22
NEGV [mm]	-0.05
POSIN [mm/m]	0.75
NEGIN [mm/m]	-0.81

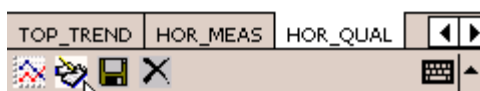


POSV = maximum positive versine, NEGV = maximum negative versine, POSIN = maximum positive inclination, NEGIN = maximum negative inclination (over 20 cm, based on the filtered signal).

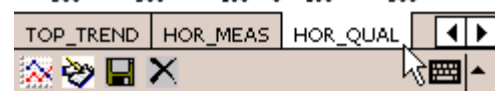
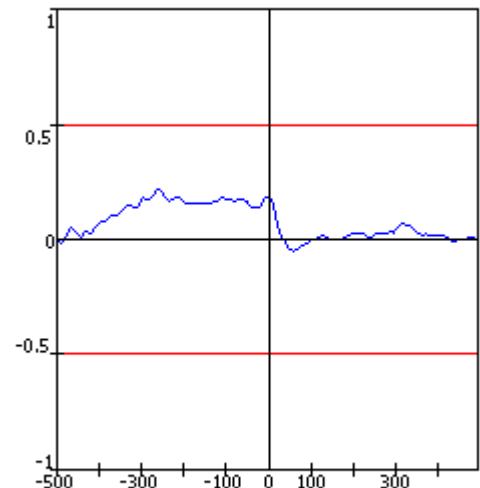
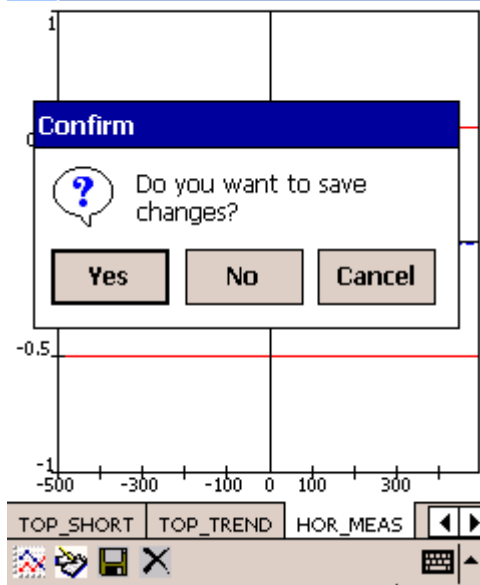


QI_POSV_HOR [mm]

QI_NEGV_HOR [mm]



QI_posp_horj and QI_negp_hor = speed dependant ProRail norm for the versines



The actual values for the versines can be found in the screen HOR_MEAS



Device Status

Serial	RP4184
Version	050323
Battery (%)	19.73
Temperature (C)	20

Cancel

If the RAILPROF battery charge has dropped below 20 % the text is displayed in red. At 10 % the RAILPROF gives a signal and measuring should be terminated as soon as possible. At 5 % operation is blocked by the software. If the battery would be used furthermore it cannot be charged without additional measures. The battery should be disconnected from the electrical circuit and after 20 seconds be reconnected. Then the normal charging procedure can be started.

8. DEVICE STATUS

The status of the RAILPROF can be retrieved via 'Device Status'. This screen displays the serial number, version of the internal RAILPROF software, the battery status as percentage of fully charged battery and the temperature.

The battery voltage is an important measure how long the battery can still be used. Under normal conditions 8 hours continuously working should be possible, which is sufficient for measuring of 200-300 welds. If the charge is less than 20 % the PDA gives a warning and at 10 % an alarm is given.

Recharging after a shorter period of operation is possible without shortening the life of the battery. To save the battery the RAILPROF automatically switches off after 10 minutes of inactivity. In order to charge the battery the cable of the charger has to be connected with the connector at the right side of the RAILPROF. The charger will work with any voltage between 100 and 260 Volt and any frequency between 50 and 60 Hz. It is not necessary to switch the RAILPROF on. A red light close to the connector shows the battery is being charged. When the battery is almost full the color will slowly change to green. A fully charged battery shows green. Overloading a battery is not possible, the charging process stops when the battery is full. Charging an empty battery takes approximately 14 hours. The recommended procedure is to charge the battery overnight. The cable can be removed by pulling the connector, this will unlock the connector.

PULLING THE CABLE WILL CAUSE DAMAGE!

The expected lifetime of a battery is several years. After that the battery has to be replaced. Batteries are available from ECS. The battery is located in a compartment behind the lid next to the connector at the right side of the RAILPROF.

9. THE PC DESKTOP SOFTWARE

Installation:

The PC software runs under WINDOWS. The software should be downloaded via the following link:

http://www.esveld.com/Download/RAILPROF/index.php?dir=Railprof_PDA%2FDesktop_PDA_all_languages%2F

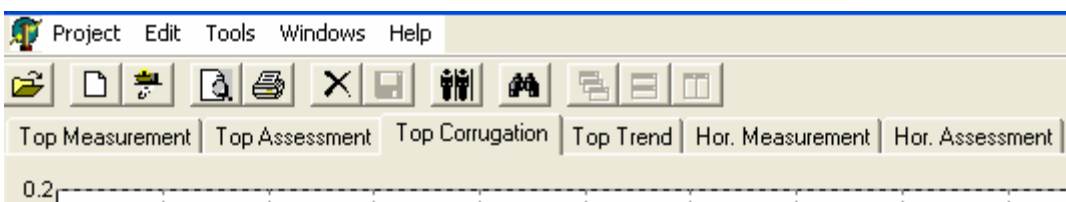
Directory Listing of /Download/RAILPROF/Railprof_PDA/Desktop_PDA_all_languages/

home > Railprof_PDA > Desktop_PDA_all_languages

File	Size	Last Modified
..	-	Aug 04 2015 10:03:39 AM
Railprof_Examples/	-	Jan 23 2017 09:53:52 AM
fortlib.dll	24KB	Jun 02 2016 06:06:35 PM
manual1_EN.pdf	116KB	Jun 02 2016 06:06:36 PM
manual1_NL.pdf	116KB	Jun 02 2016 06:06:39 PM
manual1_NL .pdf	2310KB	Jun 02 2016 06:06:38 PM
manual2_EN.pdf	1457KB	Jan 23 2017 10:01:34 AM
manual2_NL.pdf	2235KB	Jun 02 2016 06:06:42 PM
rp_gui.exe	1756KB	Jan 23 2017 10:02:32 AM
RP_GUI.INI	0KB	Jun 02 2016 06:06:47 PM
rp_gui_3.3.0.exe	1750KB	Jan 23 2017 09:54:03 AM
RP_GUI_EN.INI	5KB	Jun 02 2016 06:06:53 PM
RP_GUI_NL.INI	10KB	Jun 02 2016 06:06:53 PM

All the files should be placed in one directory. Name and location of the directory can be chosen by the user.

The main program is called RP_GUI (RP for RAILPROF, GUI for Graphical User Interface). The ini-file contains the language dependent information and can be modified by the user with a text editor such as Windows Notepad. At first the map must be opened where the reports are copied. In the directory of the desktop software a series of profiles is available in 'Profile_examples'. In RP_GUI select 'Project' and then 'Open Project' and go to for example the directory 'Profile_Examples'. Click on one of the names to view the profile data.

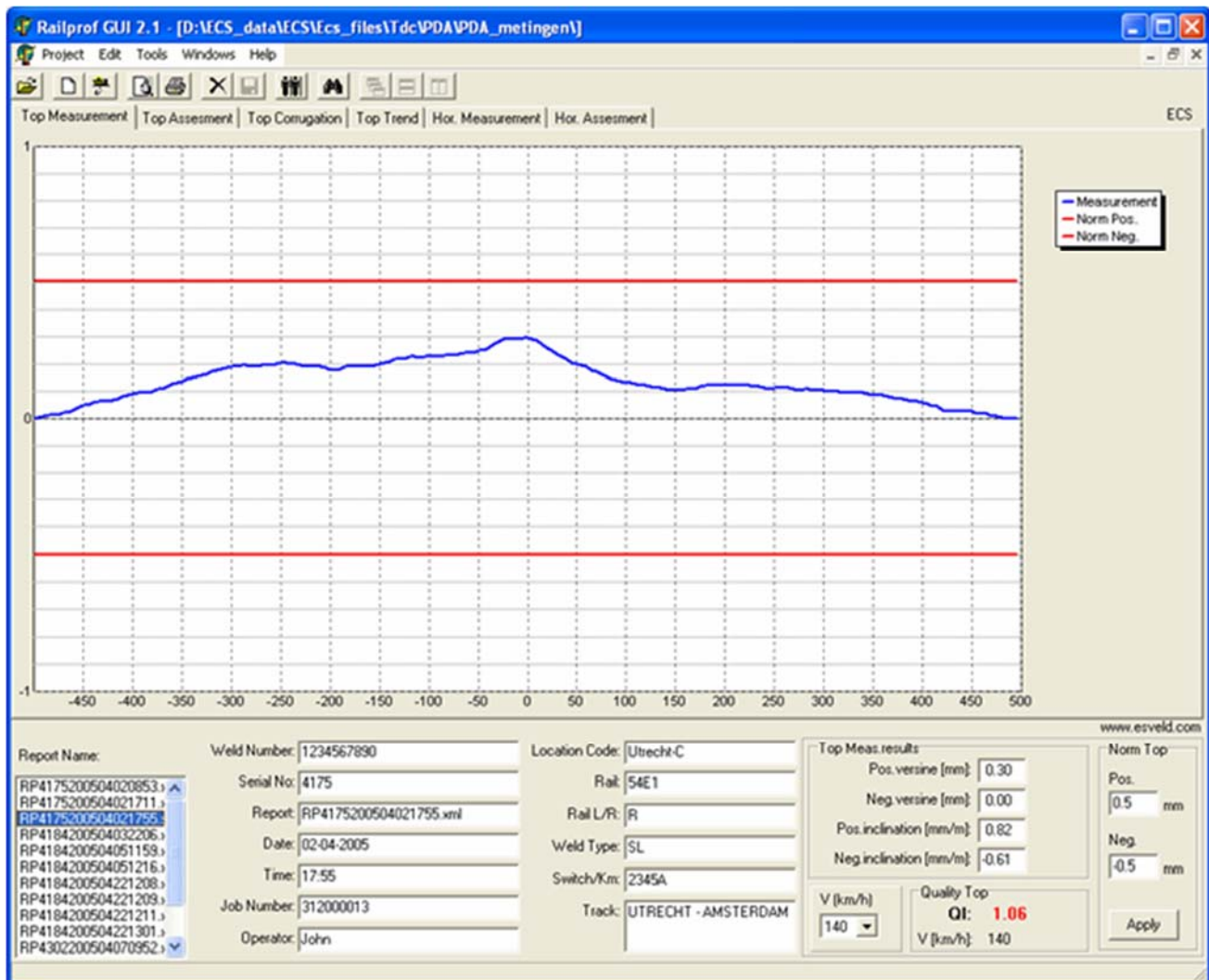


Assessment of weld geometry

Basically, the vertical (Top) and horizontal (Hor.) profiles, if measured, can be viewed. 'Top Measured' shows the profile as measured, without any filtering. The user can set the position of two red lines and click apply. Default is ± 0.5 mm. This option just gives a quick look at maximum values (versines). At the bottom of the screen the vertical positive and negative versines as well as the inclinations are given. The inclinations are calculated over a length of 20 cm.

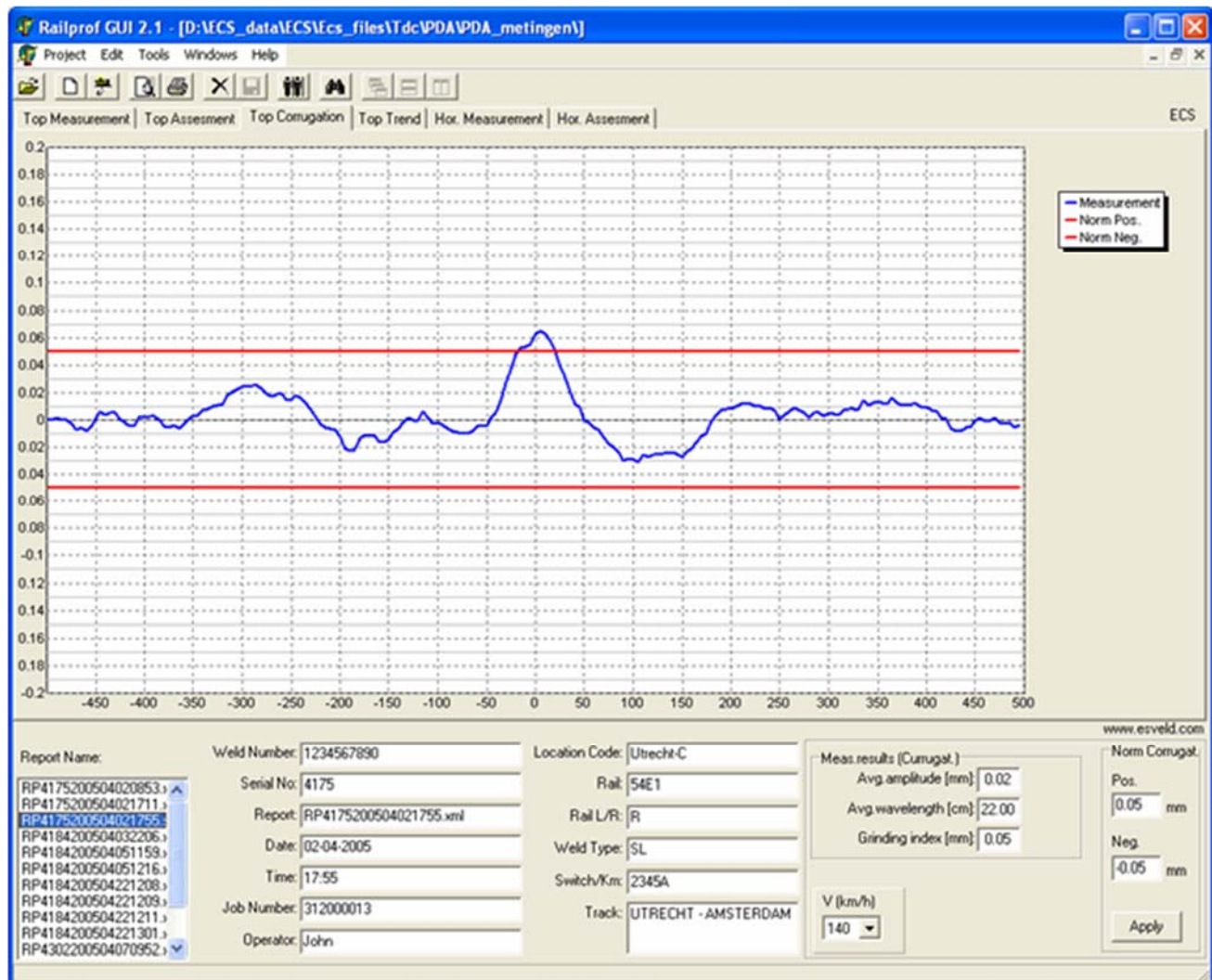
Top assessment shows the first derivative of the geometry from which the irregularities shorter than 25 mm have been removed by filtering. This signal is scaled according to the speed in such a way that if the signal is less than 1 the weld is OK and if larger than 1 is rejected. The maximum allowable inclination according to the Dutch Infra Manager ProRail is for an operational speed of 40 km/h (marshalling yards) 3.2 mrad, for 140 -200 km/h 0.9 mrad and for high-speed 0.7 mrad. For further details please refer to the article 'FORCE-BASED ASSESSMENT OF WELD GEOMETRY' in the appendix.

For the horizontal direction two screens are available. In this case only unfiltered data are used.



Assessment of rail corrugation and rail grinding

'Top Corrugation' shows the high-pass filtered vertical geometry signal in the band 0 – 20 cm. This screen should be used for monitoring rail corrugation and grinding results. The user can set the red horizontal lines to have a quick overview of exceedences. The default values are ± 0.05 mm. The user can alter the settings in the screen menu, but can also change the default values in the file RP_GUI.INI.

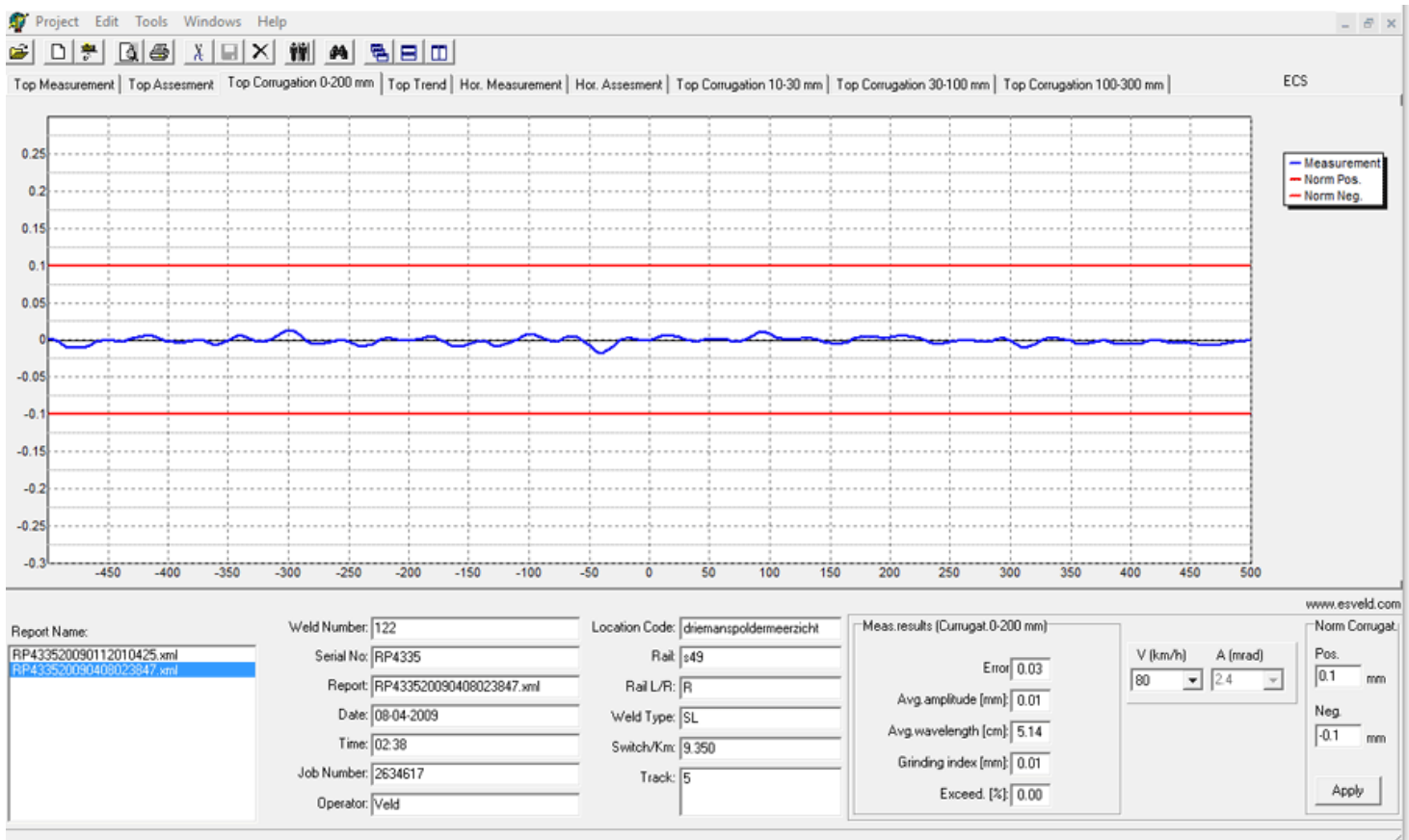


Special menu based on the German standards

To facilitate German grinding practice standards a special menu was added to the desktop software. In the wavebands 1-3 cm, 3-10 cm and 10-30 cm the percentage of exceedance of the standard is presented. The standard can be set by the user per waveband as the admissible displacement in mm.

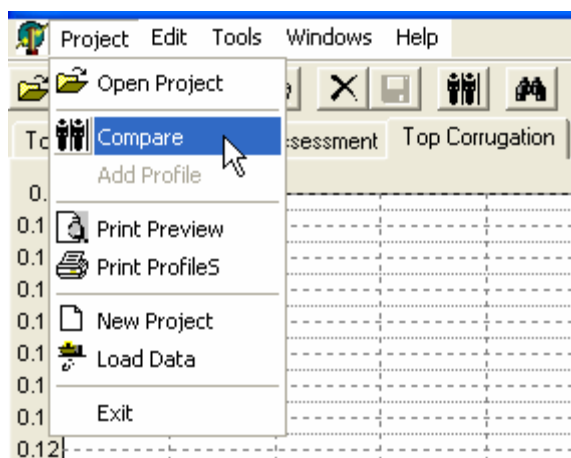
Furthermore, the following grinding indices are produced:

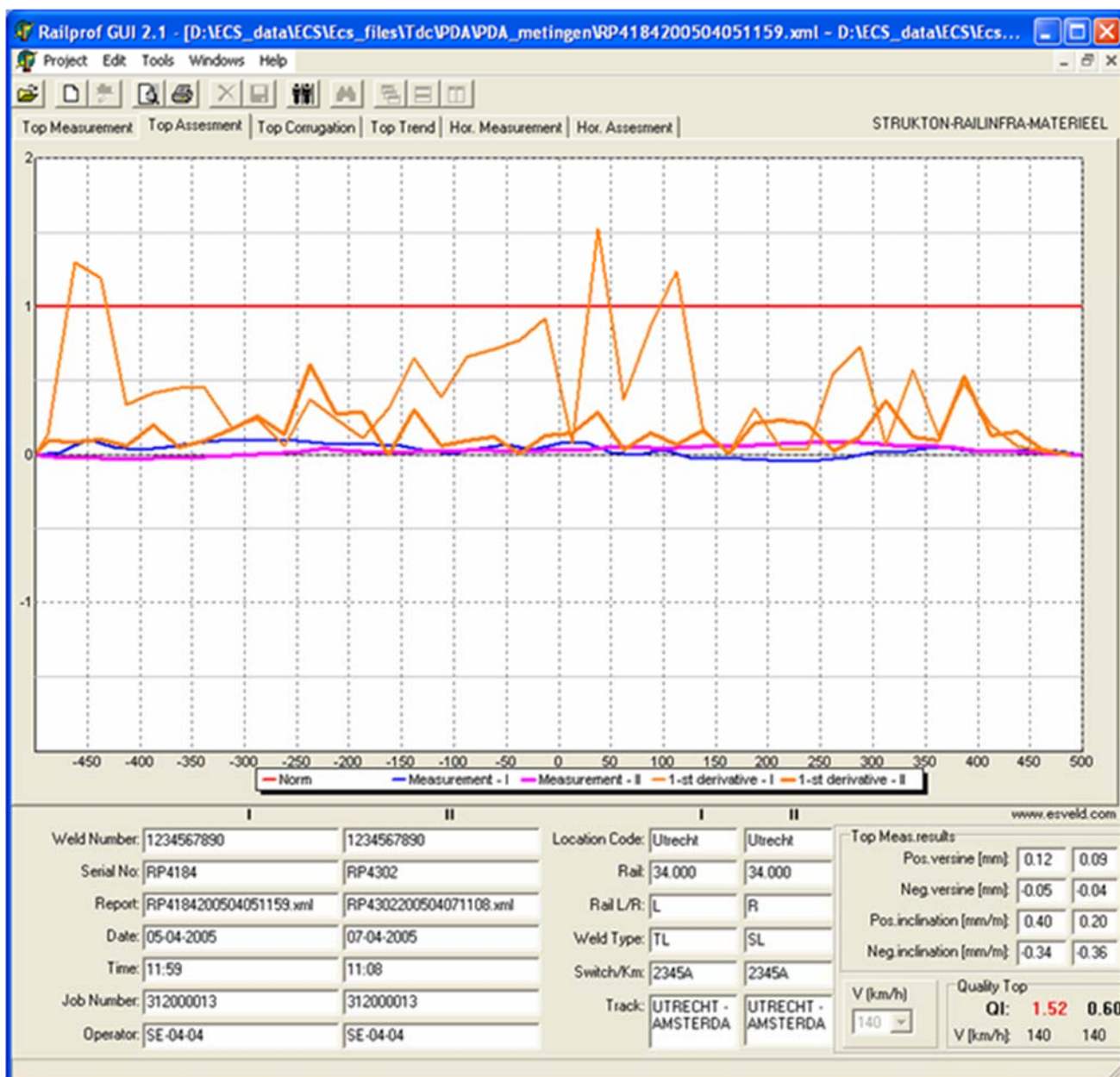
GA = Grinding Amplitude, GG = Average Wavelength, GSD = Average Grinding Depth.



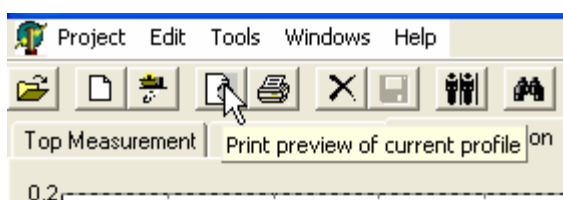
Comparison of profiles

If required two profiles can be compared (Compare) by displaying them in one screen. Both are shown.

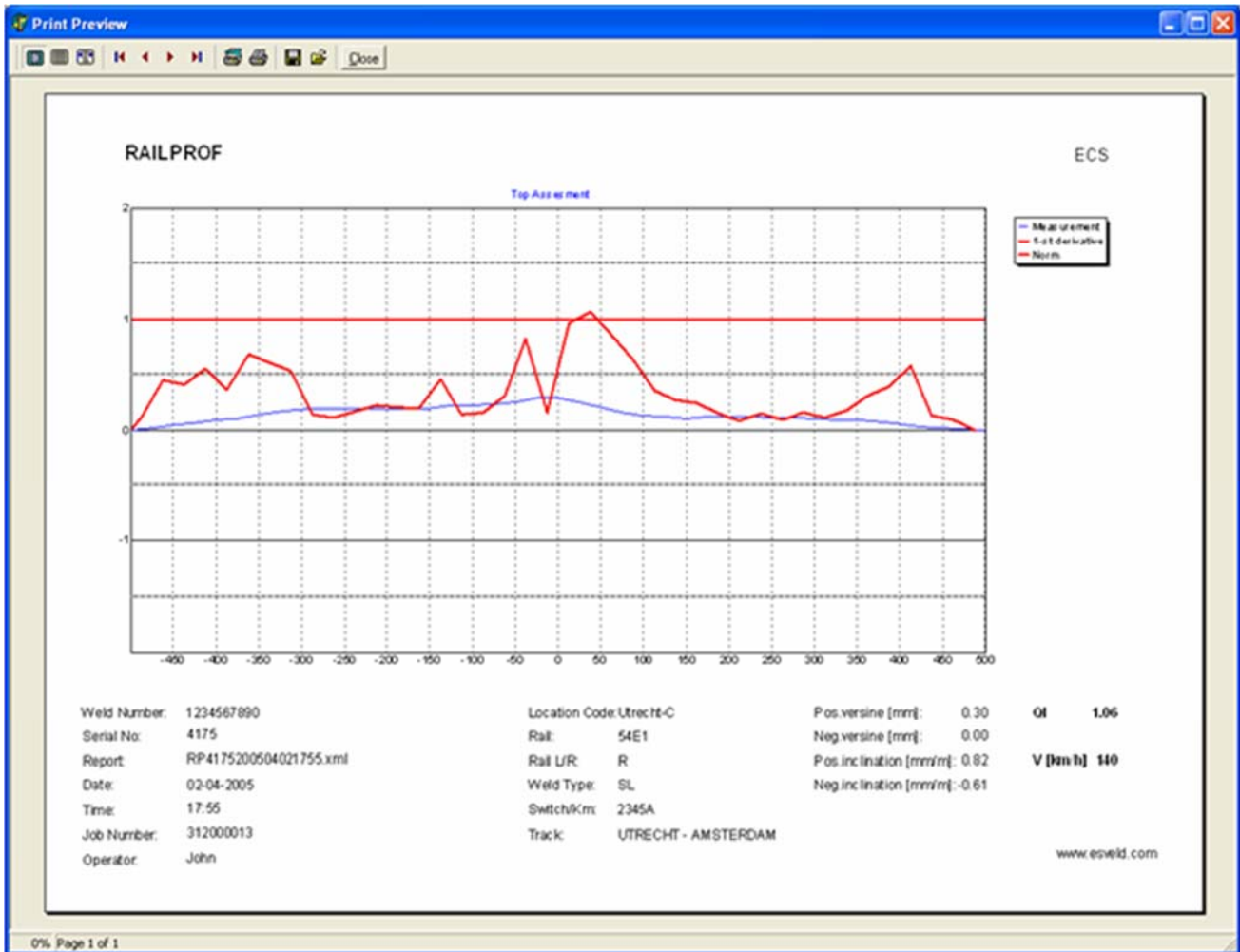




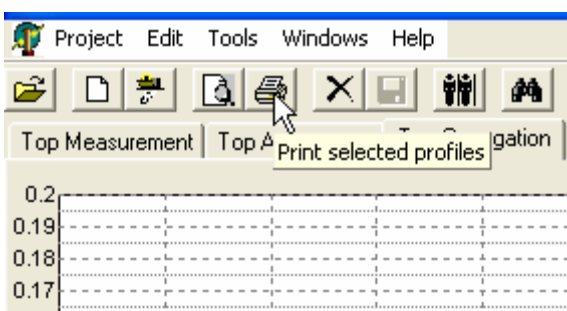
Print preview



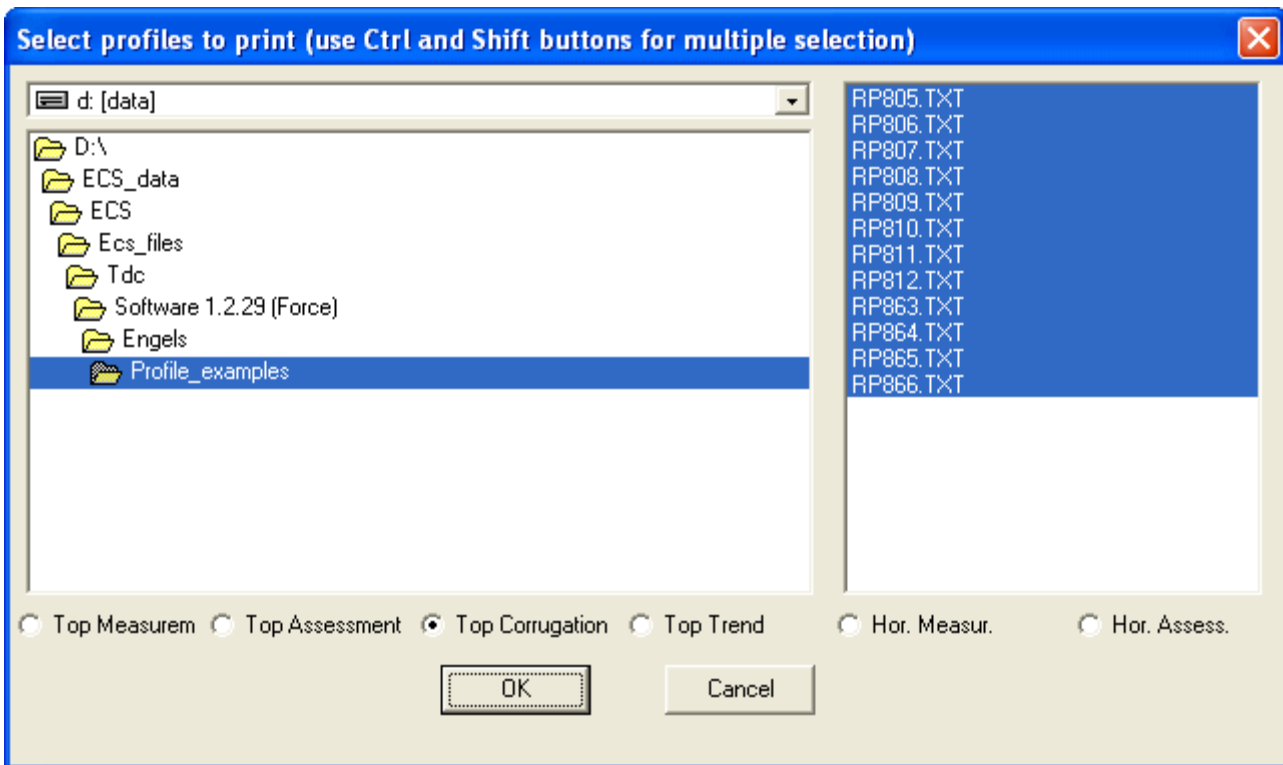
The print preview icon gives a preview of the printed page and can optionally print it.




The printer icon gives the possibility to print a number of consecutive measurements. A window appears where the relevant directory can be selected. The first file to print is chosen by clicking the filename, the last is chosen by keeping the shift key pressed, going to the last report to print and clicking its file name.

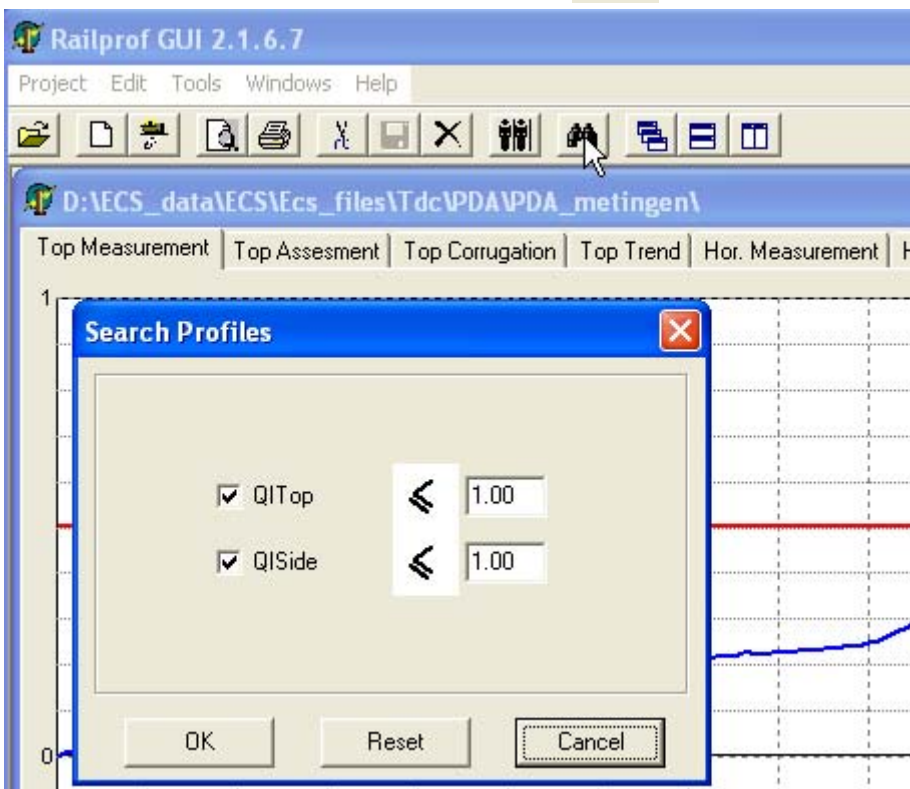


This feature is especially important if a series of measurements should be printed as one pdf file. The files are selected as described above and then one of the six evaluation screens should be selected. After pressing OK a preview of the selected files is displayed. At the top of this screen the printer setup should be selected to choose the pdf printer. Next give the print command and now one integrated pdf file is produced. An example is also stored in the directory 'Profile_examples'.



Profile selection based on QI

The desktop software offers the possibility to select records based on the quality index QI. Via the find icon a screen is opened in which a choice can be made for QITop, QISide, or both. The selection value is default 1.00, but the user can assign any other value. After OK the screen at the bottom left shows just the selected records. These can be moved to a selected directory via , or via the menu 'Edit' and 'Move to'.



It is not necessary to fill in the 'file name'. In this menu a new directory can be made, or this can be done previously with Windows explorer. The selected files are actually moved to the new directory by clicking 'Open'.

10. DEFINITIONS

The profile is defined as the deviation from a straight line connecting the first and the last measured point. This is displayed without further processing. For the other parameters the profile is split up into long waves (the trend) and short waves. The trend in every point is the mean value over a length of 10 cm on either side. The positive and negative versine are the highest and lowest points of the trend. The positive and negative slope are the steepest ascending and descending point of the trend. The short waves are the difference between profile and trend.

The average amplitude is based on the short waves. It is the average of the maxima minus the average of the minima. The average wavelength is twice the average distance between (ascending and descending) zero crossings.

A grinding index is a measure for the amount of material that has to be ground away over the measured length of 1000 mm of the rail. It is a weighted average of the positive part of the trend.

The profile is defined as the deviation from a straight line connecting the first and the last measuring point.

Explanations

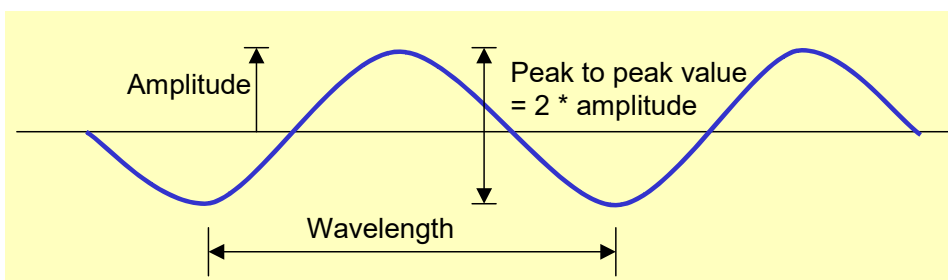
Sometimes the finer structure of the profile is not relevant, so it can be removed, leaving the general trend, also called the long waves. The short waves are explained under question 2. The trend in any point is defined as the average of the profile from 10 cm left to 10 cm right of that point. It is often used for positioning rails prior to welding. It is also used in combination with the definition of other parameters, used to describe the quality.

Versine definitions

The positive versine is the highest point of the trend. The Netherlands Railways Standards¹ require this value to be less than 0.3 mm vertical after welding and less than 0.2 mm after finish grinding. The negative versine is the lowest point of the trend. It should be greater or equal to 0 mm. The positive inclination is the steepest point of the trend, assuming the train runs from left to right on the graph, as it will do on the right rail. At this point the wheel of the train has the highest velocity in vertical direction. Over 200 mm the inclination should be less than 1:1000 in vertical direction. The negative inclination has the same effect for the other (left) rail where the train will run from right to left on the graph. So the requirements will be the same. Horizontally the requirements are: versine between – 0.5 and 0.5 mm, inclination over 200 mm less than 1:500.

Grinding index

The grinding index is a global measure of the amount of material that has to be ground away to get a rail profile with a positive versine equal to the highest allowed value. Mathematically it is the weighted average of the difference between the trend and a parabola through the first and last measuring point with its top at the highest allowed value of the positive versine, being 0.2 mm. Please note that the grinding index can be used as an indication only, as the actual grinding work depends on several factors, such as the grinding machine used for the job.



Corrugation

Corrugation is the deformation of the rail profile from a straight line into a shape as shown in the figure below. Wavelength and amplitude are indicated in the figure. In general the corrugation wavelength is 3 to 4 cm. As

¹ See Esveld, C.: Modern Railway Track 2nd Edition, ISBN 90-8004-324-3-3, page 316

compared with the trend (the long waves) the wavelength is relatively short. When corrugation takes place the amplitude of the deformations builds up gradually, creating noise as trains pass by. In the process the rail material toughens locally in phase with the corrugation waves, causing a faster reoccurrence of corrugation waves after grinding, if one waits too long with the grinding. To prevent this, grinding should take place when the amplitude of the corrugation waves is approaching 0.05 mm peak to peak.

The short wave profile is defined as the difference between the total profile and the long wave profile. If the long waves are removed one can zoom in further without the long waves causing the graph going off the screen. In this way an accurate look at the corrugation is made possible. (On the RAILPROF zooming in is done by pressing the > key, the WINDOWS software is doing it automatically.)

Deviations due to horizontal curves

The radius of a rail curve commonly in use by metro companies is 100 m. Then over a measuring length of 1.0 m the horizontal deviation from a straight line in a curve is 1.25 mm or less. As the top surface in the middle of the rail is nearly flat ($R = 300$ mm) this deviation has no significant effect (less than 1 micron) on the measurement of the profile of the rail top.

11. SPECIFICATIONS

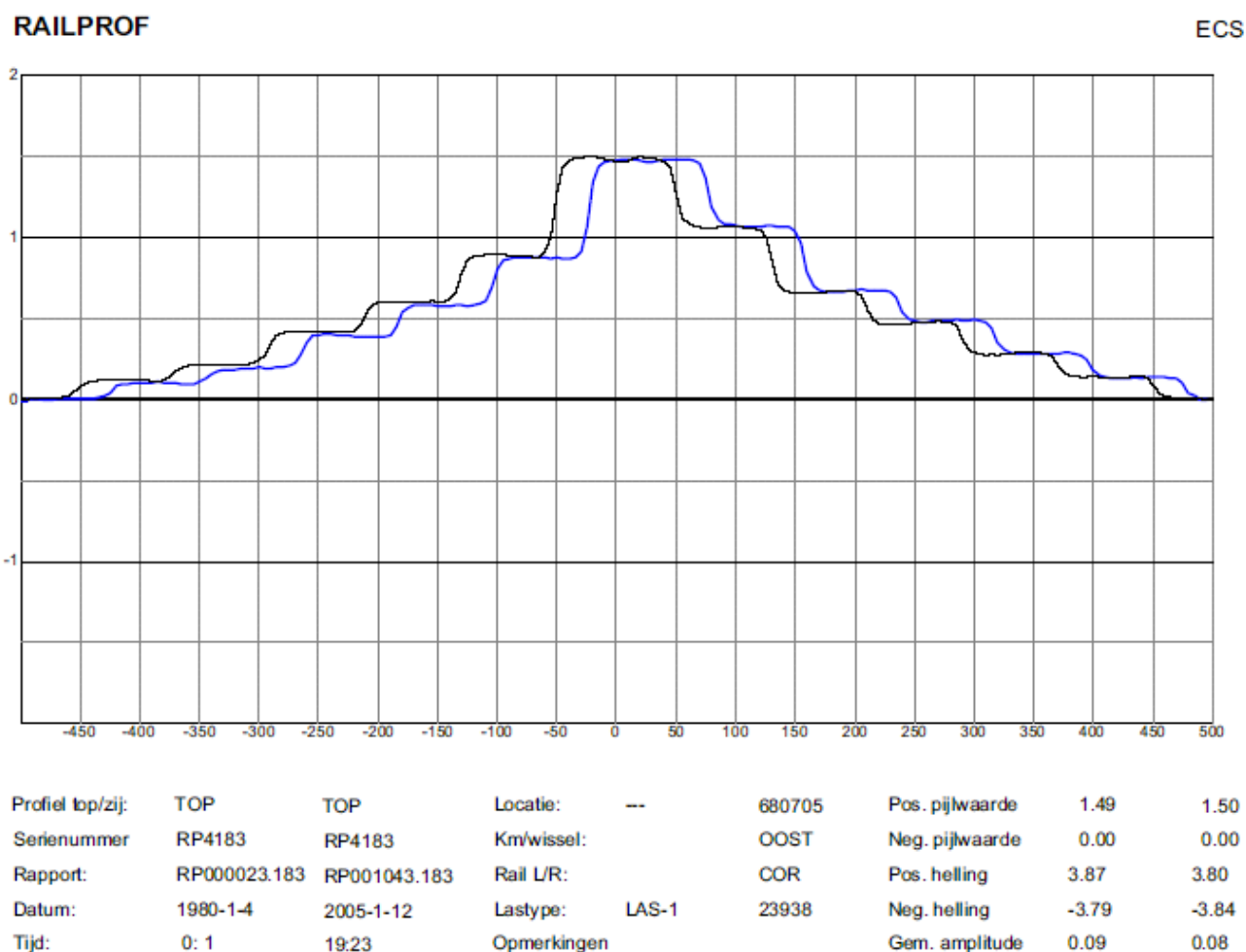
1. Weight: less than 7 kg;
2. Length: 116 cm;
3. Microsoft Windows Phone, with Windows 10:
 - Wireless communication with RAILPROF via Bluetooth to control measurements and data transfer;
 - Data analysis, such as filtering and computing of QI;
4. Measuring length: 1,000 mm in accordance with the EN standards for weld geometry; sampling interval 5 mm;
5. Measuring time: about 10 sec;
6. Time for data transfer to Smartphone and data analysis: about 6 sec;
7. Data storage: unlimited on Smart Phone internal memory, Secure Digital (SD) card, or in the Cloud;
8. Data transfer to desktop PC via mobile network, wifi, or wired synchronization;
9. Presentation of measurements on desktop PC via Windows menu. Easy generation of reports in pdf format;
10. Accuracy:
 - a. Temperature range of operation: - 5 °C and + 40 °C;
 - b. Vertical geometry: +/- 0.020 mm;
 - c. Lateral geometry: +/- 0.050 mm;
 - d. Inclination associated with QI: +/- 5 %;
11. Measuring principle transducers: eddy current. Results are not influenced by moisture, rust and dirt, so that actual metal surface is measured;
12. Bottom of RAILPROF is resistant to temperatures up to 150 °C;
13. Shipping information:
 - a. Total weight of flight case, RAILPROF, PDA and carton protection box: approximately 19 kg;
 - b. Dimensions: approximately 137 x 43 x 17.5 cm.

12. SOFTWARE LICENSES

The licenses for smartphone and desktop software are considered as one combined license coupled to the serial number of the RAILPROF.

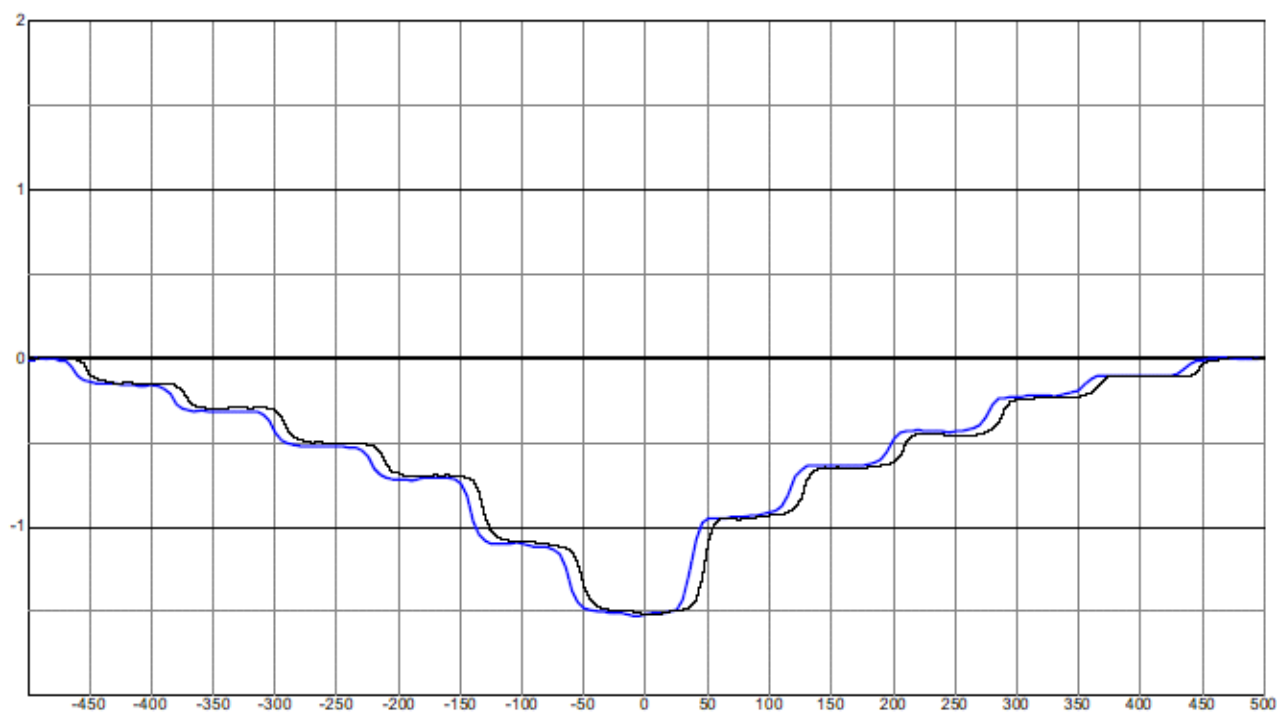
ACCURACY OF RAILPROF

For calibrating the RAILPROF use is made of so-called step rails, one having positive versines up to 1.5 mm and the second one with negative versines up to -1.5 mm. The measurements below show results of a comparison with a time difference of about 3 years. The absolute deviation relative to the straightness standard was about 0.03 mm, whereas the repeatability as difference in versine was 0.01 mm.



RAILPROF

ECS



Profiel top/zij:	TOP	TOP	Locatie:	--	680705	Pos. pijlwaarde	0.01	0.01
Serienummer	RP4183	RP4183	Km/wissel:		OOST	Neg. pijlwaarde	-1.53	-1.52
Rapport:	RP000029.183	RP001046.183	Rail L/R:		COR	Pos. helling	3.87	3.77
Datum:	1980-1-4	2005-1-12	Lastype:	LAS-1	23938	Neg. helling	-3.77	-3.81
Tijd:	0: 5	19:24	Opmerkingen			Gem. amplitude	0.07	0.07