FORCE-BASED ASSESSMENT OF WELD GEOMETRY

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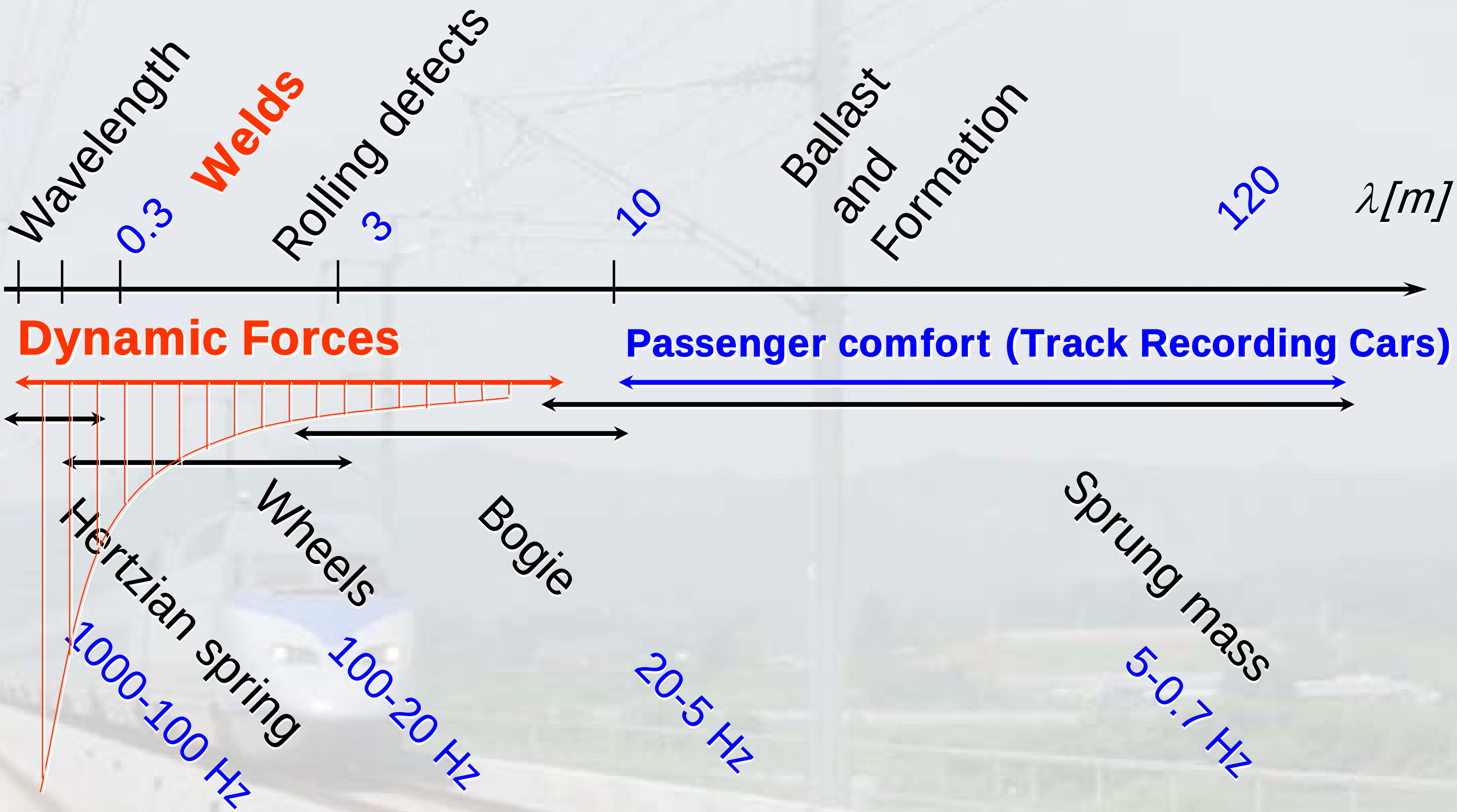
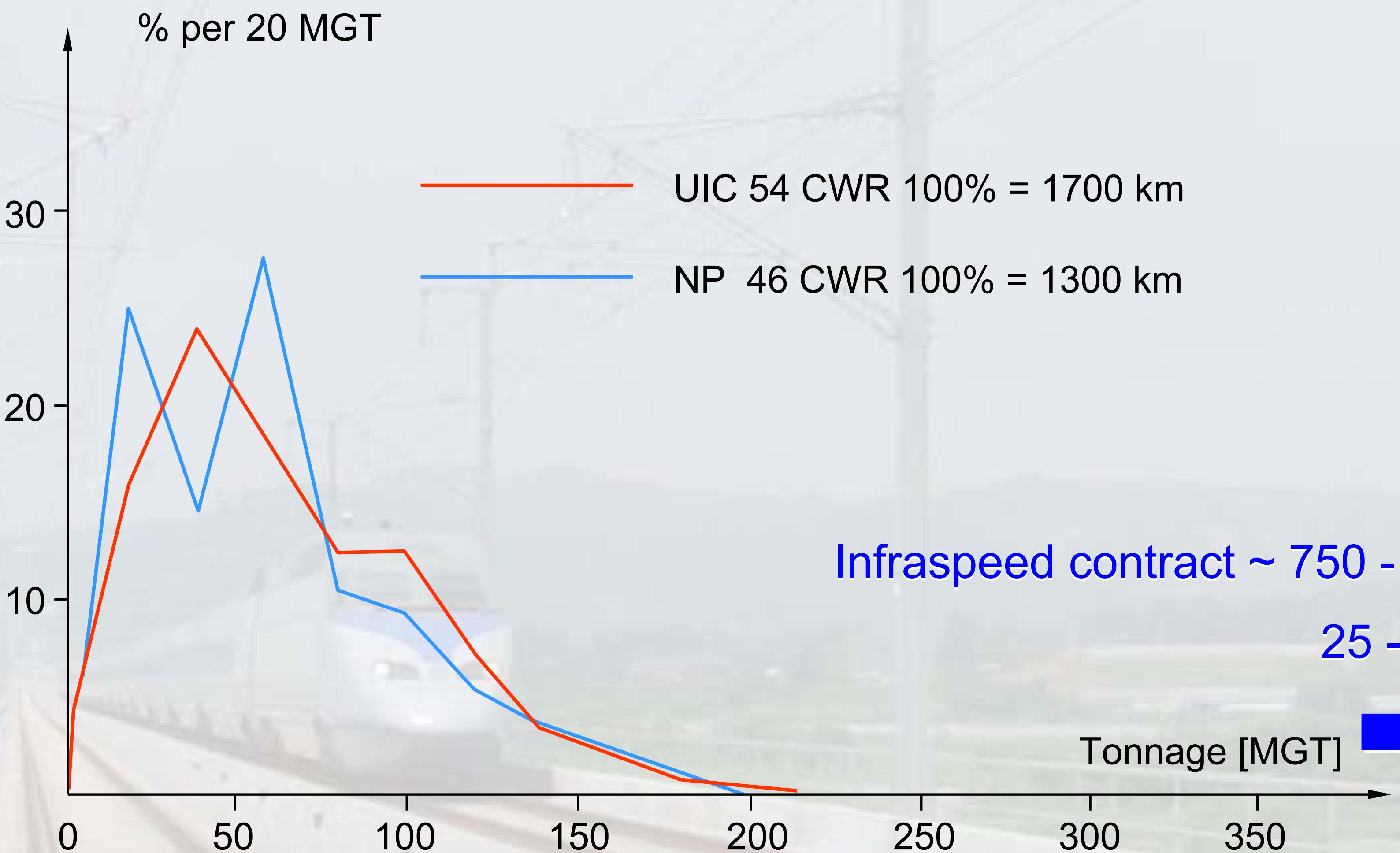
TRACK LOADS

- *Wavelength λ*
- *Frequency f*

$$\lambda = \frac{v}{f}$$



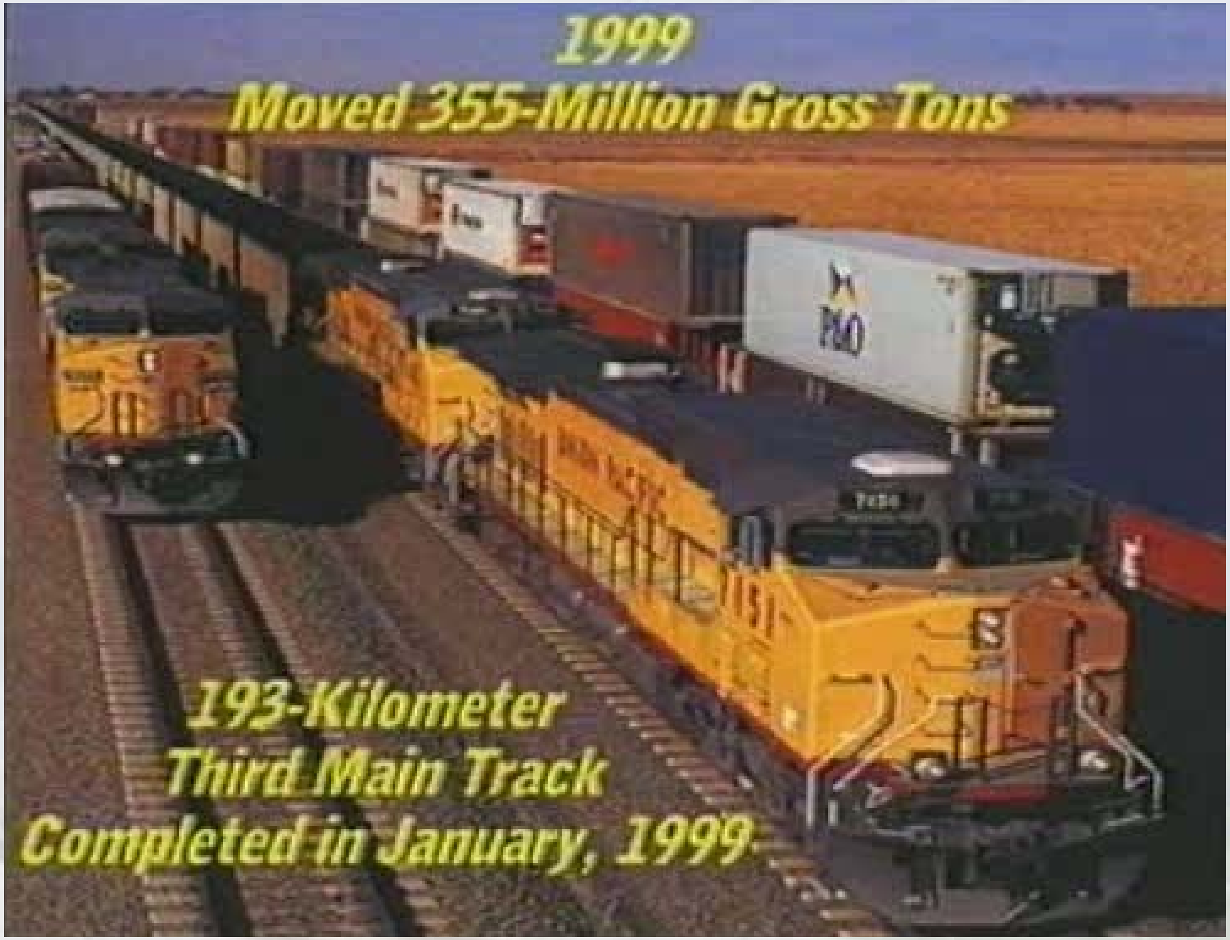
TONNAGE BORNE ON NS PER 01-01-1988



Infraspeed contract ~ 750 - 900 MGT

25 - 30 years

TONNAGE BORNE ON UNION PACIFIC



DAMAGE DUE TO POOR WELD GEOMETRY

EXISTING WELD GEOMETRY STANDARDS

For example

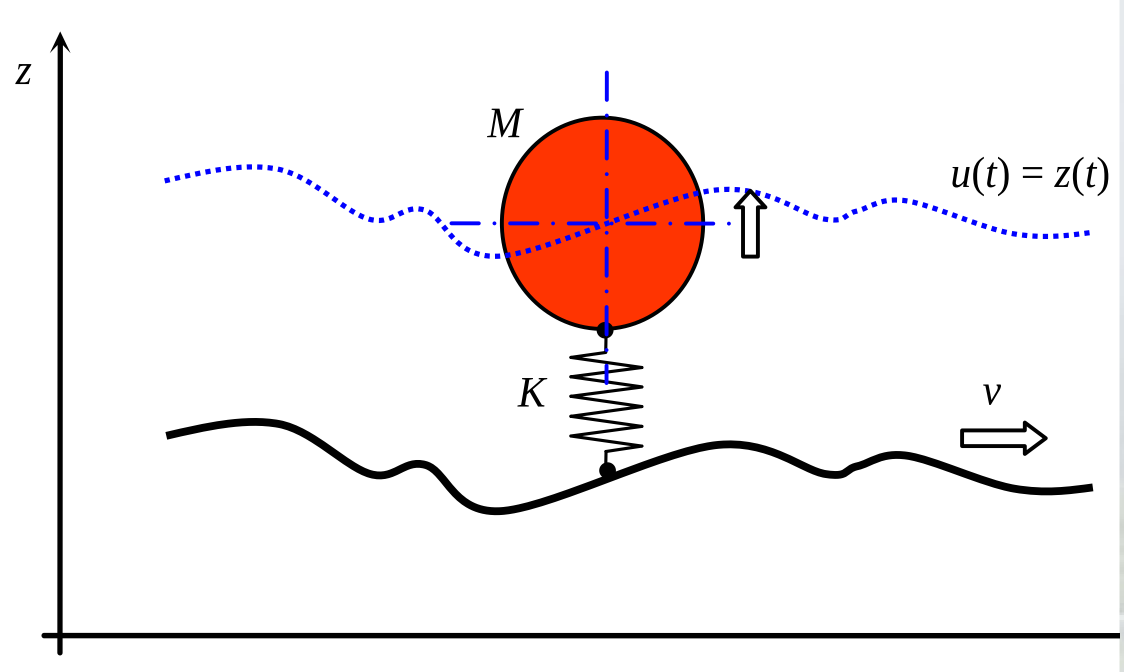
Versine: $0 < p < 0.3$ mm

ACCELERATION APPROACH

- Wheel follows rail irregularities;
- Dynamic part of contact force is governed by:

$$F_{dyn}(t) = M\ddot{z}(t)$$

$$F_{dyn} = \alpha M v^2 \frac{d^2 z}{dx^2}$$



VELOCITY APPROACH (1)

Assumption:

Equivalent wheel mass is proportional to wavelength:

$$F_{dyn}(t) = M_e \ddot{z}(t)$$

with:

$$M_e = \frac{1}{L_0} ML = \frac{1}{L_0} M \frac{v}{f}$$

and: $$\ddot{z} = \dot{z} \frac{2\pi v}{L}$$

VELOCITY APPROACH (2)

The dynamic contact force as a function of the first time derivative:

$$F_{dyn} = M \frac{2\pi v}{L_0} \dot{z}$$

The dynamic contact force in terms of the spatial derivative, including calibration factor β:

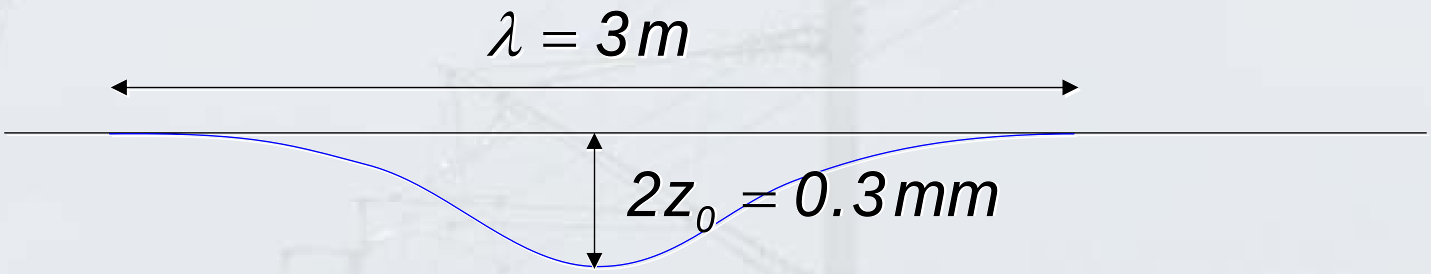
$$F_{dyn} = \beta \frac{M}{L_0} v^2 \frac{dz}{dx}$$

QUALITY INDICES (QI)

$$QI = \frac{\left| F_{max,\ actual} \right|}{F_{norm}} = \frac{\left| \frac{dz}{dx} \right|_{max,actual}}{\frac{dz}{dx}_{norm}} \leq 1 \quad \Rightarrow \quad OK$$

- *QI* ≤ *1:* Accepted
- *QI* > *1:* Rejected

RAIL MANUFACTURING



$$z = z_0 \sin \frac{2\pi x}{\lambda}$$

$$\frac{dz}{dx} = \frac{2\pi}{\lambda} z_0 = \frac{2\pi}{3} 0.15 \approx 0.3\ mrad$$

EXTENSION TO HEAVY HAUL AND HSL (1)

Total wheel load versus velocity:

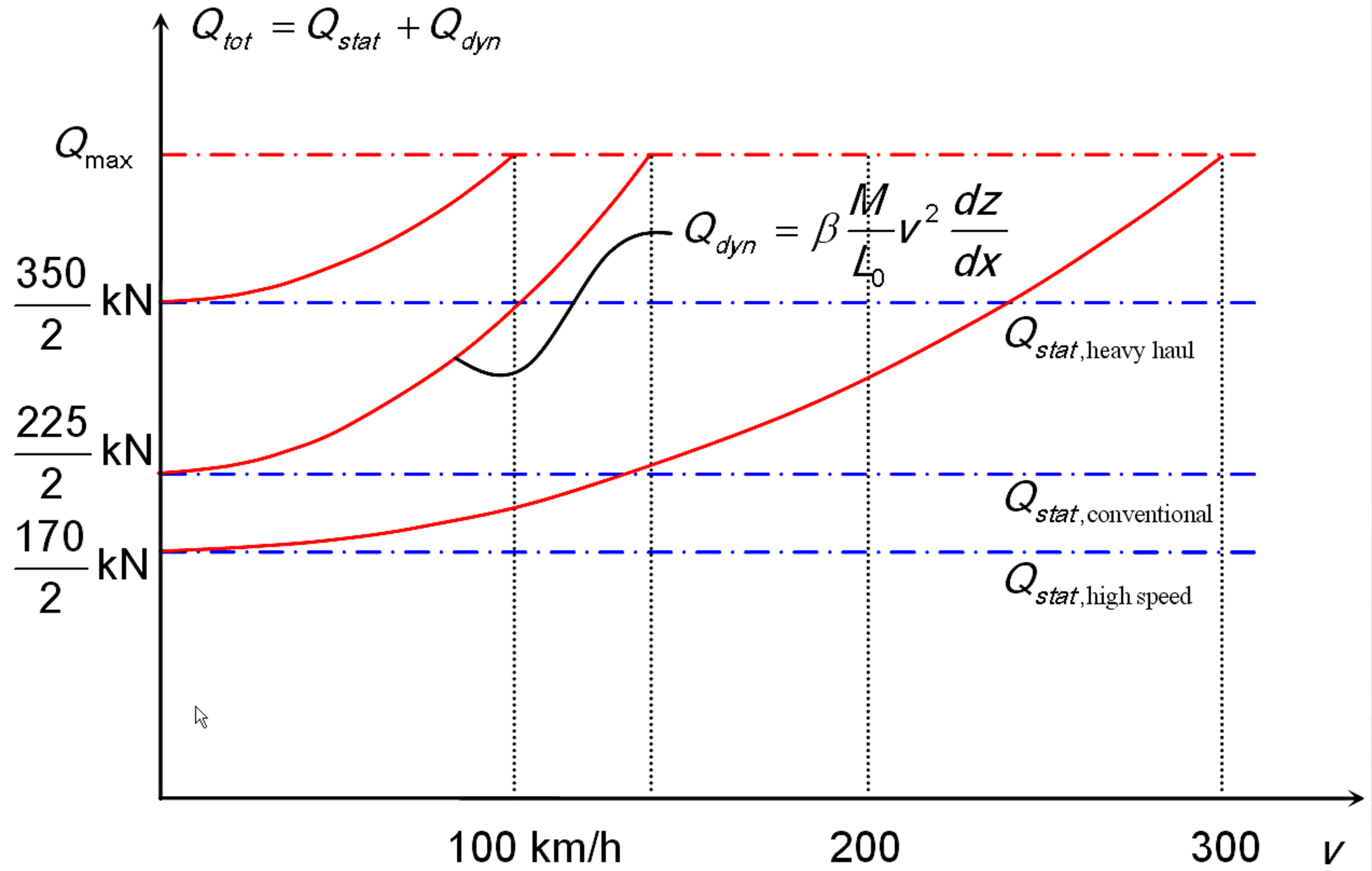
$$Q_{tot} = Q_{stat} + \beta \frac{M}{L_0} v^2 \frac{dz}{dx} \Rightarrow$$

$$\frac{dz}{dx} < \Delta Q \frac{1}{\beta} \frac{L_0}{M} \frac{1}{v^2}$$

Q_{max} is approximately 450/2 kN = 225 kN

M = 2,000 kg

EXTENSION TO HEAVY HAUL AND HSL (2)



EXTENSION TO HEAVY HAUL AND HSL (3)

Intervention values for Heavy Haul and HSL lines:

	[kN] ΔQ	v [m/s]	$\frac{dz}{dx} \cdot \frac{\beta M}{L_0}$	**Norm value [mrad]**
Conventional	225/2	40	0.070	**1.8**
Heavy Haul	100/2	30	0.056	**1.4**
High-Speed	280/2	85	0.019	**0.5**

FORCE-BASED STANDARDS

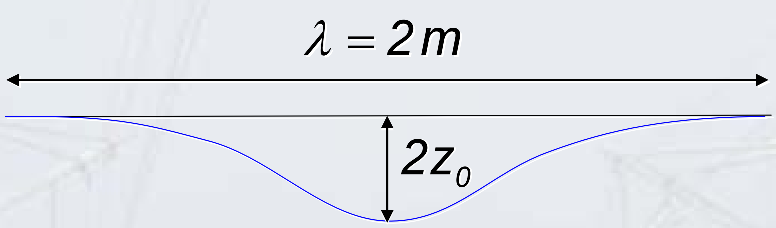
	Velocity	F_{Dyn}	Inclination
Conventional	40 km/h	5 kN	3.2 mrad
	80 km/h	15 kN	2.4 mrad
	140 km/h	35 kN	1.8 mrad
	200 km/h	65 kN	0.9 mrad
HSL	300 km/h	140 kN	0.7 mrad
HH	100 km/h	50 kN	1.4 mrad

Implemented in RAILPROF

Total force in principle 225 kN

QI=1

NEW VERSUS OLD NORM



$$z_0 = 0.3\,mm$$

$$z = z_0 \sin\frac{2\pi x}{\lambda}$$

$$\frac{dz}{dx} = \frac{2\pi}{\lambda} z_0$$

$$= \frac{2\pi}{2} 0.3 \approx 1.0\ mrad$$

Velocity	Versine [mm]	Inclination [mrad]
40 km/h	0.96	3.2
80 km/h	0.72	2.4
140 km/h	0.54	1.8
200 km/h	0.27	0.9
300 km/h	0.21	0.7
Old Norm	0.30	1.0

For 80 km/h the new norm is 2.4 times more favorable than the old norm, provided short waves have been ground off.

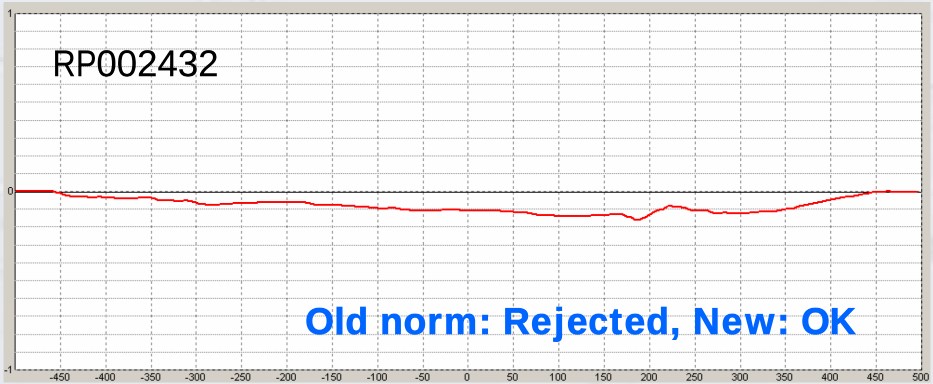
LATERAL GEOMETRY STANDARDS

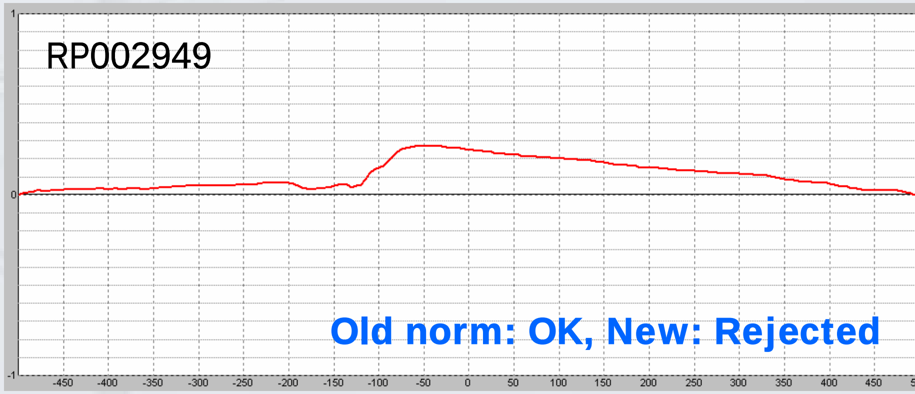
Velocity	Versine
40 km/h	1.0 mm
80 km/h	0.7 mm
140 km/h	0.5 mm
200 km/h	0.5 mm
300 km/h	0.5 mm

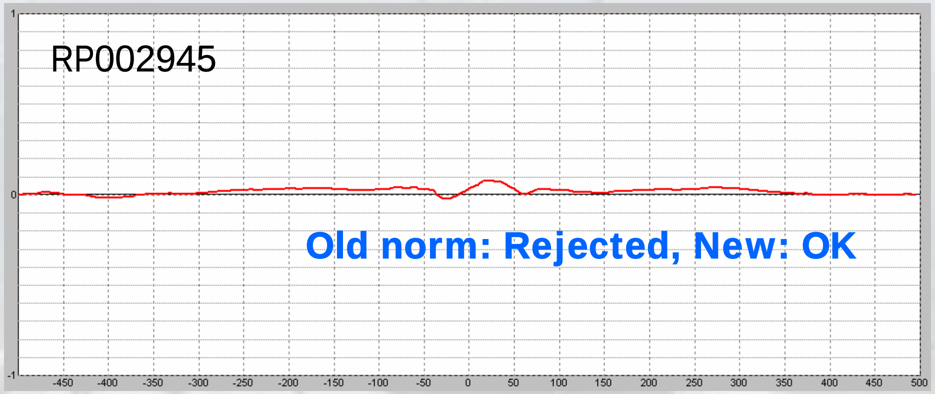
Implemented in RAILPROF

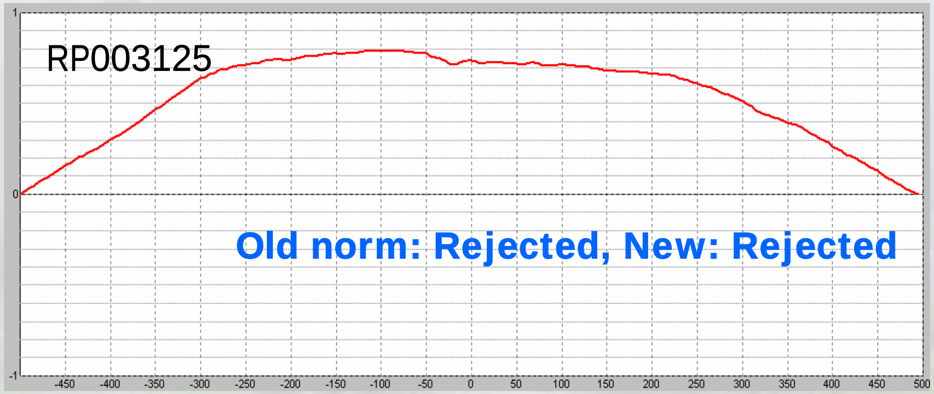
QI=1

ASSESSMENT OLD AND NEW ON PRORAIL

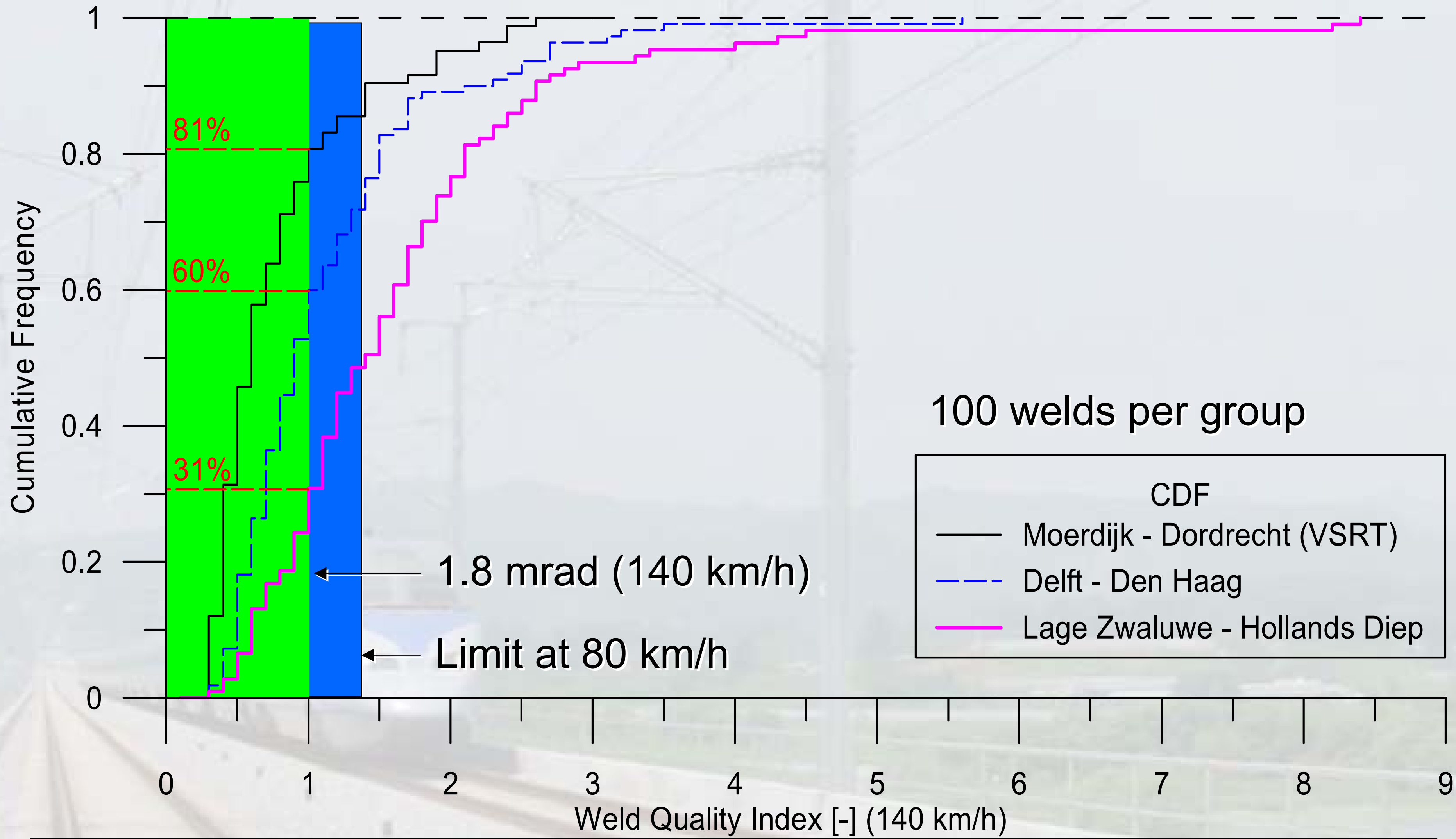




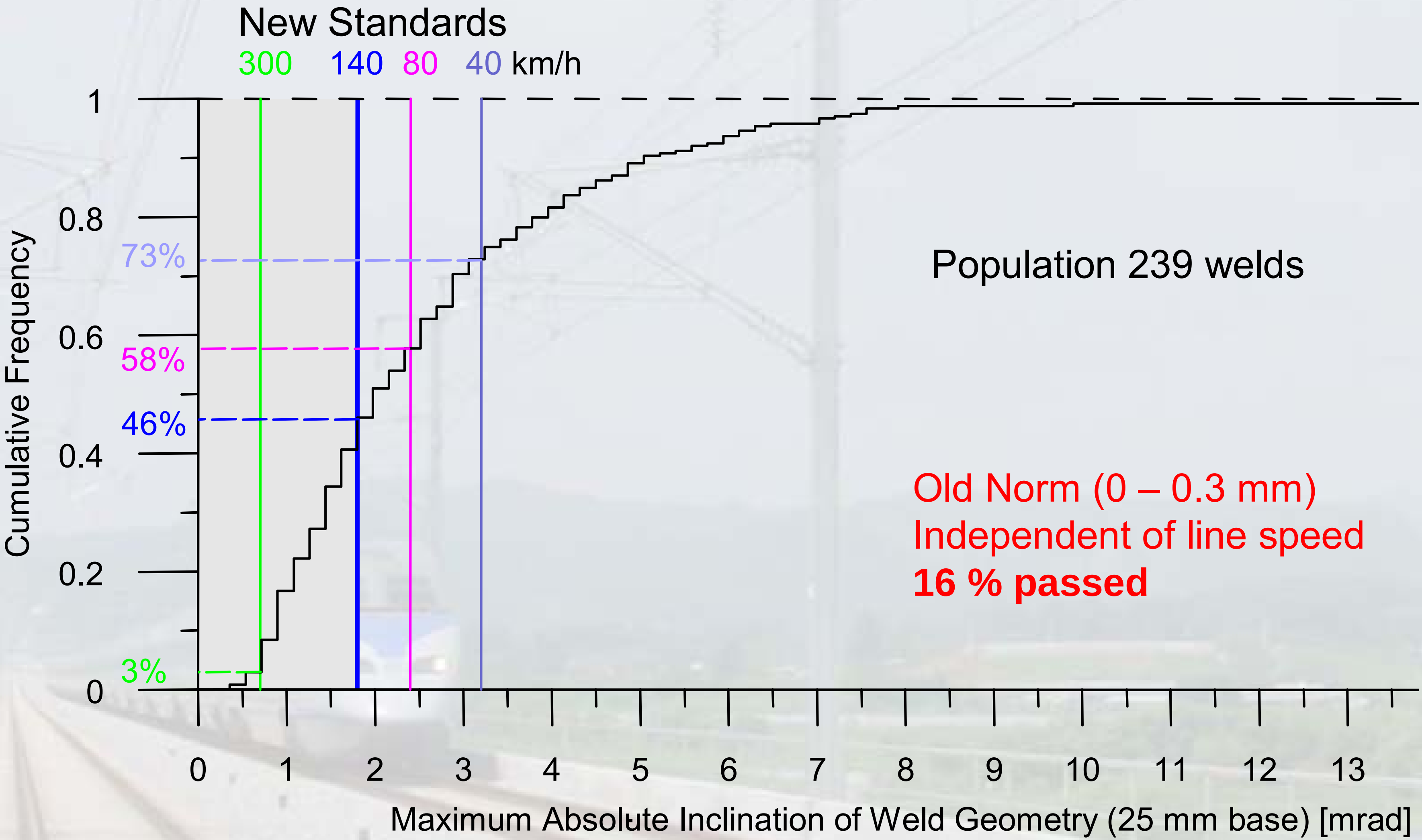




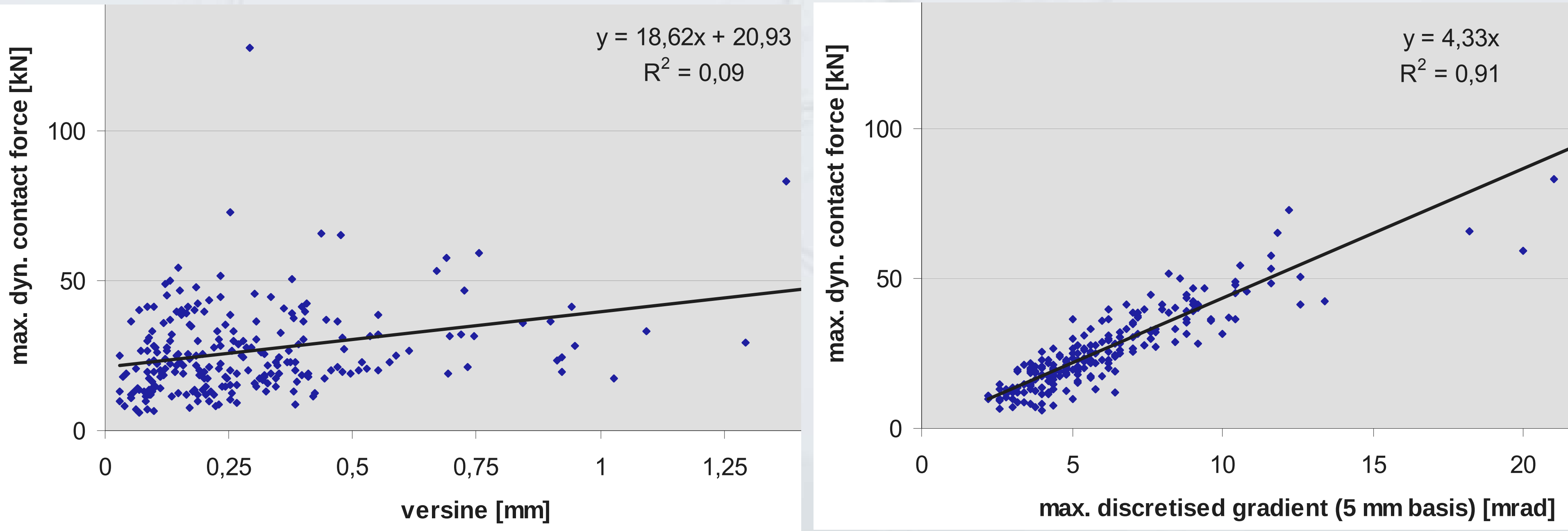
SELECTION ON PRORAIL



OLD VERSUS NEW STANDARDS



DYNAMIC FORCE



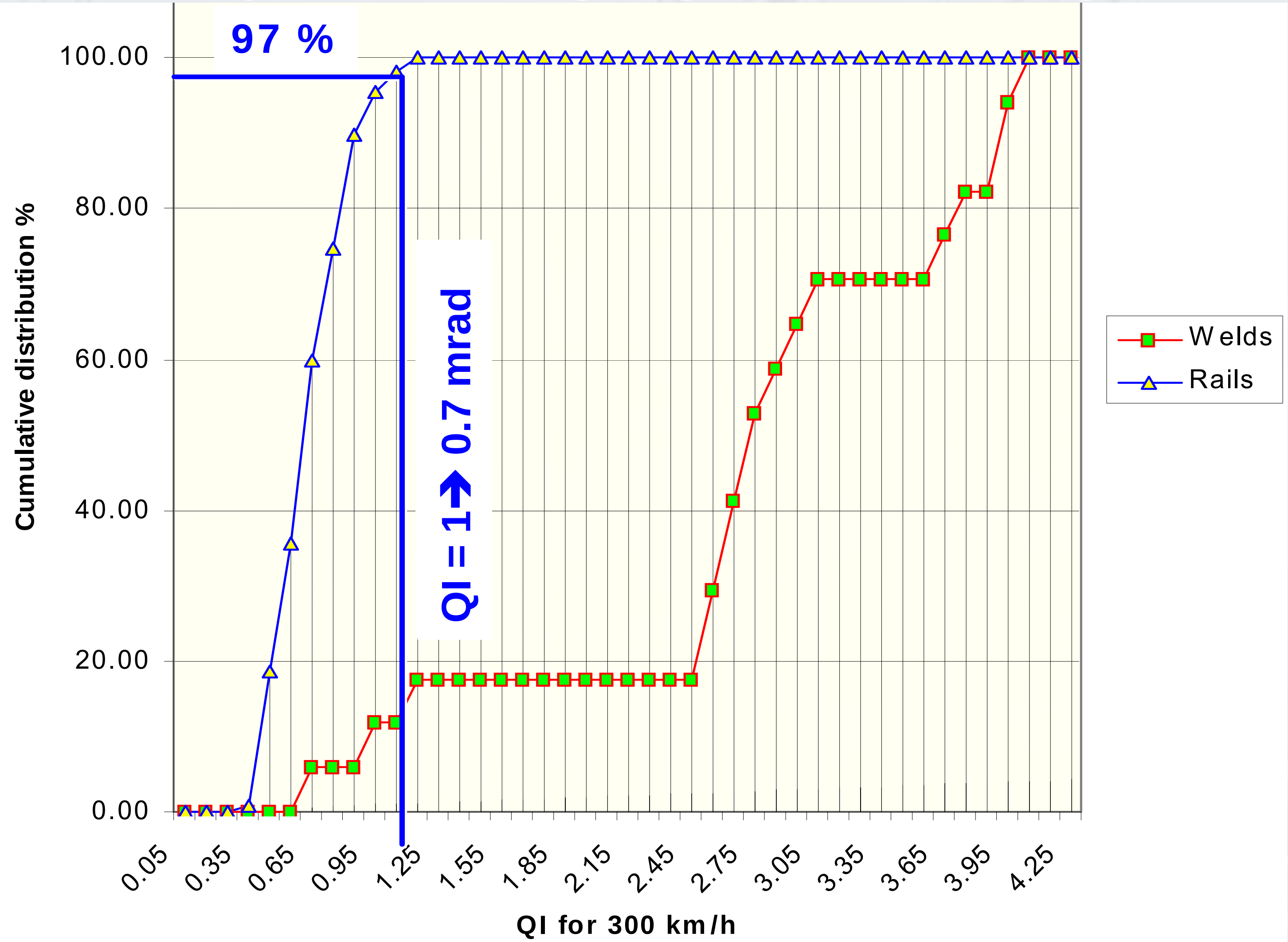
Low correlation force and versine

High correlation force and QI

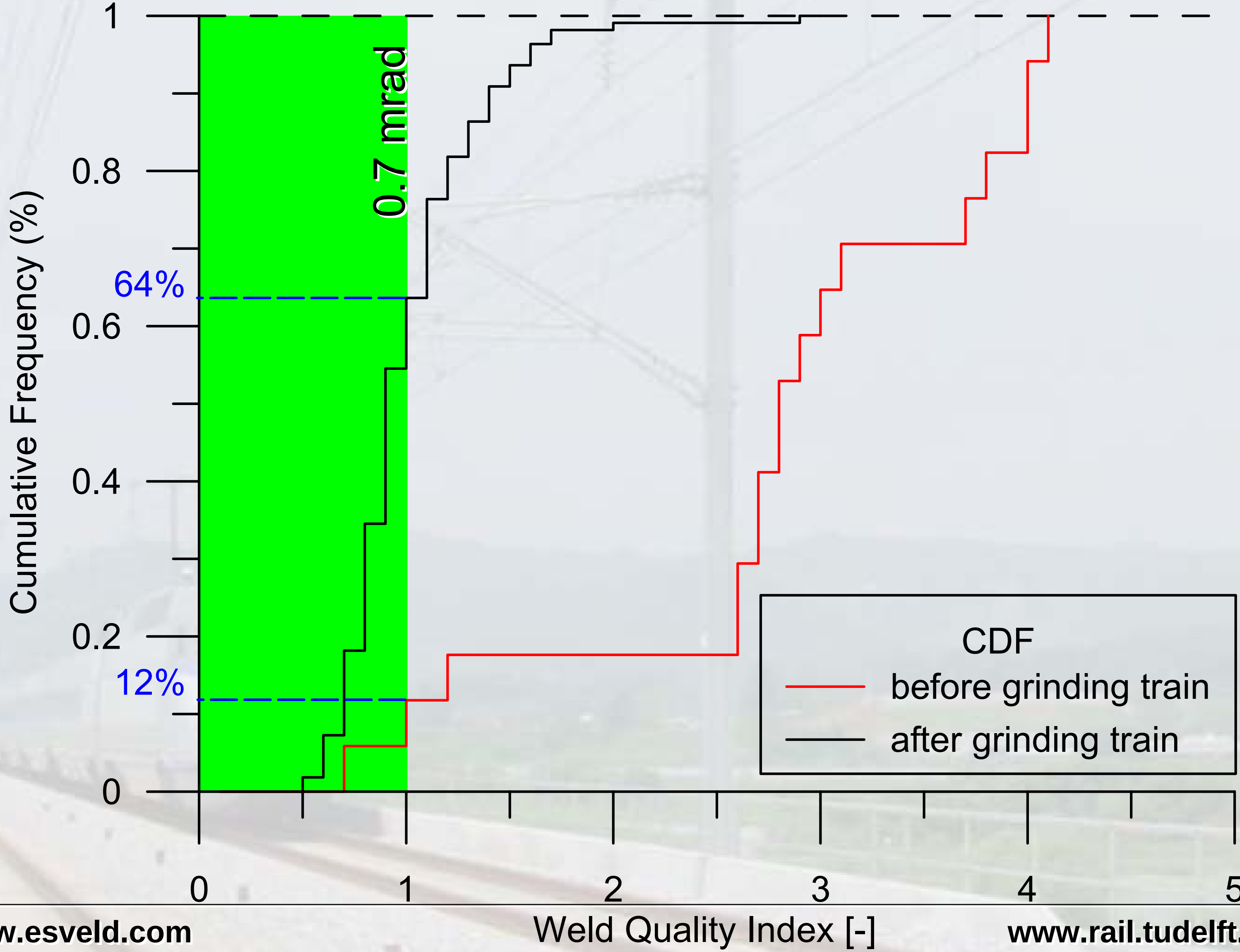
HSL STANDARD

- The value of 0.5 mrad as max. inclination for HSL was changed to 0.7 mrad based on 100 measurements of new HSL rails;
- 97 % of rails is better than 0.7 mrad → QI = 1;
- Standard can only be achieved by QI via Electronic Straightedge
- In new tracks apply grinding train (Plasser GWM).

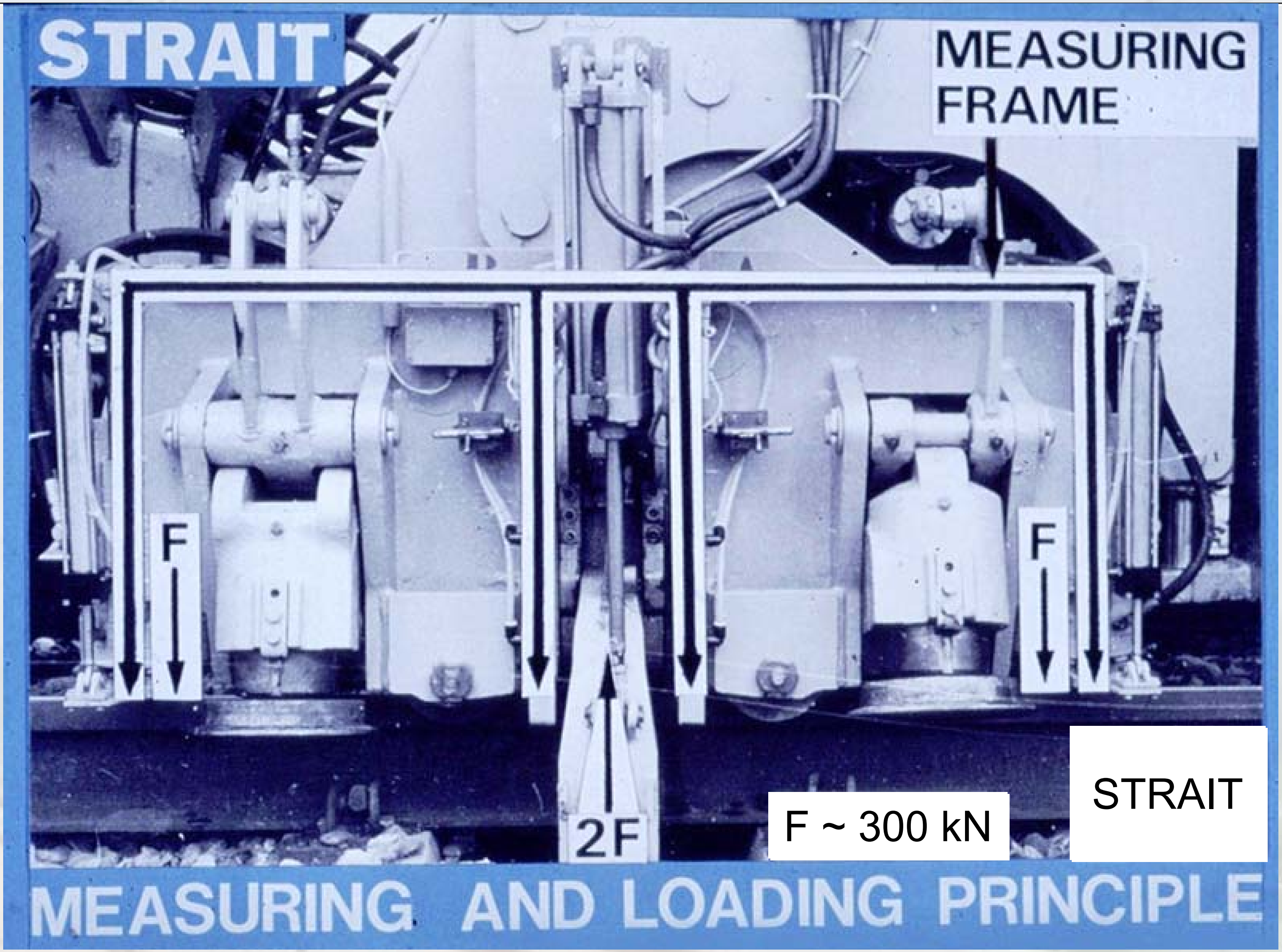
RAIL & WELD GEOMETRY HSL



WELD GRINDING HSL-SOUTH WITH GWM

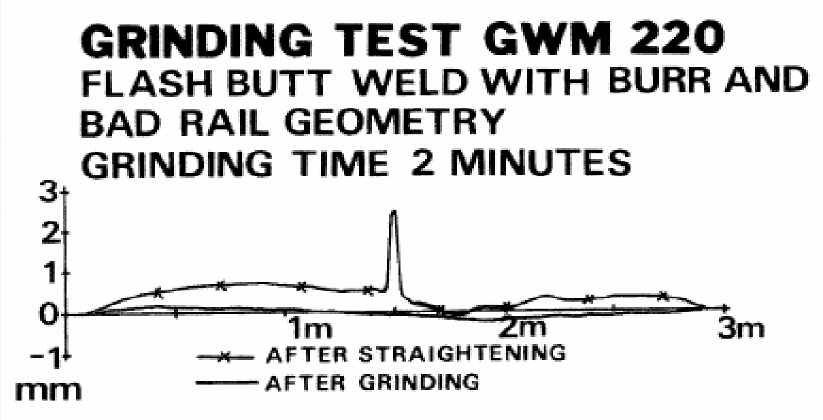


WELD STRAIGHTENING VIA STRAIT

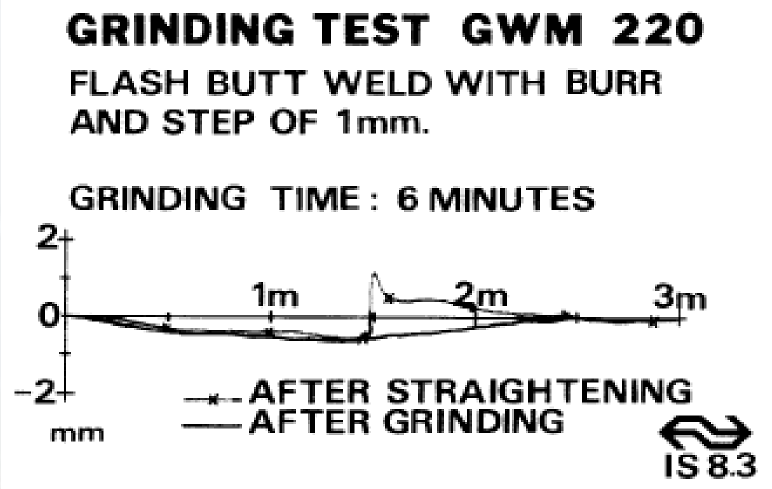

STRAIT
MEASURING
FRAME
F
F
2F
F ~ 300 kN
STRAIT
MEASURING AND LOADING PRINCIPLE

WELD GRINDING VIA PLASSER GWM

PLASSER GWM EXAMPLES



Esveld, C.: 'STRAIT: Innovative Straightening of Welds, Rail International, Schienen der Welt, July 1983.



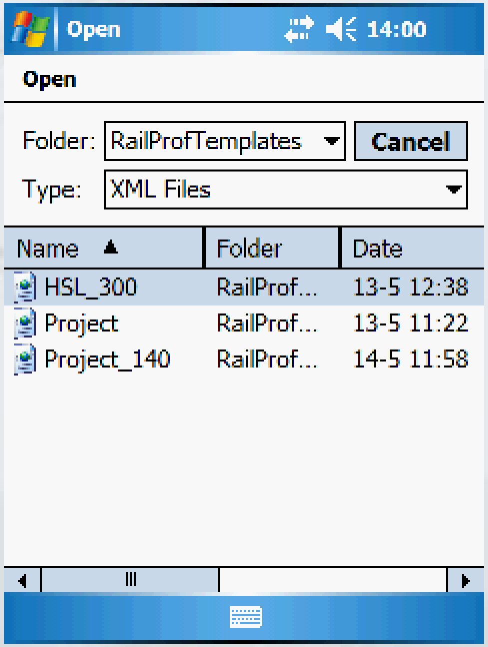
PRACTICAL IMPLEMENTATION (1)

Procedure:

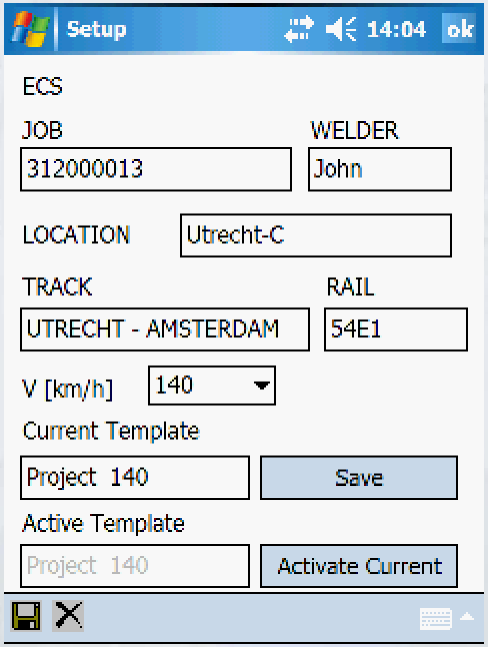
- Sample weld geometry with digital straightedge
- Filter measured signal
- Determine 1st derivative (inclination)
- Normalize with intervention value for line speed
- Calculate QI.
- QI < 1: OK, otherwise: grinding.

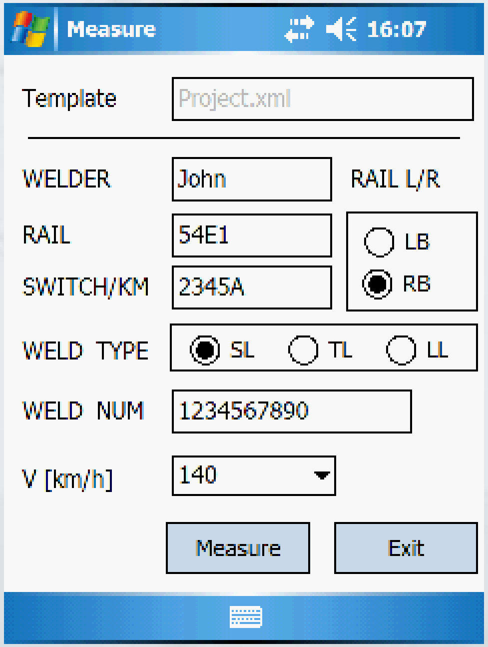
PRACTICAL IMPLEMENTATION

EXAMPLES OF PDA SCREENS (1)

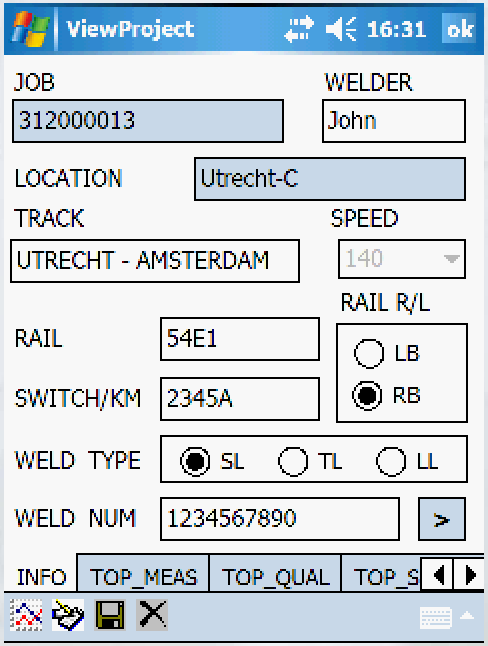


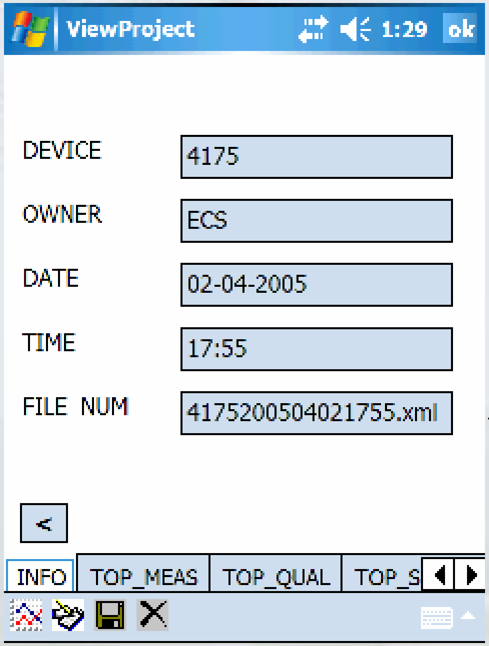
EXAMPLES OF PDA SCREENS (2)





EXAMPLES OF PDA SCREENS (3)



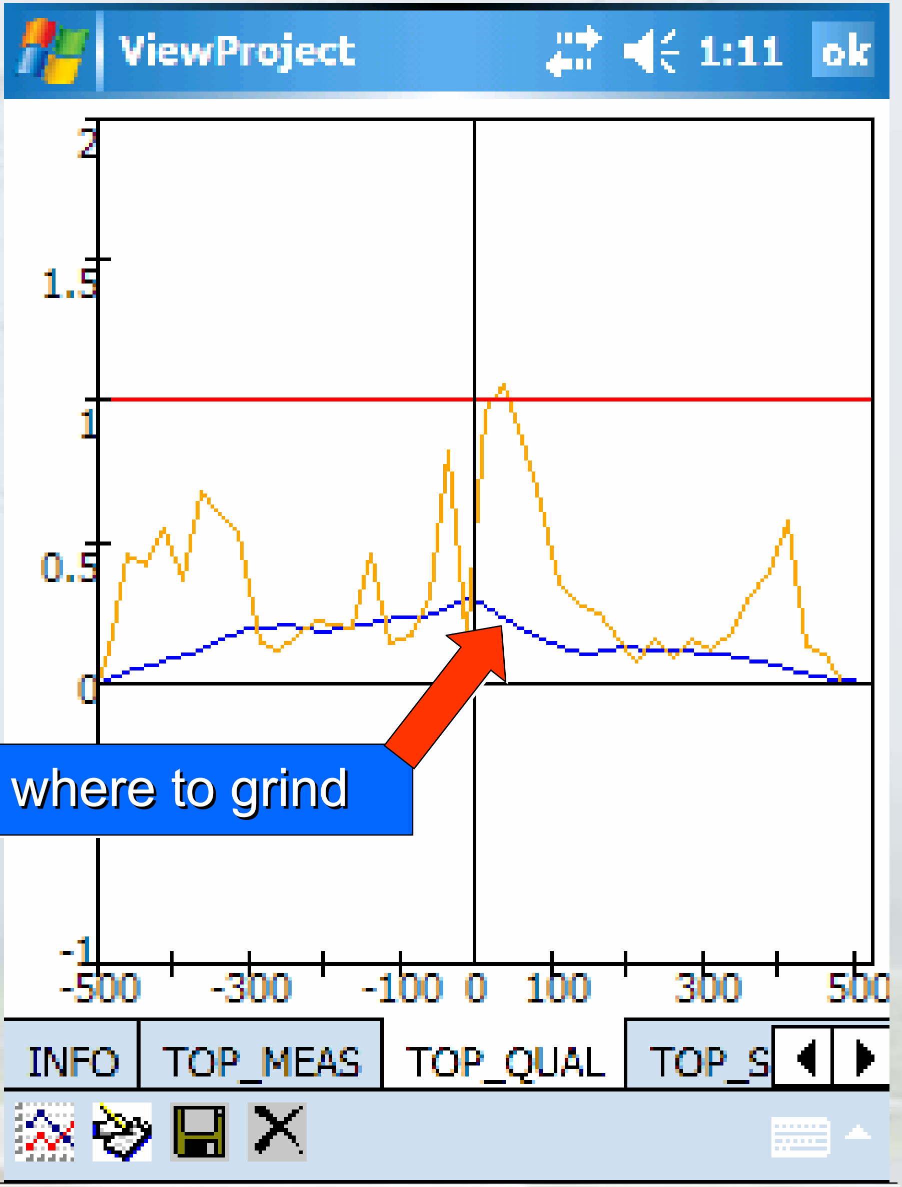


Now seconds added

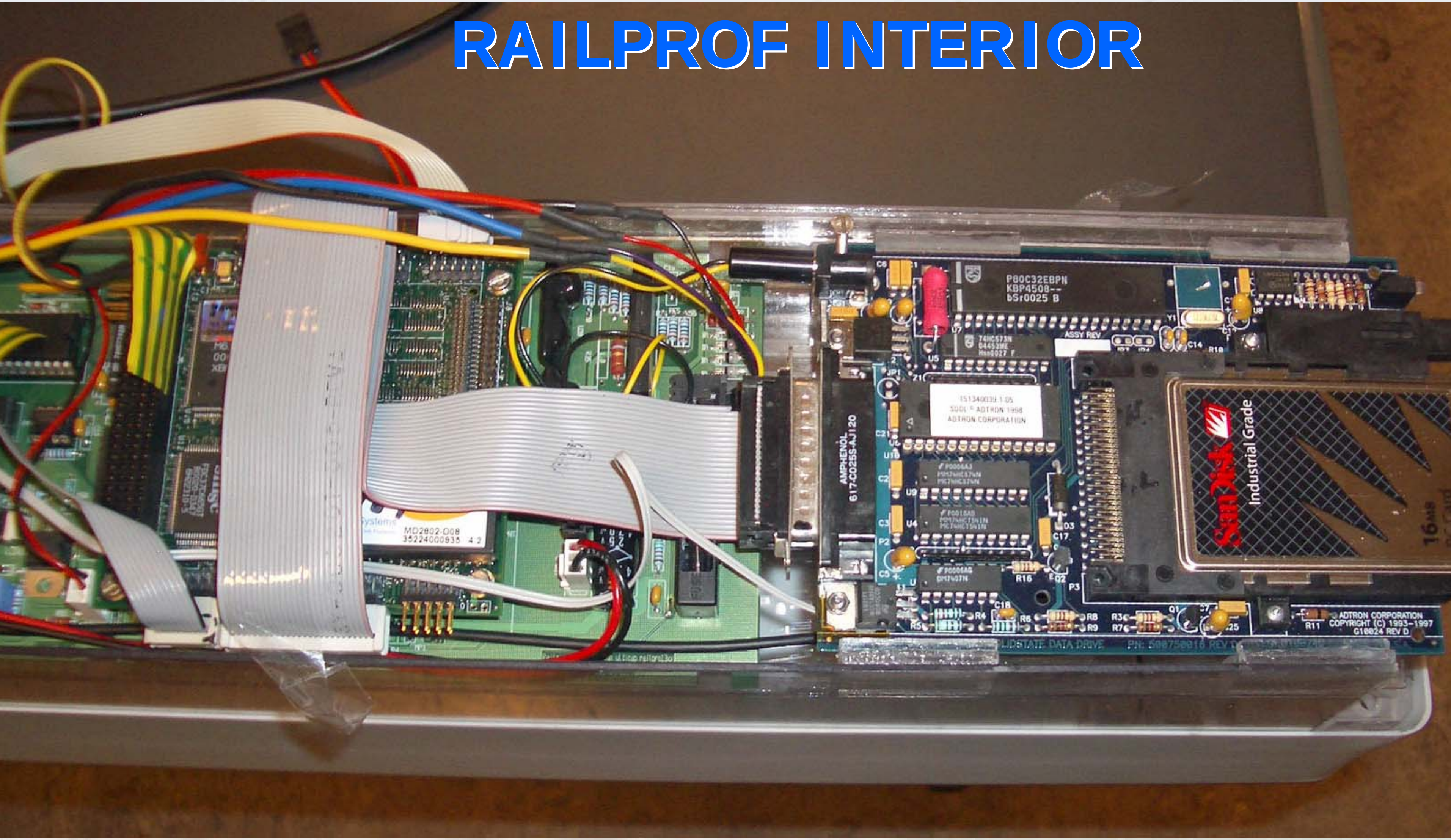
PDA SCREEN

V = 140 km/h
QI = 1.06

QI uniquely shows where to grind

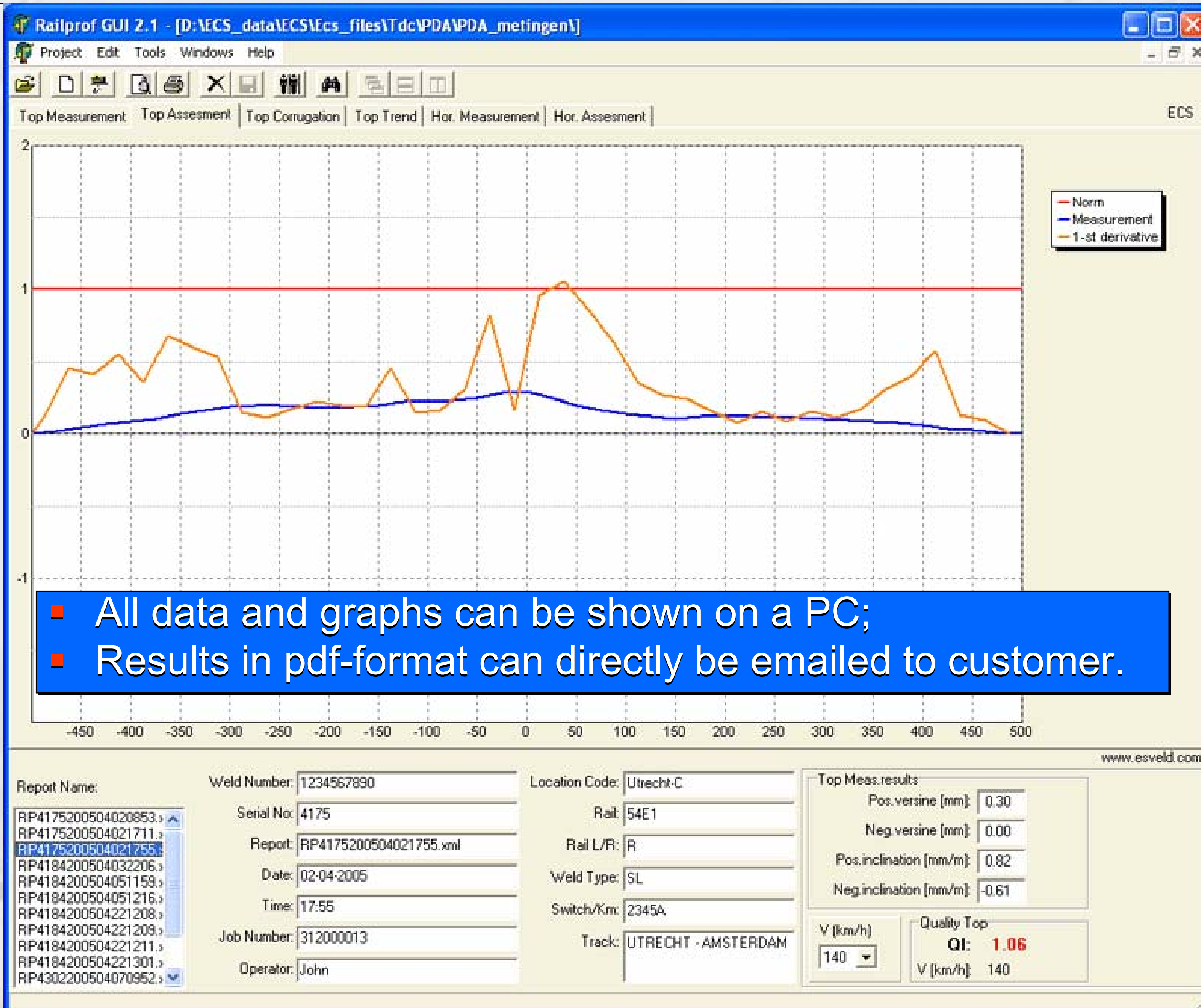


RAILPROF INTERIOR



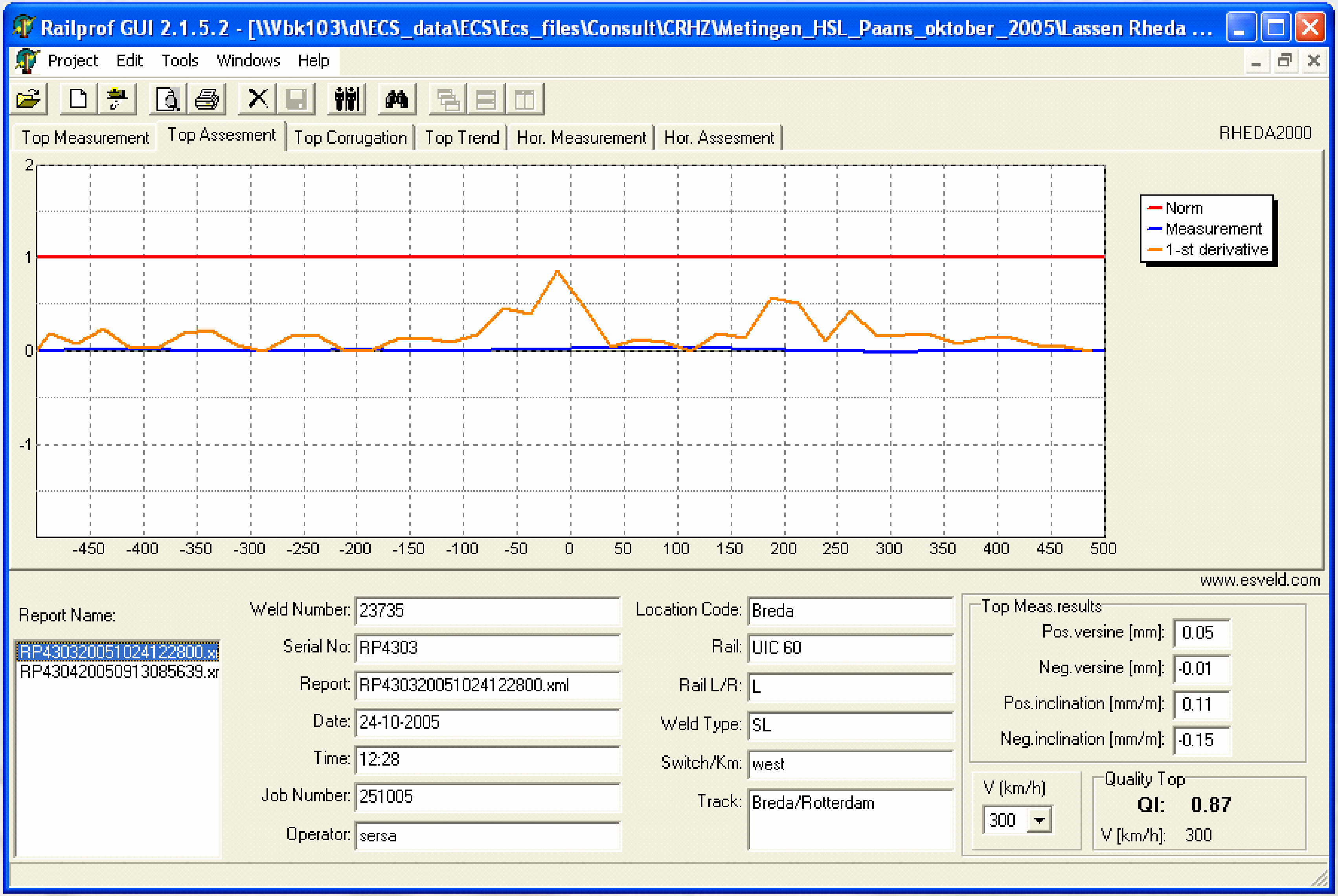
Data transfer to PC

DESKTOP SOFTWARE



- All data and graphs can be shown on a PC;
- Results in pdf-format can directly be emailed to customer.

Example of HSL-South



CONCLUSIONS (1)

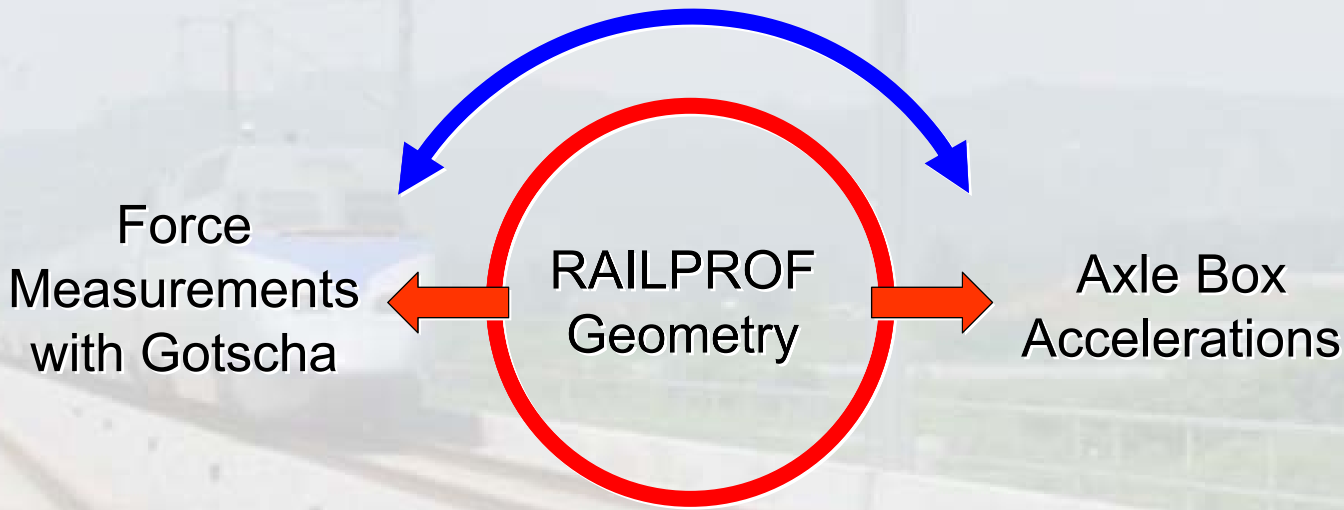
1. Theory based on first derivative works fine in practice;
2. Steel straightedge is absolutely inadequate;
3. Instead electronic straightedges with QI (RAILPROF);
4. High correlation of force and QI, low correlation with versine;
5. With RAILPROF QI measurement:
    - You see what you do;
    - Higher quality;
    - Less rejections provided short waves are ground properly (also negative welds allowed);
    - Extension of life cycle.

CONCLUSIONS (2)

6. New, high quality rails have a first derivative < 0.7 mrad;
7. Mechanical grinding (GWM) is inevitable to achieve such an accuracy for weld geometry;
8. The presented concept is very well applicable to heavy haul tracks and high-speed tracks.

CONCLUSIONS (3)

9. Validation will be carried out early 2006 by TU Delft:
   - Dynamic track force measurements at welds for different trains at different speeds;
   - Axle box acceleration measurements;
   - RAILPROF measurements;
   - Statistical analysis to determine relationships.



SOME EXAMPLES OF HSL SOUTH

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Serial | year, month, day | hh,mm,ss

START OF DESKTOP SOFTWARE

www.esveld.com