Non-destructive Monitoring of Stress-Free Temperature (SFT) / Neutral temperature and longitudinal force

Goldschmidt Thermit GmbH, Leipzig, Germany

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Swedish Welding Commission AG 60 Meeting
Halle (Saale), 17th-18th November 2008

ET MEAUSING TECHNIQUE TODAY – ET MESSTECHNIK HEUTE

Trading business Measuring devices

- **Longitud. rail profile**
  - El. Straightedges SEC, R2S, SED, LSED
- **Track geometry**
  - Measuring trolleys TrackScan 3 & 4
  - Track gauge K700
  - Track clearance
- **Temperature**
  - MO40LC
  - Special applications
- **Bridge/component testing**

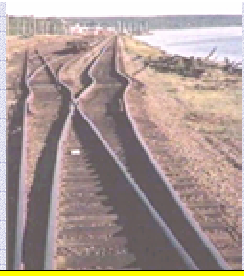
Expert services

- **RailScan SFT Service**
- **Consulting** e.g. for track maintenance & strategy etc.
- Stress & displacement monitoring/ supervising (Strain gages, lasers, telescopes)
  - Short-/ Long-time
  - Bridge testing
  - Other components

Standard services

- Geometry (e. g. with TrackScan)
- Straigthness SEC, SED
- Corrugation R2S
- Long waved straightness LSED
- Ultrasound

RailScan SFT- Service –
Nd- Stress- Free Temperature / Neutral temperature determination



- **SFT defines maximal tensile and compressive rail stresses**
- **SFT is equal to the rail temperature at which the longitudinal rail load forces/stresses become zero**
- **SFT is not detectable *by visual inspection***
- ***Buckles and breaks can occur if SFT is not managed***
  ⇒ Endangering of track stability and safety

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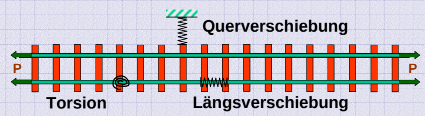
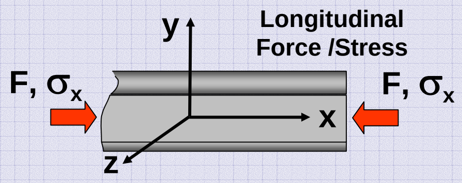
Neutral-/ Stress- Free Temperature – Longitudinal forces Definition





Neutral temperature $T_N = \sigma_x \times E^{-1} \times \alpha^{-1} + T_R$

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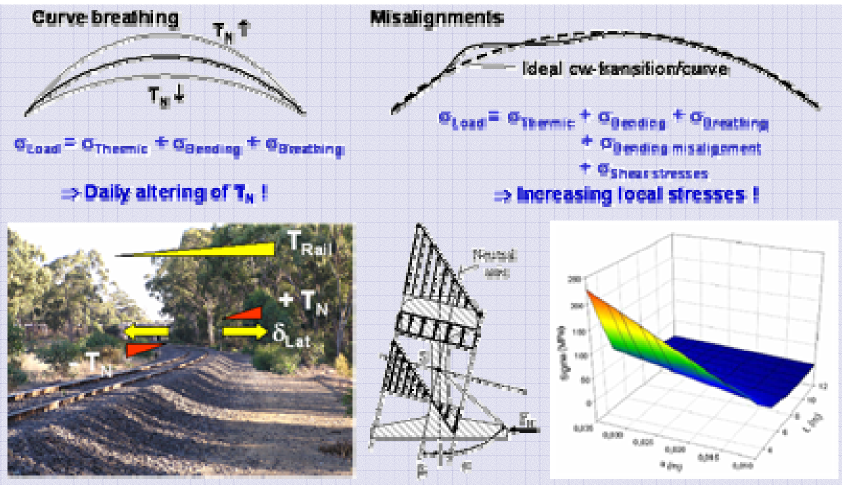
RailScan SFT- technique –
Behaviour and Stresses in real continuously welded railways



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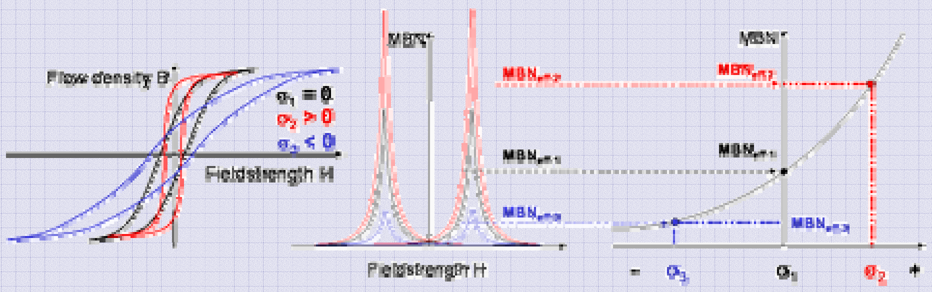
RailScan SFT technique –
Calibration of measuring signal on longitudinal rail stress

Stress dependant Hysteresis

Measured effective values of MBN

MBN calibration on Load Stress



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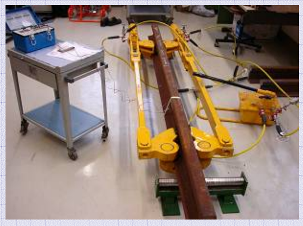
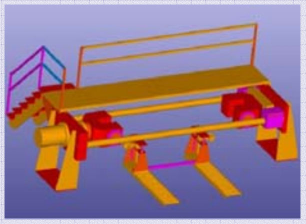
Calibration techniques – RailScan
In-Lab calibration in rail tensor / test rig

Rail tensor + strain gauge | **Test rig for large stresses** | **Automated test rig**





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RailScan SFT determination –
Calibration procedures

1. Setting of the excitation parameters

Each rail type/grade/manufacturer
⇩
Coupling and magnetizing
⇩
Determination of the optimal Excitation amplitude
⇩
Device ready for calibration

2. Calibration of nd-value on stress

Application of the longitudinal stress
⇩
Coupling and magnetizing
⇩
Measurement of effective value of rectified MBN wavelet
⇩
Determination of value ß and mean value $ß_{AVG}$
⇩
Plotting of the calibration curve

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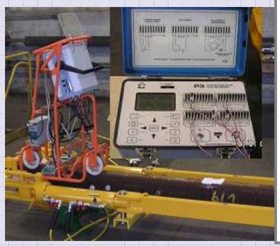
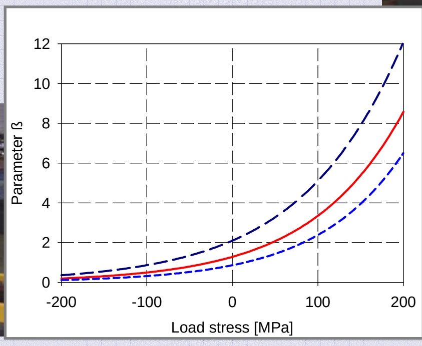
RailScan SFT technique – State-of-the-art

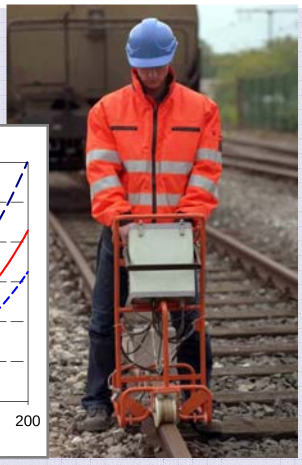
- ✓ Calibration in test rig
- ✓ Measurement at only 1 rail temperature



Calibration



Calibration curves



Reading at cw-rail

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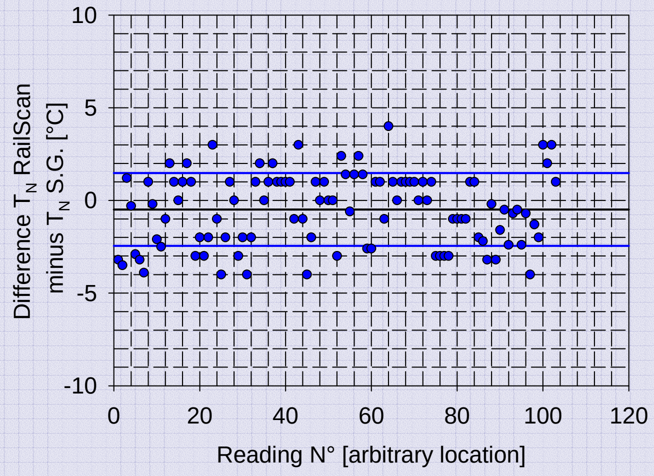
RailScan – Specification Method / Device

Technical Data

Measurement rate	Approx. 90/h
Accuracy	± 3 °C
Weight	< 20 kg
Dimensions LxBxH	600x900x380 mm
Power-on time	minimum 8h
Temperature range:	
Air	-10 ... 60 °C
Rail	-10 ... 60 °C

RailScan – Specification
Accuracy



Determination of accuray:

„Error“:
T_N RailScan – T_N S.G.

Mean value of error:
$| E_M | = 0.4$ °C

Standard deviation of error:
$E_\Sigma = 1.9$ °C

RailScan SFT- technique –
References (Railway/metro/tram operators and contractors)

Germany: Mr. Ende, DVB Dresden
Mr. Richter, SERSA GmbH
Mr. Meissner, DB AG, Leipzig
Mr. Schneider, DB Systems, Frankfurt am Main
Mr. Hoffman, MOS, Radebeul
Mr. Cramer, DEGES, Berlin
Mr. Kilian, SSF & Partner, Halle und München

Denmark: Mr. Christian von der Maase, banedanmark

The Netherlands: Mr. Schulmeister ETS Spoor
Mr. Frans Pronk, Strukton
Mr. Eric von Rijen, BAM
Mr. Dollevoet, Prorail

France: Mr. Yves Baillon COLAS / SECO-RAIL Paris

Hungary: Mr. Béli, MAV, Budapest

Australia: Mr. John Furness, ARTC Sydney

RailScan SFT- technique –
Experiences summarized in technical homologation manual

- ✓ Technology / Specification
  - ➢ Physical background
  - ➢ Evaluation/Documentation
  - ➢ Application technique
- ✓ Specification and Measurement System Capability
- ✓ Measuring process and chain
- ✓ Accuracy
- ✓ Reproducibility
- ✓ Operator influence
- ✓ Detailed results of comparison measurements

SFT inspection inquiry

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Collection of required information – Customer defines measuring task:

➢ Scope/total length of track to be measured
➢ Location of the sections to be measured
➢ Further information about the track: Speed category, traffic, possibility of track possession, working time (day and/or night shift)
➢ Information about the superstructure: New/age/maintained/not maintained
➢ Rails to be measured: Type, grade, manufacturer, production year (rail marking)
➢ Further information: Required activities for track access of the staff (safety courses)
➢ Equipment (e.g. colour of safety clothing)
➢ Required safety flagman

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➢ Definition of the measuring strategy (Measuring point distance, number of measuring instruments, number of operators, …)
➢ Definition of required calibration wors: required calibration rails, required time for the calibration, consumables
➢ Required equipment (Vehicles, safety clothing, lamps, torchs, power supply, ..)
➢ Required training (Saftey courses, track access, ..)

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Quotation / Project- or measuring plan

RailScan SFT- technique – Project flow I

Project / Measuring- and/or inspection order

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Customer defines and communicates:
- Project resposnible, project leader, contact persons, infrastructure and track flagmen

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- Procurement of calibration rails (if required)
- Preparation of calibration (Strain gages, probe production .. if required)
- Performance of the calibration measurements
- Determination of the calibration curve/table
- Preparation of the measuring device(s)

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Measuring team

- Documentation of relevant track-/rail data
- Performance of the inspection measurements
- Evaluation

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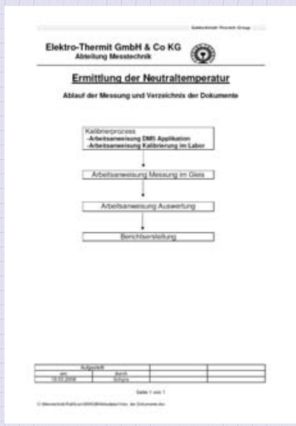
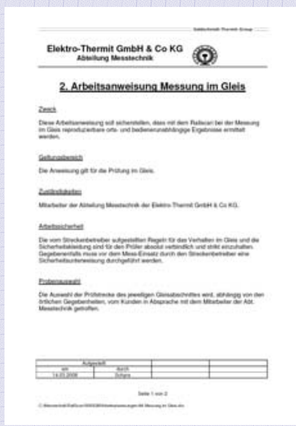
Discussion of the measuring results with the customer
Report creation

RailScan SFT- technique – Project flow II

RailScan SFT determination – Working instructions – measurement at cw-rails


Elektro-Thermit GmbH & Co KG
Abteilung Messtechnik
Ermittlung der Neutraltemperatur


Elektro-Thermit GmbH & Co KG
Abteilung Messtechnik
2. Arbeitsanweisung Messung im Gleis

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RailScan SFT technique – Measurement procedure / Evaluation

Reading of 30 (50) measuring points along
Basic length of 33m or 65m
Required time – approx. 20min

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Data transfer RailScan - PC

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Evaluation measuring data
Result: Neutral temperature / Stress- Free Temperatur

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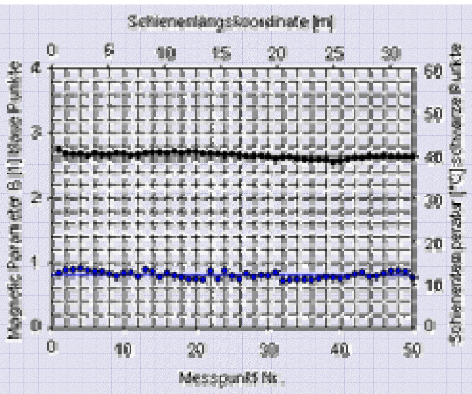
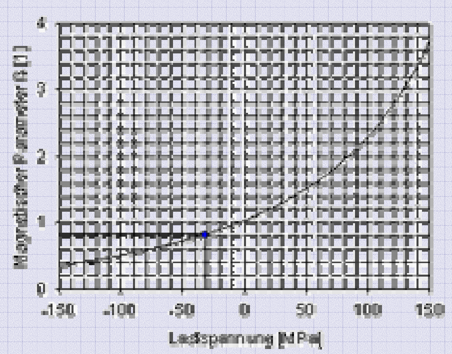
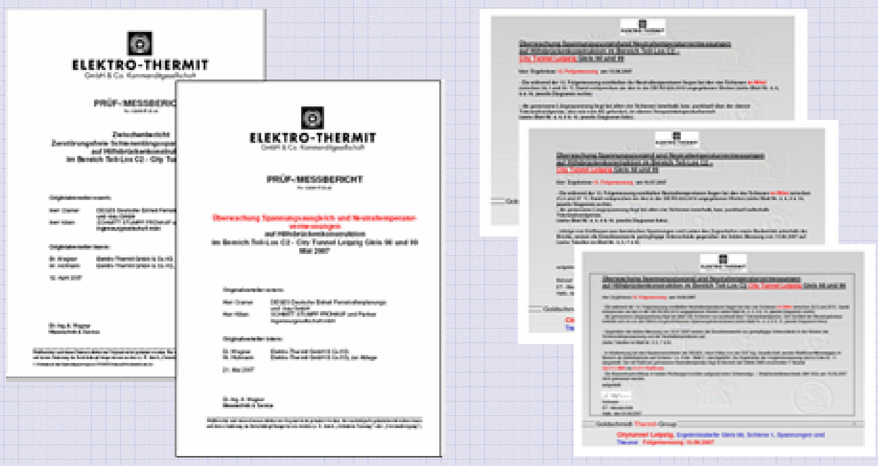
RailScan SFT technique – Measurement example





Neutral temperature $T_N = \sigma_x \times E^{-1} \times \alpha^{-1} + T_R$

Inspection reports / documentation of measurements



Measurement-/Inspection examples

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Thermit Australia RailScan Inspection service (N.S.W. + Vic.)

Track stability /
Stress- Free Temperature (SFT) testing

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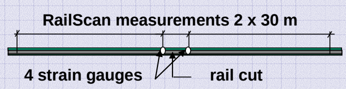
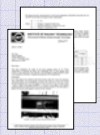
Experiences in Australia - Example: RailScan Inspections on ARTC Line Melbourne to Albury

SFT inspections in Australia –
Start-up by SFT comparison RailScan with strain-gage-&-cut

I. Homologation measurements on straight track

Approval by comparison measurements:
RailScan SFT – Strain-gauge-&-cut SFT





Section	km location	T_N [°C] RailScan	T_N [°C] S.G.-&-cut	Difference [°C]
Arrarat	244.300	21	25	-4
Pura-Pura	195.620	31.7	33	-1.3
Seymour	102.750	33	35	-2
Seymour	105.900	38	35	+3

II. Curve inspection along 100 track kilometers

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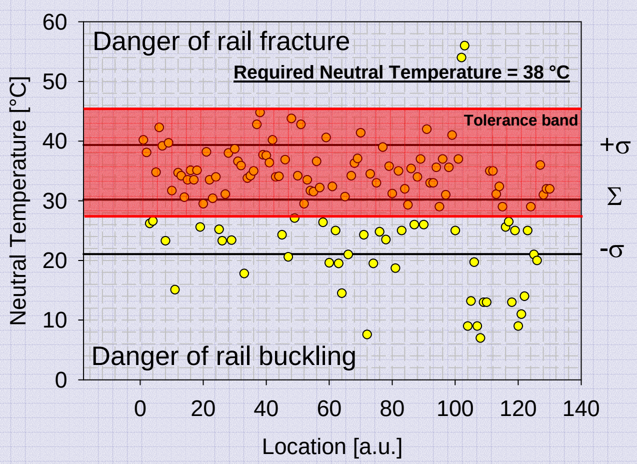
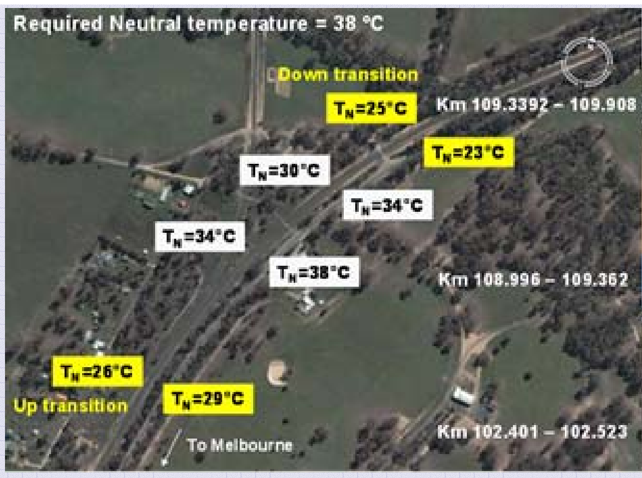
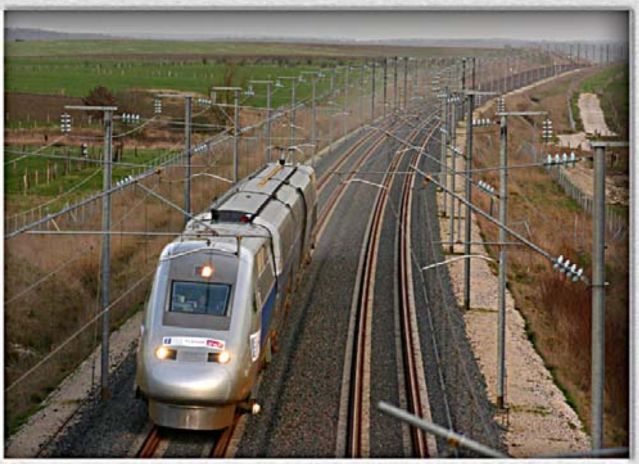
Neutral temperature results ARTC Line Melbourne-Albury
130 Neutral temperature measurements with RailScan



Neutral temperature results ARTC Line Melbourne-Albury
Results II – Visual plot



France 2006/2007 - RailScan SFT inspections on 574 km/h speed record line - LGV EST Européenne Paris-Straßbourg before line opening



RailScan SFT technique – Verification of RailScan results by comparison with strain gage (S. G.) SFT

Introduction procedure:

- Application of S.G. on non-welded rails and welding of LR's
- RailScan test measurements for verification of settings & calibration

RailScan SFT – Results on LGV EST Verdun, Bar-Le-Duc Week48, 2006

RailScan SFT inspections LGV EST 2006 – Result table

Date essai	Type de libé	Voie	T° de libé	T° Rail	Zone 1	TN° RAILSCAN	T° Rail	Zone 2	TN° RAILSCAN
26 September 2006	Tendeurs	1	25 °C	17°C	214.968	33,5 °C	18°C	214.690	31 °C
26 September 2006	Tendeurs	2	25 °C	16°C	215.200	23,5 °C	19,4°C	214.900	31,9 °C
27 September 2006	Tendeurs	1	25 °C	14°C	non effectué		20,5°C	222.975	23 °C
27 September 2006	Tendeurs	2	25 °C	10°C	227.389	24,2 °C	13°C	227.235	24,2 °C
28 September 2006	T° ambiante	2	26 °C	26°C	236.149	27,2 °C	13 °C	235.887	27,6 °C
28 September 2006	Tendeurs	1	25 °C	11°C	236.225	21 °C	20 °C	235.920	24,4 °C
29 September 2006	Tendeurs	2	25 °C	20°C	216.250	19,9 °C	19 °C	215.950	19,8 °C
28 November 2006	Tendeurs	2	25 °C	14°C	284.000	25 °C	17,5 °C	283.700	24 °C
28 November 2006	Tendeurs	1	25 °C	16°C	284.000	25 °C	16,5 °C	283.700	25 °C
29 November 2006	Tendeurs	1	25°C	5°C	266.000	27 °C	12,5 °C	266.333	29 °C
29 November 2006	Tendeurs	1	25 °C	14°C	266.800	32 °C	13 °C	266.500	31 °C
29 November 2006	Tendeurs	2	25 °C	4°C	266.000	23 °C	11,5 °C	266.333	Non effectué
30 November 2006	Tendeurs	1	25 °C	14°C	293.622	24 °C	7,5 °C	293.872	25 °C
30 November 2006	Tendeurs	2	25 °C	13°C	293.850	25 °C	9,5 °C	294.150	22 °C

France 2006/2007 – 574 km/h speed record TGV EST Neutral temperature non-destructively measured by RailScan

Inspections for contractor STRUKTON INFRA, Holland - RailScan SFT measurements after ballast tamping

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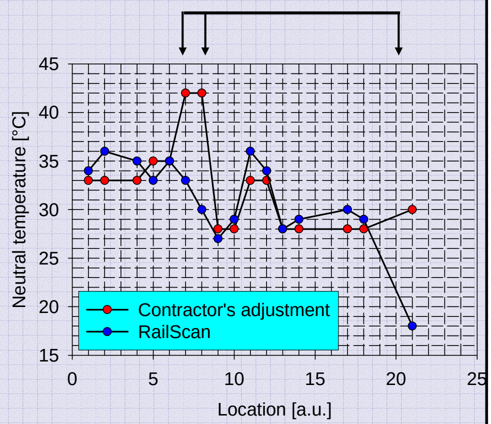
Inspections for contractor STRUKTON INFRA, Holland - RailScan SFT measurements after ballast tamping - Results

RailScan			
File	Rail temperature TRail [°C]	Neutral Temperature TN [°C]	Neutralization temperature
M1_ 0930z	15,5	34	33°C
M2_ 0953a	14,1	36	
M3_ 1016z	Data loss		33°C
M4_ 1040a	16,6	35	
M5_ 1130z	27,2	33	35°C
M6_ 1150a	20,5	35	
M7_ 1230a	23,9	33	42°C
M8_ 1300z	25,5	30	
M9_ 1355z	14,9	27	28°C
M10_ 1425a	20,2	29	
M11_ 0810z	9,6	36	33°C
M12_ 0830a	14,2	34	
M13_ 0950z	10,8	28	28°C
M14_ 1010a	11,6	29	
M15_ 1130z	Changed rail type (TSTD UIC54 260Mn)		28°C
M16_ 1200a	Changed rail type (TSTD UIC54 260Mn)		
M17_ 0815a	11,8	30	28°C
M18_ 0850z	9,0	29	
M19_ 0930a	Changed rail type (TSTD UIC54 260Mn)		34°C
M20_ 0950z	Changed rail type (TSTD UIC54 260Mn)		
Z1_ 0930z	16,9	18	30°C



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Inspections for contractor BAM, Holland – Zwijndrecht
RailScan SFT measurements

- Detection of locations of low neutral temperatures
- Control of neutralization

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Inspections in Germany – DRESDEN
Dresdner Verkehrsbetriebe DVB

- Detection of locations of low neutral temperatures
- Control of neutralization

Inspections in Germany – DRESDEN
Dresdner Verkehrsbetriebe DVB

Zone 1: Curve, inclination

Zone 2: Curve transition, inclination

Zone 3: Straight, inclination located between railway crossing & switch

Location	Rail type	Rail temperature T_R [°C]	T_N [°C] RailScan	Load stress σ [MPa]
Zone 1	*Thyssen 99&97 S49 HH*	4,9	12	16
Zone 2a	*Thyssen 01 S49 (320Cr)*	14,1	28	34
Zone 2b	*Thyssen 01 S49 (320Cr)*	18,4	22	9
Zone 2c	*Do 03 S49 E1 (350HT)*	17,8	35	41
Zone 3	*K 93X S49 (260)*	16,9	14	-7

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Carolabrücke Dresden – Schienenband und DMS- Messpunkte

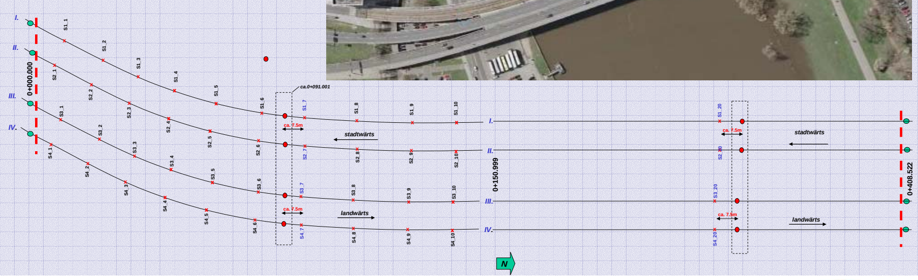
Legende:

x = DMS, Abstand ca. 15m, Mitte Schiene, neutrale Achse beginnend bei Schiene 1, endet

= Dilatationsstoß

S1_7 – S4_7 = Schlussschweißung

I. – IV. = Strangbezeichnung lt. Schiener = Schlussschweißung



Carolabrücke Dresden – Track renewal August 2007

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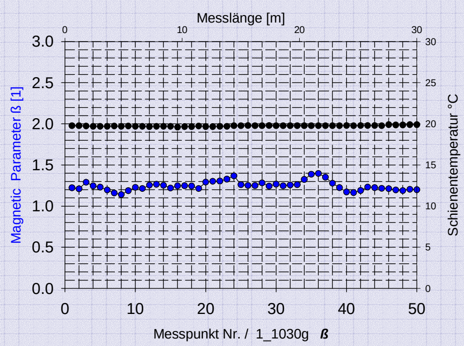
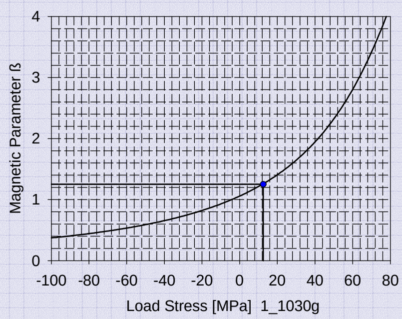
Carolabrücke Dresden – Supervision of neutralization / stress re-establishment with RailScan (Example)





$$Tn = \frac{\sigma}{E \times \alpha} + Ts = \frac{12{,}5\,N/mm^2}{1{,}15 \times 10^{-5}/°C \times 2{,}06 \times 10^{5}\,N/mm^2} + 19{,}75°C = 25°C$$

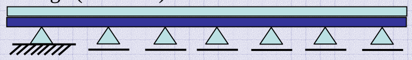
Inpections in Leipzig, Germany – Rail Stress Control on bridges

- Control of correct and accurate neutralization
- Observation of longitudinal rail stresses

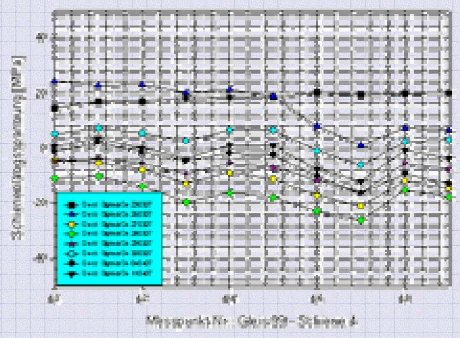
Project City Tunnel Leipzig

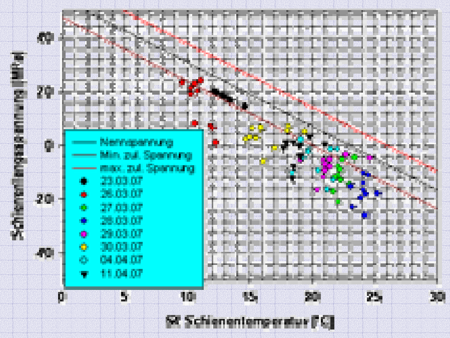
Inpections in Leipzig, Germany – Rail Stress Control on bridges

Bridge (shematic)



Detection of to low Neutral temperatures





RailScan SFT Inspections in Denmark 2007 + 2008 for Banedanmark

- SFT Inspection of altogether approx. 60 km track length

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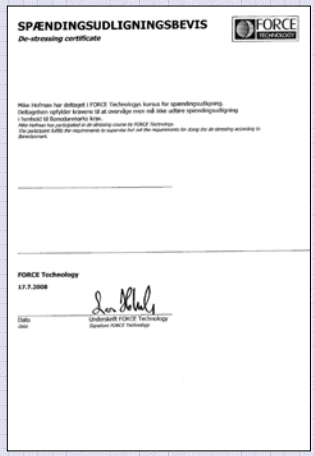
Admission of RailScan SFT- technique in Banedanmarks' directives for cw-rail production / Re-establishment of stress condition – Certification of ET- RailScan technicians


Teknisk

meddelelse

Net, Teknisk Drift,
Spor


SPÆNDINGSUDLIGNINGSBEVIS

De-stressing certificate

FORCE

FORCE Technology

17.7.2008

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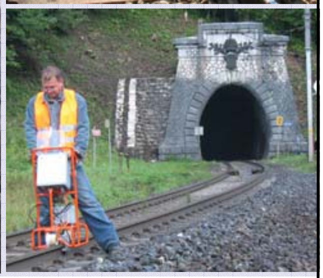
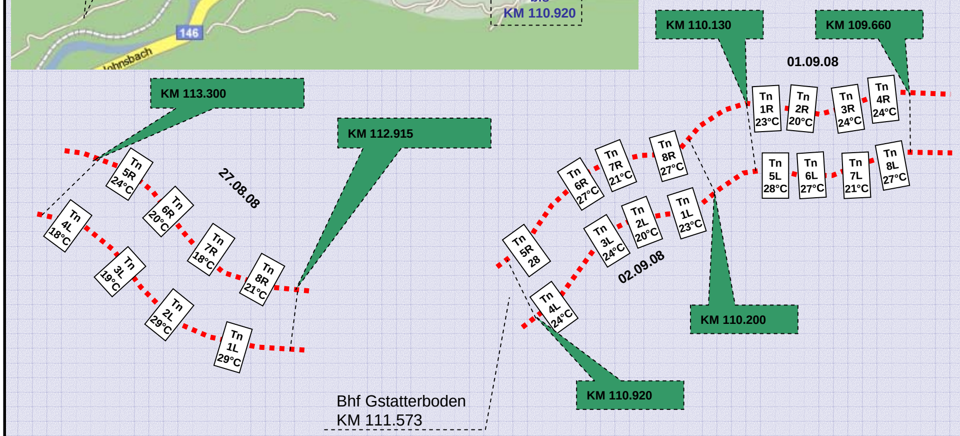
RailScan Inspections in Austria 2008 for ÖBB



RailScan Messungen 2008 Österreich für ÖBB



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RailScan introduction in Sweden –
First trials at Banverket, Borlänge in 2007

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RailScan introduction in Sweden

- First trials at Banverket, Borlänge in 2007
  - 2 comparison measurements performed against strain gauges

  Result: 1 x difference of <1°C

  1 x difference of 5 °C

- Futher tests intended for 2009
  - 10 comparison measurements against strain gauge SFT

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Non- destructive SFT technique - Advantages

- Enabling of:
- ✓ Verification / control of neutralization / stressing degree
- ✓ Determination of actual neutral temperature
- ✓ Periodical measurements / long term stress observation
- ✓ Control of destressing and/or /restressing works
- Decrease of maintenance coasts by direct measurement of the actual situation
- Significanty less expensive in comparison to conventional and/or destructive methods (> 50%)
- Further cost saving by:
  - Enabling of predictive maintenance
  - Judgment and optimization of maintenance strategies

Thank you for your attention !