VERSE® Demonstration

Pagney-sur-Moselle

28th February 2008

Peter Shrubsall
Managing Director
Vortok International
1. Introduction
   a. In the early autumn of 2006, SNCF used their VERSE® equipment to take measurements of the Stress Free Temperature (SFT) of newly completed rails on the LGV Est near Metz. The findings are understood to have been unsatisfactory but we have not seen the reports. This track had been built by SECO, a French contractor. SECO challenged the findings and further measurements had been taken by SNCF.
   b. During these second measurements, different results were observed and the repeatability of VERSE® results at the same location was put into question.
   c. The objective of the demonstration near Pagney-sur-Moselle was to prove again both the accuracy of VERSE® and the repeatability of the process.

2. Executive Summary
   a. Measurements at two locations one to show accuracy and another repeatability clearly demonstrated that the accuracy of VERSE® is yet again shown to be very close to that achieved using strain gauge and cut, the only practical yet destructive alternative method of measurement with a difference of only 0.17°C. When the rail temperature is stable and not changing significantly during a series of readings, the tests showed irrefutably that VERSE® gives highly repeatable readings at a location. The demonstration showed that this could be within 0.4°C. As the working tolerance for SFT in France in 12°C this shows the consistency to be less than the resolution of the rail temperature measurement method specified by SNCF.
   b. The tests demonstrate conclusively that the apparent change in SFT seen by SNCF during their measurements was due to a rapidly changing rail surface temperature and that the measurements were not taken under recommended conditions.
   c. These results come as no surprise as the VERSE® procedure and equipment have been validated by organisations of the highest international reputation before, namely BR Research, The Railway Institute in Prague and the TTCI in Pueblo (USA). Their reports are available separately if required. Also, the fact that there are almost 100 sets of equipment in service in 16 countries around the world with more planning to introduce it this year shows the international confidence in the equipment and technique. None of these users has ever found VERSE® to be incorrect when used correctly and under the recommended conditions and no competing system has been able to come close in terms of accuracy, usability and practicality on a working railway.
3. **Background**

a. When SNCF had used their equipment to take measurements they had obtained SFT results at odds with the expectations of SECO and when asked to take a series of readings at one location, 10 minutes apart had seen results changing by more than 3°C. It had been concluded by Mon Yves Baillon, the Chief Engineer of the project that VERSE® was inconsistent, inaccurate and that the VERSE® measuring process itself changed the state of the track and thus created the inconsistency. He believed that the fact of unclipping the track, lifting it onto blocks and above all of lifting the rail during the VERSE® measurement pulled the rail through the rail fastenings and thus changed the SFT.

b. During a meeting in Paris with M Baillon and M Pharose the technology was discussed and the SNCF findings explained a demonstration of VERSE® replicating the circumstances was offered to SECO and the offer was accepted.

c. When the accuracy of VERSE® is quoted by Vortok it is explained that the verification took place in the late 1990s by BR Research (latterly AEA Technology Rail) by taking some 500 service measurements and comparing them with "strain gauge and cut", the only other accurate, though destructive, measuring technique. The statistical comparison showed the mean difference over the 500 comparisons to be only 0.2°C and a standard deviation of 1.3°C.

d. This accuracy figure had been understood by both SNCF and SECO to be that the results of a measurement were always within 0.2°C and so when results were obtained that varied beyond 0.2°C the accuracy of VERSE® was challenged.

e. At one location SNCF had taken a VERSE® measurement and then the rail was restored to its original condition; i.e. it had been put back into the rail seats and clipped up again. The complete measuring process was repeated at least twice more. (We do not know exactly as the SNCF report has not been made available to Vortok.) The results of this series of measurements showed an apparent change in the SFT, rising by more than 3°C.

f. When they returned to a previously measured site the VERSE® reading was different by more than two degrees.

g. Experience of the use of VERSE® over 15 years from 16 countries, and in excess of 150,000 measurements, tells us that measurement of the rail temperature is the most crucial aspect of the accuracy of the final result and that it is not as simple as it may appear. Consistency of measurement technique is very important and a stable rail temperature another. It is always recommended that measurements be taken at night when rail temperatures are at their most stable but that rapidly changing temperatures under sunlight should be avoided. Temperature distribution across a rail section under sunlight is complex and not instantaneous, as many will assume.

h. VERSE® measures the stiffness of the rail and this is a direct consequence of the total stresses in a length of rail. These stresses are as a consequence of the tensile load and temperature distribution over the measurement length. This distribution can be regarded as the rail’s bulk temperature. Surface temperatures can easily be 5°C different to the bulk temperature.
i. Surface temperature is taken during a VERSE® measurement as it is the simplest available method but any difference between this and the bulk temperature will mean that the SFT result will be incorrect by this same amount. Rail temperature stability is therefore the crucial if ultimate accuracy is required.

j. The equipment provided by Vortok with the VERSE® kit has been a digital thermometer with a clamp to attach to the rail foot. It is calibrated but it is not possible to calibrate it with the clamp but provides a measurement within +/- 1°C.

k. SNCF standards call for the rail not to be measured directly but by use of a 300mm (approx) long piece of rail with a hole drilled into the end of the head into which a brass bodied mercury thermometer is inserted. This piece of rail is located close to the actual rail being worked. It is assumed that the core temperature in this piece of rail is representative of the bulk temperature of the rail being worked.

l. The actual bulk rail temperature may be different by a few 10ths of a degree but no comparison figures are available. It is of course limited in accuracy anyway by the resolution of the thermometer at only 1°C.

m. It must be remembered that the working tolerance of the SFT on the LGV Est is 20°C to 32°C so discussions over decimal places of accuracy are somewhat academic.

n. Vortok sought in this demonstration to show that VERSE® is both accurate and consistent and provides the ideal check of the quality of stressing in a rail. To do this the rail was to be fitted with strain gauges to compare and measurements taken on a rail with stable temperature to demonstrate consistency.

o. Present at the demonstration was Mon Jean-Luc Pharose, a senior track engineer from SECO, a team of track workers from SECO, two technicians from Elektro-Thermit from Halle, Cédric vanoverfeldt from Railtech International, Andrew Slowe from Pandrol’s laboratories and the author of this report, Peter Shrubsall of Vortok International who took the VERSE® measurements.
4. Methodology
   a. Location and conditions.
      i. The location of the LGV track was close to Pagney-sur-Moselle and measurements were all taken on the left rail of the Paris bound track. At location one there was a gradient but as this would not affect the results, its precise value was not measured. There was no curve and the rail was UIC 60E the head of which had been ground. Measurements showed typically 0.6mm below the nominal new rail height of 172mm. Location two was very close to horizontal.
      ii. Permission had been sought prior to the demonstration that the measurements be taken at night when the rail temperature would be at its most stable. Unfortunately, SNCF would not allow this. However, it transpired that the weather was overcast during all the “repeatability” measurements and the sun came out only briefly during the first measurements. It remained dry throughout the VERSE® measurements and temperature changes were helpfully, very small indeed.

   b. VERSE® measurement
      i. The VERSE® measurement technique used was just as recommended in the training and manual. Because the track has twin block sleepers, a support plank was used as the individual blocks are shorter than the span of the feet of the VERSE® frame. The plank was placed between two sleepers for these measurements but it could have been positioned at one end of a sleeper just as acceptably. The measurements are not affected at all by the positioning of the VERSE® frame except inasmuch as the lift must always be directly above the rail thereby preventing side forces on the rail while lifting.
      ii. As the rail was cold and the heavy rail consequently stiffer, to reduce disturbance of the sleepers to a minimum at the ends of the measurement length, 35 metres of rail were unclipped.
      iii. Two locations were measured. At the first location strain gauges were applied to either side of the rail on the neutral axis. This work had been done on the previous day by a technician from Pandrol’s Worksop laboratory. Both devices were shown to have remained unchanged since their fitment with unchanged correction factors despite heavy rain both during and after installation. It demonstrated the integrity of the installations and the care taken.
      iv. Three measurements were taken at location one. The first was a quick one-lift measurement to establish the range we were working in...
and to show the rail to be safe. Three more lifts, a standard measurement, were then taken. The final measurement at this location was taken some 2 hours 15 minutes later and was immediately followed by cutting the rail and showing the change in strain from the gauges. The SFT results obtained by these two techniques could then be compared.

v. At the second location, some 400m further along the track, again 35m of rail was unclipped by SECO track men and lifted onto the standard 60mm spacer blocks. At this location the spacers were slightly asymmetric in their positioning but as consistency of measurements was the objective the fact that this was not perfect was of no consequence so was left unaltered. Three sets of measurements were taken at 10 minute intervals with the rail being returned to the rail seats between measurements but not re-clipped.

vi. At location one extra strain gauges were attached to the rail between the two sleepers by technicians from Elektro-Thermit from Halle. Exactly what was attached and the readings obtained were not given to Vortok.

vii. At the second location, the ET technicians attached a device that would measure the vertical lift and any longitudinal movement. (See photographs) Again the readings were not provided but the rail behaviour was observed by the naked eye by Mr Slowe.

c. Temperature measurement

i. It was decided to use the most accurate device available to Vortok throughout the measurements. This was a calibrated thermistor device with digital output. This gives measurements to within 0.1°C and the manufacturers claim an accuracy of +/- 0.1°C at this temperature. It gave readings up to 1°C lower than the readings from the SECO mercury thermometer in the rail piece. There is no way of knowing which is the most accurate but as we worked always with the Vortok device, differences were inconsequential.

d. Strain Gauges

i. Two gauges of the TML type from Tokyo Sokki Kenkyuo Co were applied to the neutral axis on either side of the rail. Each was attached after suitable surface preparation of the rail surfaces to bare metal and finished with 250 grit abrasive paper. The surfaces were chemically cleaned and the devices were attached using the manufacturer's recommended adhesive, M-Bond 200 following the Instruction bulletin B-127-14. They were then protected from moisture by a rubber type sealant and aluminium foil.

ii. The units were then tested and zeroed and the gauge factors recorded.
iii. On the day of measurements the units were checked again and re-zeroed but no significant changes had occurred showing both units to be in full working condition.

iv. The gauges were installed more than one metre away from the point of VERSE® measurement and subsequent rail cut.

5. Results
   a. Location 1
      i. First reading
         Rail temperature 9.2°C to 9.6°C  Average 9.4°C
         
         | Lift number | 1  | 2  | 3  | Average |
         |--------------|----|----|----|---------|
         | Result       | 28.4°C | - | - | 28.4°C |
      
      ii. Second reading
         Rail temperature 9.9°C to 10.1°C  Average 10.0°C
         
         | Lift number | 1  | 2  | 3  | Average |
         |--------------|----|----|----|---------|
         | Result       | 28.8°C | 28.6°C | 28.7°C | 28.7°C |
      
      iii. Third Reading
         Rail temperature 11°C to 11.4°C  Average 11.4°C
         
         | Lift number | 1  | 2  | 3  | Average |
         |--------------|----|----|----|---------|
         | Result       | 27.4°C | 27.7°C | 27.7°C | 27.6°C |
      
      iv. Strain Gauge Reading After Rail Cut
         Rail temperature 12.4°C
         
         | Strain Gauge | Field Side | Gauge Side |
         |--------------|------------|------------|
         | Reading change | 176µm | 172µm |

Calculated Result
Thermal coefficient of expansion of steel is taken to be: 11.5 x 10^{-6}
As the readings are m x 10^{-6} the readings and coefficient of expansion are in the same units.
SFT = Strain change/ coefficient of expansion + actual temperature of rail

\[ \frac{(176 – 172)/2 + 172}{11.5 + 12.4^\circ C} = 27.53^\circ C \]

v. Difference in results of two methods
   1. VERSE® method 27.6°C
   2. Strain gauge method 27.53°C
   3. Difference 0.17°C

b. Location 2
   i. First reading
      Rail temperature 10.4°C to 10.4°C Average 10.4°C
      
      | Lift number | 1    | 2    | 3    | Average |
      |-------------|------|------|------|---------|
      | Result      | 28.7°C | 29.0°C | 29.0°C | 28.9°C  |

   ii. Second reading
      Rail temperature 9.9°C to 9.9°C Average 9.9°C
      
      | Lift number | 1    | 2    | 3    | Average |
      |-------------|------|------|------|---------|
      | Result      | 29.2°C | 29.3°C | 29.4°C | 29.3°C  |

   iii. Third Reading
      Rail temperature 10°C to 10°C Average 10°C
      
      | Lift number | 1    | 2    | 3    | Average |
      |-------------|------|------|------|---------|
      | Result      | 28.9°C | 29.2°C | 29.1°C | 29.1°C  |

   iv. Difference in readings over 3 measurements (9 actual measurements) = 0.4°C

   v. See Appendix for measurement data screens

c. Observations
   i. When the rail was lifted onto the spacer blocks, a vertical lift was observed on the first sleeper still attached to the rail. This is quite unusual and the rail returns to its original position when the blocks are removed. No longitudinal movement was observed but with a toe load force on the rail of 20kN none would be expected, certainly no plastic movement of the rail.
   
      The maximum longitudinal strain shown on the gauges during a measurement was 5µm showing the additional longitudinal force in the rail to be well below its elastic limit.
   
   ii. No information on the readings obtained by ET were made available so no conclusions can be drawn.
6. Conclusion

a. It was clearly demonstrated in these tests that the accuracy of VERSE® is yet again shown to be very close to that achieved using strain gauge and cut, the only practical yet destructive alternative method of measurement with a difference of only 0.17°C. Indeed, even strain gauges have their tolerances.

b. When the rail temperature is stable and not changing significantly during a series of readings, VERSE® gives highly repeatable readings at a location. The demonstration showed that this could be within 0.4°C. As the working tolerance for SFT in France in 12°C this shows the consistency to be less than the resolution of the rail temperature measurement method specified by SNCF.

c. The tests demonstrate conclusively that the apparent change in SFT seen by SNCF during their measurements was due to a rapidly changing rail surface temperature and that the measurements were not taken under recommended conditions.

d. To achieve an accurate and consistent result with VERSE® it is crucial that the rail temperature is stable, the temperature measurement method is consistent and that due care is taken in all aspects of the procedure.

e. These results come as no surprise as the VERSE® procedure and equipment have been validated by organisations of the highest international reputation before, namely BR Research (AEATR and now DeltaRail Group) (UK), The Railway Institution in Prague, (Czech Republic) and the TTCI in Pueblo (USA). Their reports are available separately if required. Also, the fact that there are almost 100 sets of equipment in service in 16 countries around the world with more planning to introduce it this year shows the international confidence in the equipment and technique. None of these users has ever found VERSE® to be incorrect when used correctly and under the recommended conditions and no competing system has been able to come close in terms of accuracy, usability and practicality on a working railway.
Appendix

Measurement 1

Measurement 2
Lift 1
### Measurement 2
#### Lift 2

![Image of Lift 2 measurement screen]

#### Lift 3

![Image of Lift 3 measurement screen]
Measurement 4
Lift 2

Measurement 4
Lift 3
Measurement 6
Lift 2

Measurement 6
Lift 3