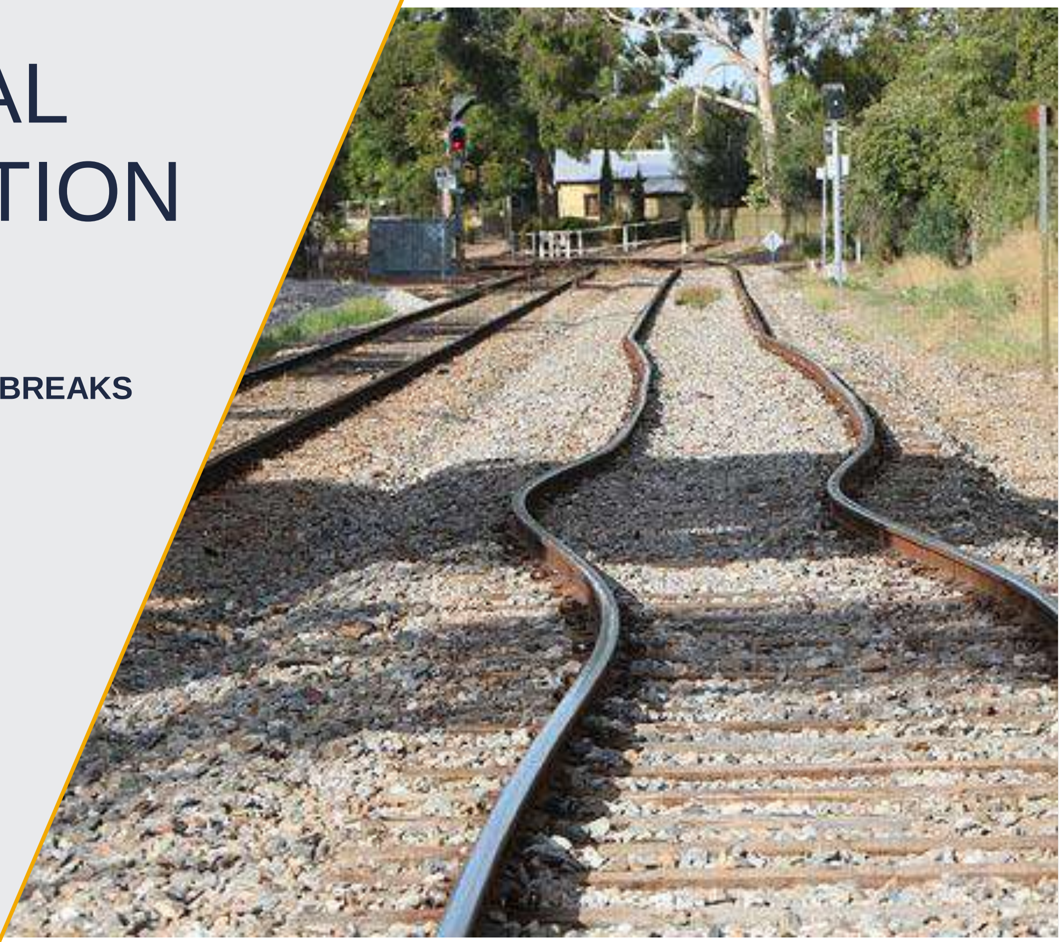
PANDROL

VERSE® TECHNICAL INFORMATION PACK

PREVENTING BUCKLES & BREAKS



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24th July 2023

Partners in excellence

Contents

1. Introduction

VERSE®

Vertical **R**ail **S**tress **E**quipment is an internationally accredited scientific instrument which is used to non-destructively measure the Stress Free Temperature (SFT) of Continuously Welded Rail (CWR). It is an essential tool in modern Rail Stress Management program to ensure management of track buckling and rail break risk.

Taking a VERSE measurement involves unclipping a short length of rail track, raising that rail up onto two simple supports and then deflecting the rail using the VERSE equipment. As the VERSE system deflects the rail it accurately measures the force and displacement profile of the deflection. The higher the tension in the rail, the more force will be required to deflect the rail. Using this principle and recorded data, together with the known rail temperature at the time of measurement, the SFT can be evaluated directly with no damage caused to the rail.

The VERSE system eliminates the need to cut the rail, significantly reducing the time and cost of evaluating track SFT. It also measures the SFT directly from the rail installed in track, and therefore requires no prior knowledge of the rail residual stress at the time of manufacture.

The system ensures the highest level of accuracy through compensation for rail section geometric properties, rail wear, track curvature and by using a simple and easily followed user procedure.

The handheld computer steps users through the measurement process with critical data being inputted by the user. It then guides the user through the rail deflection process and returns an instant SFT result trackside together with an evaluation of data quality. The lift data files can be stored on the handheld and transferred to a PC to be analysed and stored in the office space.

The VERSE system is the recognised standard has been evaluated by a number of railway research institutes including; British Rail Research, Transportation Technology Centre Inc. (Subsidiary of Association of American Railroads) and Railway Research Institute, Czech Republic.

The accuracy, repeatability, usability and benefit of VERSE has been recognised though Product Approval (Type Approval) with a wide range of railway authorities internationally.

Through the use of VERSE and its non-destructive method of measurement, railway authorities are able to survey their railway in a fraction of the time of traditional methods allowing teams to focus on maintenance issues which carry the highest risk. Further to this, VERSE has also become a recognised method of evaluating the quality of contracted track laying by providing a convenient quality inspection tool that can save the contractor time and provides the client with peace of mind.

The Pandrol (Vortok) Sales Team are available to discuss the application of VERSE and how it can be used to enhance your business safety and efficiency.

2. Management of Neutral Temperature in Continuous Welded Rail

2.1 Introduction

The avoidance of derailment, caused by either track buckles or rail breaks, is always at the forefront of priorities of railway companies and their track engineers. Maintenance of high levels of availability of the track, avoidance of unplanned repairs and raising standards of safety are all important to a railway but they are in conflict with the need to make savings to invest in other ways and of course keep the railway open.

All railway maintenance involves technical and business risks, but these can be minimised by modern engineering and management techniques. This paper seeks to identify those risks with respect to neutral temperature (stress-free temperature) and explain how they can be managed technically and commercially.

2.2 Neutral Temperature of Rails

When the temperature of a rail increases it wants to extend its length and when it decreases it wants to shorten. The rail fastenings, the sleepers and the ballast are all designed to prevent the rail from expanding or contracting so temperature changes result in the rail going into compression when the temperature goes up and into tension when the temperature goes down.

If there is excess compression the track will buckle – if there is excess tension the rail will break, probably at a weld, as it is here that the rail is usually at its weakest. Both of these phenomena are dangerous, especially the buckle.

Rails are usually installed at a temperature towards the lower end of the climatic spectrum and therefore to minimise the risk of either breaks or buckles, axial stresses are put into continuously welded rail at installation, rail renewal or repair to counter the effects of temperature changes on the rail from night-time lows in winter to daytime highs in the summer.

The definition of Neutral Temperature (or Stress Free Temperature) in the British Railway Track, 6th Edition, p614, is that temperature at which the rail must be free of longitudinal thermal load. Put another way it is the temperature at which the rail is in neither tension nor compression.

The appropriate neutral temperature is chosen by the track engineer and is usually 5° or so above the mid-point between the highest and lowest temperatures the rail is likely to reach. This will vary with the local climate. As with all such standards, a tolerance is applied both above and below the chosen temperature. The extent of the tolerance will vary even in similar climates depending on the rail type, sleeper and fastening system and also the type, speed density and weight of the traffic. For high speed lines this is often only ±2°C but for low speed is frequently ±5°C.

	Type of failure	2013-14(r)	2014-15(r)	2015-16(r)	2016-17(r)	2017-18
Mainline	Broken rails	119	95	107	86	76
	Buckled rails	19	14	9	7	14
	Total	**138**	**109**	**116**	**93**	**90**
LUL	Broken rails	18	9	9	12	11
	Buckled rails	0	0	0	3	1
	Total	**18**	**9**	**9**	**15**	**12**

2.3 The benefits of well managed neutral temperature

Companies who manage neutral temperature well will reduce temperature induced track faults, thereby increasing availability, reducing safety risks and enhancing business potential. The use of a non-destructive neutral temperature measurement method will facilitate much more cost effect management than traditional methods. Good computerised databases will facilitate the long-term study of the behaviour of track and provide the engineer with the ability to plan his track maintenance more efficiently.

The rail company will be able to maintain better detailed and up-to-date records to demonstrate to its own management, auditing and licensing bodies its diligence in safety management and thereby reduce the opportunities for clams for negligence and litigation.

Overall the adoption of modern measurement techniques will result in the business benefiting from improved operating performance, more effective maintenance investment and greater customer satisfaction and thus competitiveness and profitability

2.4 The technical risks of incorrect neutral temperature

Temperature forces can manifest themselves in a number of different ways, each of which poses a threat to safety. Each 10°C change in temperature will produce forces in the order of 18 tonnes. Let us consider each situation.

Compression

When a rail goes into compression it has the potential to behave in several ways depending on whether the track is straight (tangent) or curved, either horizontally or vertically or in a super-elevation transition. The forces involved are very high indeed under these circumstances and continue to increase as the temperature rises above the neutral temperature.

When tracks buckle or curves move, there are very serious safety implications. The greatest risk is of derailment. A derailment is at best inconvenient but at worst, on high-speed lines, can result in substantial loss of life.

(Track buckle)

Straight track

If the track geometry is in excellent condition, along with the fasteners, sleepers and ballast then the rail will have nowhere to go and will not buckle until there are very high stresses. However, the slightest loss of straightness will result in the track buckling. The vibration of an approaching train can trigger this. The pent up stresses are such that the sideways movement can be more than a metre as the rail wants to reach its stress-free length. If the ballast shoulders are in poor condition the lateral stability of the track is low and the buckle will be horizontal.

If the ballast shoulders are good the buckle can be vertical such that sleepers are lifted out of the ballast resulting in the track hanging in the air, totally unsupported.

Horizontal curve

The compressive stresses will push the curve outwards, possibly to a point where there is little or no support to the track. As the track is already bent into the curve, track movement in these circumstances is likely to occur more readily than in straight track at similar excess temperatures above the neutral temperature.

Vertical curve

When a track is on a vertical curve, especially at a summit, it is possible that the compressive forces will result in the track being lifted out of the ballast but a horizontal buckle can occur under these circumstances too.

Super-elevation transition

Here the track is twisting as it enters a curve and a buckle under these circumstances can result in more complex movements in both the horizontal and vertical planes.

Where the neutral temperature of one rail is significantly different to the other rail on the same track, the imbalanced force induces a bending moment in the track that will result in the track moving sideways under extreme conditions. Whereas this is unlikely to be so severe as when both rails are incorrect, it can still result in just as dangerous a condition, as the track will not be properly supported at its extreme thereby putting twist into the track. Slewing of the sleepers can also occur in imbalanced situations, creating undesirable forces on the fasteners and sleepers creating gauge spread as well.

Tension

When the rail goes into tension it can result in curve movement too, this time pulling the curves into the centre. However, by far the most common consequence of excess tension is for the rail to break. This is usually at a weld but can also be where there is a flaw in the rail or of course at a weak joint.

2.5 Factors that can change neutral temperature

It is a remarkably common assumption that once a rail is stressed to a certain value it will not change. This is a fallacy – or a forlorn wish! Even though when installed the neutral temperature of the rail may be correctly set, there are several factors that can make it change.

The prevention of problems is achieved by attention to the following basic design and maintenance factors:

- Fastenings having good resistance to longitudinal rail creep
- Sleepers of the appropriate design and spacing
- Correctly filled and consolidated ballast beds with heaped shoulders
- Sound and stable formations
- Inclusion of breathers

Traffic

It is well known that ballast is a dynamic structure that moves with load and vibration, both elastically and plastically. When trains frequently brake or accelerate on the same section of track it will have the result, over time, of moving the rail ahead in braking and behind in traction. The effect of this is to increase the tension and hence the neutral temperature at one end of a section of track and decrease the neutral temperature at the other. The rate of change will depend on the type of traffic and the condition of the ballast, sleeper type, fasteners and their condition as well as train and traffic characteristics.

Gradients are similarly affected as trains apply brakes and traction. Likewise, curves can gradually move with vibration and loads, which can result in neutral temperature changes. Again, the rate of change will depend on track conditions and train characteristics.

Mechanised track maintenance

The vibrating action of tampers, especially in curves, can result in the curves moving, changing the rail length between the end points thereby changing the neutral temperature. Ballast cleaning, sleeper changing machines and ballast stabilisers and regulators all have the potential to change the neutral temperature as well.

Track fastening degradation

The tension is maintained in the rails by the rail fasteners transferring the loads to the sleepers and thence the ballast. If the fasteners do not apply sufficient toe load or rail anchors are incorrectly fitted or performing badly, they will be unable to contain the forces adequately and the neutral temperature will change. Pad wear, rail seat wear and rail foot gaul will have the same effect.

Degrading ballast condition

Ultimately, it is the ballast or track support that provides the reaction to the tensile and compressive forces in the rail. Therefore, if it is in poor condition, the neutral temperature will inevitably change away from the ideal.

Poor quality repairs

If rails are re-welded without the correct re-tensioning, then the neutral temperature over greater lengths of rail can be adversely affected. Letting in new insulated joints or other rail sections without correct de-stressing can also cause problems.

Extreme weather conditions

Continuous cycling is believed to affect the neutral temperature of rail over long period but, until now, it has not been cost effective to study exactly how. Extra-ordinarily high or low temperatures can permanently change the neutral temperature too.

Ground conditions

The formation and its stability can also result in changes to the rail length. Mining subsidence is well known to occur and will often result in increased tension. Heave can have the same effect.

2.6 The business risks of incorrect neutral temperature

Safety is always paramount for a railway business, no more so than with a passenger carrying company and this is even more so for those running trains at high speed. Both track buckles and rail breaks can be the cause of a derailment. With high-speed derailments there is a major risk of loss of life. Apart from the direct costs of compensation and repair there is also the serious risk of loss of business as the confidence of the travelling public suffers.

The costs of a derailment include that of renewing the track and that alone is substantial but even the correction of a track buckle or rail break will result not only in the direct material and labour costs but more importantly, loss of availability of the track. The cost of delaying trains is better understood now than ever before. These costs can be as a consequence of individual journey contracts, by performance penalty regimes that exist in longer-term commercial contracts or indeed regulatory standards. Again, confidence in the ability of the train operator to provide a good service will be affected by poor availability. Even minor train delays such as TSRs have longer-term erosive effects on custom.

All businesses now have to demonstrate to statutory bodies that they are managing safety diligently and professionally. In the railway industry this can be tied to licenses affecting the fundamental right to operate at all.

Records need to be kept to demonstrate that neutral temperature is being appropriately managed. Failure to do so could result in loss of licenses or actions in law of negligence in the case of serious incidents.

2.7 Minimising risks and costs

There are many costs involved in the maintenance of track but it is widely accepted in all engineering maintenance that prevention is more cost effective than repair. Planning when and where any kind of maintenance should be carried out depends on knowing the state of the track and neutral temperature is just like any other track safety characteristic in this respect.

The re-stressing of rail that is at its incorrect neutral temperature is disruptive, expensive and it introduces another weld, a risk in itself. It will usually involve 12-16 men, heavy hydraulic tensioning equipment and of course the welding equipment. As it is expensive, it is important to only undertake the work where and when it is necessary.

To plan work to manage the neutral temperature can only sensibly be made possible by measuring the state of the track. Until now this has meant cutting the rail, measuring the stress change and re-stressing the rail. As has already been described, this is costly. Where money is limited this is often one of the first things to be sacrificed and many railways admit privately that they have not checked some neutral temperatures in many, many years.

Historically, many permanent way engineers, knowing that the track buckle is the more dangerous and that neutral temperature might well reduce over time (but not necessarily), have understandably erred on the side of caution and set the neutral temperatures even higher than the standard. Despite modern rails being able to bear considerable tensile forces without breaking, the price of this tactic has been a higher frequency of costly and disruptive rail breaks. They may seek to find stronger and higher quality welding techniques but that will not change the thousands of welds already in track.

If the neutral temperature is known, then appropriate action can be planned at locations of highest risk, thereby reducing the number of rail breaks yet still avoiding the track buckle.

When new rail is installed either on brand new track or as replacement for worn or damaged rail, the last thing the track engineer wants to do is cut his new rail to check whether he, or his contractor, has done a proper job. It is usually left unchecked, introducing another risk.

Being pro-active and using a non-destructive technique to measure the actual state of the track, will thereby, enable these savings to be made and bring the extra confidence that safety is being managed professionally.

2.8 Existing methods for the Establishment of the Neutral Temperature of the Rails as found

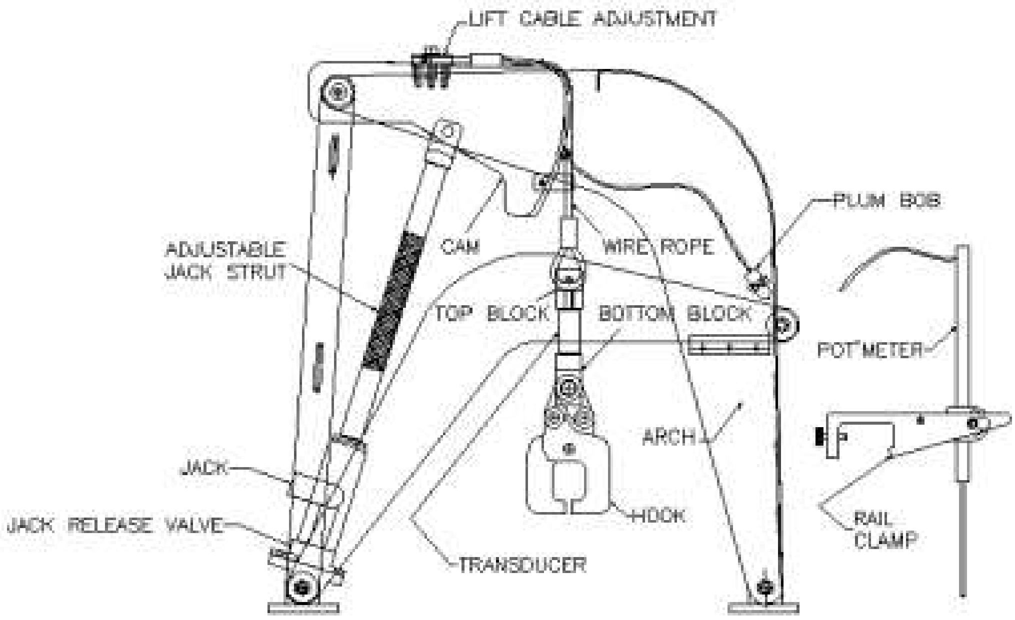
The only way to date to measure the neutral temperature has been to cut the rail and measure the stress change and then re-stress the rail. For an accurate measurement, the fitment of strain gauges is necessary and this requires specialist technicians, preparation and equipment.

Many companies have relied on measuring the relaxation distances of the cut rail ends but this is known to be at risk of large errors. 15°C errors have been seen, especially where the movements of the sleepers still attached to the fixed end of the rail are not measured as well. Measuring accurately over long distances is notoriously difficult too.

Another technique that has been tried to establish the Neutral Temperature measures a phenomenon called Barkhausen noise. This noise is generated in a stressed body on the decay of a magnetic field but when taking such stress measurements in a railway rail, the accuracy is adversely affected by the residual stresses in the rail from the rolling mill. Magneto-strictive-ultrasonic damping is another technique that has been tried but is also adversely affected by the residual stresses.

2.9 Proposed Method of Measurement of Neutral Temperature using VERSE® Apparatus

The advent of a method which offers both fast and low cost measurement now makes SFT management more practical and financially viable. The **VERSE®** system, developed jointly by Pandrol (VORTOK) Ltd and AEA Technology, brings SFT measurement into the 21st century.



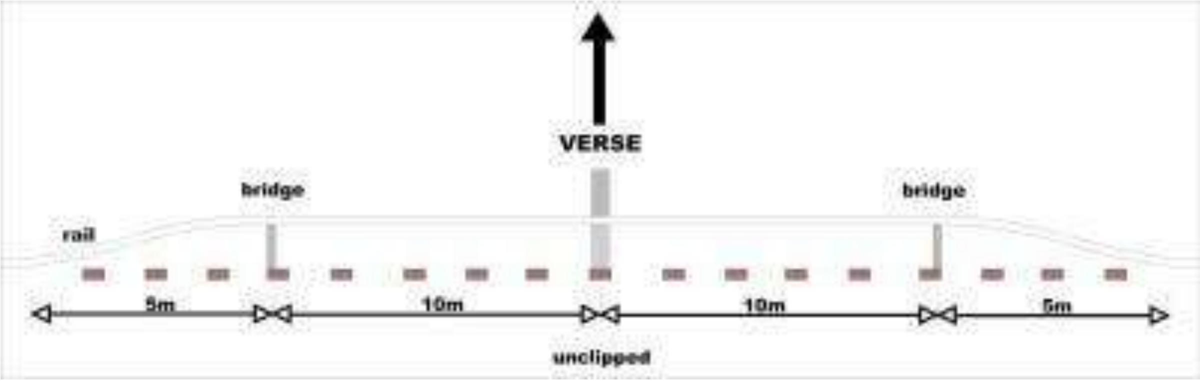
(Schematic Drawing of the **VERSE®** Hardware)

VERSE® is a non-destructive method that can be completed quickly and at less

than 5% of the cost of traditional methods, all of which rely on cutting and re-welding the rail. **VERSE®** is a combined mechanical/software system that will produce initial results trackside from a handheld computer. One unique feature of **VERSE®** is its ability to measure SFT directly. The inherent stress and stress history of the length of rail is not required. Neither are measurements required to be taken at different rail temperatures. Provided the rail is at a temperature less that the SFT, then **VERSE®** will produce a result. This means, for instance, that **VERSE®** can be used during the cooler night and early morning temperatures so that special possessions are not necessarily required.

VERSE® is supplied complete with both handheld and PC software, the latter incorporating a PC data base that will hold comprehensive data sets for a whole rail network - the crucial tools a modern railway needs to plan and manage effective re-stressing programmes.

VERSE® has been designed for ease of use. Highly portable, it can be carried in a small estate car or medium hatchback, so it can be easily deployed on site.



(SFT Measurement with **VERSE®**)

Firstly, the rail must be at a temperature lower than its SFT so that the rail is in tension. Taking a measurement requires around thirty metres of track to be unclipped which is normally done by two persons whilst another one sets up the **VERSE®** frame which sits on the sleeper and straddles the rail.

VERSE® incorporates a clamp to the rail head which allows the rail to be lifted with its built-in hydraulic jack. A measurement entails lifting the rail to 10 kN (monitored by a load transducer) and logging the load and displacement monitored by a displacement transducer at regular increments. The output from both transducers are routed via a dedicated signal condition system to a hand held computer.

(Hand Held Computer)

(**VERSE®** Measurement)

Along with some other data such as ambient rail temperature, rail profile (a simple selection from a software menu) and height of the rail, the handheld software produces the SFT result. The height of the rail is included to take account of rail head wear and rail grinding which will naturally affect the stiffness of the rail. Typical testing time will be 20 to 30 minutes for an experienced crew depending on the type of rail fastening. Downloading the site data sometime later to the PC software will allow further analysis of the data and enable the results to be added to the **VERSE®** database.

Validation

Validation of the **VERSE®** technique has been carried out by AEA Technology during the research phase of perfecting the technique which has taken place over several years. These tests show an accuracy of ± 0.2 °C and a standard deviation of 1.3°C when compared with strain gauges. Validation was carried out by using tensors to pull the rail to known tensions as read by strain gauges and then measuring using the **VERSE®** technique and by strain gauge and rail cut in service conditions.

Further validation has been conducted by other organisations. Most recently the Transportation Technology Center Inc (TTCI), Pueblo, Colorado has conducted tests on large section American rails. Hydraulic rail tensors were set up in track to enable a range of SFT's to be superimposed above the ambient rail temperature.

2.10 Lessons already learnt

In the UK alone, over 100 **VERSE®** kits are currently in service and many unnecessary re-stressing operations have been avoided, high-risk situations corrected before serious incidents have occurred and new, comprehensive records have been created. Valuable lessons have been learnt too about the state of the track and questions raised about standards and procedures.

Some **VERSE®** users have taken as many as 1000 measurements in a matter of weeks allowing them to really understand the state of their track. This has allowed them to correct those sites where there are serious faults and plan the correction of less crucial ones when they can have access to the track or when other maintenance is required at the same location.

Contractors have been shown to have laid new rails incorrectly in error or negligence and problems have been avoided by corrective action being taken before service commenced. Some contractors in the UK are already using this procedure to demonstrate to their customers that they have produced the correct quality of track.

Some areas have found as many as 30% of the sites measured to have a problem. These can be significant differences of stress in one rail to the other in the same track or large variations between one section and another only 400m along the track. This should be no surprise if track, ballast, fasteners and pads are all in good condition, as they will contain the variations in stress. These variations have always been there – we have just not seen it before. One contractor is now seeking to change the procedure for replacing one rail at a site such a neutral temperature measurement is made on the rail not to be replaced before work starts to help plan the stressing needs of the location.

Canadian National Railways company is studying the effect on neutral temperature of ballast cleaning machines and other mechanical track maintenance procedures. Dallas Area Rapid Transit is checking brand new track before commissioning and are finding problems with previously assumed stressing techniques. Railway companies in Finland, Italy and Sweden are also just starting, as are Union Pacific and Burlington Northern- Santa Fe, Illinois Central and Long Island Railway in the USA. Other railway companies in Europe are in the final stages of evaluating the strategy and many are expected to commit to it shortly.

Stressing techniques, rigorously followed, have been shown to be flawed in their accuracy. On one newly laid track, greater than 5% variation has been found between one rail and the other and long used de-stressing methods are being shown to give inadequate results.

This variation between the two rails has been shown to exist in many locations both in the UK and in Canada. It can be assumed that it will exist elsewhere too but the reasons why are not yet fully understood.

One user has used **VERSE®** in conjunction with a tamper to correct the neutral temperature through a curve without conventional de-stressing by getting the tamper to move a curve outward to put the tension back and checking it with **VERSE.** This is reported to make considerable savings.

On more than one railway safety margins and tolerances on the neutral temperature standards are being challenged and lessons continue to be learned.

2.11 The Future

Since 2000, **VERSE®** is now in use in over 25 countries worldwide. We have a means now to research the behaviour of track that would have been totally impractical with techniques requiring cutting of the rail. This gives us the opportunity to study the effects of time, traffic, maintenance, weather cycling and track component condition and better understand the long term behaviour and risks.

We have the ability too, to challenge the standards and importantly, the techniques and procedures for the establishment of the correct neutral temperature.

Pandrol (Vortok) now has a cost effective system for measuring the ongoing changes to the Neutral Temperature over time, particularly suited to braking zones, entrances and exits of stations, curves, switches and gradients.

All it needs is the steady building of the database of measurements but there is the opportunity too to undertake specific research without damage to track and I would encourage the industry to embark on such a programme.

In the long term, track engineers will be able to more accurately correlate the frequency of failures with actual neutral temperatures of their track, the rates at which the neutral temperatures have changed, the circumstances that made them change. They will then be able to refine their neutral temperature standards and tolerances to minimise these risks.

Let us not forget that there was much research and development done in the 1950s that could be brought up to date by validation with a non-destructive measuring technique.

2.12 Summary

The adoption of a more rigorous, pro-active, neutral temperature management regime is now possible because of the availability of an accurate, non-destructive measurement method.

This strategy can bring real benefits of reduced dangerous incidents, increased track availability, improved understanding of the behaviour of the track, better maintenance planning, reduced risk of litigation and better maintenance expenditure. These are all powerful motivators in making the railway more competitive and cost effective and above all, safer.

3. Current VERSE® users worldwide

4. Appendices

A. **Report from AEA Technology Rail, UK on the use and accuracy of VERSE® using comparative methods**

B. **Report from TTCI, Pueblo, Colorado on the use and accuracy of VERSE® using comparative methods**

C. **Report from RRI, Prague, Czech Republic on the use and accuracy of VERSE® using comparative methods**

D. **Report by Mr Peter Shrubsall, demonstrating VERSE® in Pagney-sur-Moselle, France**

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F. **Testimonial - Thermit Welding (GB) Limited**

G. **Testimonial - Canadian National Railway**

H. **Testimonial – Verification of Newly Laid Track on St Louis Metro**

I. **Testimonial – VR, Finland**

J. **Network Rail Approval Certificate**

APPENDIX A

RESTRICTED - COMMERCIAL
RR-TCE-204 Issue 1

Trial of the New VERSE® Method at Bevercotes Colliery Branch

I Banton

November 1998

Title	Trial of the New VERSE® Method at Bevercotes Colliery Branch
Customer	AEA Technology Rail Growth Panel
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Contents

1 Introduction

As part of the ongoing VERSE® AEA Technology Rail Growth R & D development programme, a trial was conducted on the Bevercotes Colliery Branch during the period 5 to 9 October 1998 in order to evaluate a new VERSE® method. A series of VERSE® stress free temperature measurements (SFTs) were made on rails to which a range of different SFTs had been installed. The rails being measured had strain gauges attached so that the installed SFT could be determined for comparison with the VERSE® estimate. This report details the findings from this trial.

1.1 BACKGROUND

The original VERSE® procedure involved unclipping 30m of rail and lifting the rail from its unclipped position. Problems were encountered during attempts to measure rails on tight radius curves and baseplated track. It was found that in these cases unknown frictional forces were introduced to the rail being lifted as a result of the contact between the rail foot tip and the fastenings. Further problems were encountered where the sleepers supporting the rail were voided. This resulted in unpredicted increases in the length and mass of the rail being lifted. All of these events degraded the accuracy of the VERSE® SFT estimate.

A new method of VERSE® was proposed, which it was considered would give an improved accuracy and allow VERSE® to be used on tight radius curves (>1000 m), which would be important for VERSE® sales abroad . This comprised unclipping the rail and supporting it on packing pieces so that the centre 20 m span was lifted clear of the fastenings. By adopting this procedure, it was considered that the problems experienced with the original method could be overcome. An algorithm was developed that enabled the rail SFT to be calculated from the recorded rail load/deflection characteristic. Initial trials of the new method had shown that the relationship between the applied load and vertical displacement of the rail was linear. The original method produced a non-linear rail load/displacement relationship.

1.2 THE NEW VERSE® METHOD

The new VERSE® method comprises unclipping 40m of rail, jacking the rail up and inserting 65mm packing pieces at a nominal span of 20m. The rail at either end of the supported span is unclipped to give a nominal equal length of approximately 10m. Originally, the method was tried with unclipped end lengths of 5m. However, it was found that this resulted in the sleepers adjacent to the unclipped length being lifted. The VERSE® frame is then positioned so that it is at the centre of the supported span, the packing pieces being adjusted over the width of the sleeper so that each half of the supported span is equal in length. Figure 1 shows a schematic diagram of the rail set-up for a VERSE® measurement. The procedure then follows the standard VERSE® method[1] with three scragging runs followed by three measuring runs.

Once the measurement has been completed the data is downloaded to a PC in the standard way and processed using the calculation program `VER_CALC.EXE` and associated interface file `Z_V_CALC.DAT`. This program asks the user to input the supported rail length in metres and the length of the two end spans. Once this data has been entered, the program calculates the mean, minimum and maximum SFT for each of the measuring runs and writes the results back to the data file.

1.3 EQUIPMENT

Three versions of the VERSE® equipment were used during the trial. The MkI system, the first prototype, incorporating a separate signal conditioning unit and a 700 series Polycorder. The MkII system, comprising the advanced prototype folding frame and the Pro 2000 Polycorder, which both powers and conditions the transducer signals. The Vortok system, this system comprises a new easy-to-set-up frame and shares the same instrumentation as the MkII system.

2 The Trial

Two sections on the Bevercotes Branch were selected for VERSE® testing during the trial. The first section comprised an 86m length of CWR between two sets of breather switches on a curve of 1136m radius. The track was made up of BR98lb rail on F27 concrete sleepers with Pandrol fastenings. Both rails were measured using the new VERSE® method. The first measurement was carried out using the MkII VERSE® system, however, it was found that,due to the low stiffness of the rail section being lifted, VERSE® could not provide enough lift to apply the full 10 kN load. To get round this problem the measurement was repeated using the MkI system. At the point at which the maximum lift of the system was reached, a group of people stood on the lifted rail to increase the measured load to 10 kN. By adopting this method it was possible to capture acceptable load/deflection data over a load range of 0 kN -8 kN. Strain gauges were attached to the rails adjacent to the lifting position prior to carrying out the VERSE® measurements. On completion of the VERSE® measurements the strains were measured prior to and following cutting of the rail to enable a comparative measure of the SFT that was present in the rail during the VERSE® measurements. The data from these two measurements were named BEV1.DAT (high rail) and BEV2.DAT (low rail). The rails' SFTs were reinstated then welded up. Details of the site are shown in Figure 2.

The test location was then moved to the far end of the branch onto a long section of CWR on a curve of 2600m radius. The track at this location was made up of BS11 113A rail on F27 concrete sleepers with Pandrol fastenings. Details of the site are given in Figure 3. Strain gauges were attached to the rail adjacent to the lift point to enable the state of strain in the rail to be monitored. Details of the strain measurements are given in Table 1. The low rail was marked up and measured using the original VERSE® method with 30m of the rail unclipped (AA000062.DAT). The rail was then marked up for the new method and a repeat measurement was made with the rail supported on packing pieces (AA000063.DAT). The rail was then cut and unclipped throughout the 62m section, and the strain change was measured. Hydraulic tensors were applied to the rail so that new SFTs could be introduced prior to taking further VERSE® measurements. Each time a new SFT was introduced the change of strain, distance that the rail was pulled up and rail temperature were recorded, these data are shown in Table 1. Rollers were placed beneath the unclipped rail at every tenth sleeper then the rail was pulled up by 6mm. The rollers were removed and the rail reclipped to the start of the VERSE® lift length.

A VERSE® measurement was then carried out using the MkII system and the new method (AA000064.DAT). This procedure was repeated for a range of eleven different SFTs. The VERSE® SFT estimates and strain gauge and cut SFT estimates were normalised against each other by subtracting the ambient rail temperatures. The results of these tests are given in Table 2. Examples of the processed data files from tests AA000069.DAT and AA000071.DAT are given in Appendix 1.

2.1 STRAIN GAUGE AND CUT MEASUREMENTS

Strain gauges were attached to the rail adjacent to the lift point prior to carrying out the VERSE® measurements. This enabled the variation in the axial strain in the rail between its original state and after cutting to be determined. From this measurement the SFT of the rail was calculated to provide a datum against which the accuracy of the respective VERSE® SFT estimate could be compared. It was noted that the strain level in the rail with the rail unstressed showed some variation between tests. This was considered to have resulted from the friction between the base of the rail and the support rollers. For the purpose of this trial, the strain in the rail in its unstressed state was taken as $731\mu\varepsilon$. With hindsight, it is considered that a more accurate method of monitoring the strain at the second site would have been to have logged the strains continuously, rather than taking spot measurements. The strain gauge procedure used throughout this trial comprised taking discrete measurements of the excitation voltage and output voltage from the strain gauge system combined with the rail temperature at the time of measurement. Table 1 gives details of the strain measurements taken during the trial.

3 Discussion

The results from the trial showed that the new VERSE® method gave a more reliable and accurate estimate of SFT than the original method. The mean accuracy of the new method was calculated to be 0.2°C with a standard deviation of 1.3°C. An additional benefit of the new method is that when running the calculation programme the software automatically identifies any data file in which the rail load/deflection relationship does not follow the expected pattern. However, by plotting the load/deflection data as an Excel chart it is possible to recover sufficient usable data to enable an SFT result to be calculated from the data omitting the erroneous data.

Figure 4 shows the relationship between the new VERSE® method SFT estimate and the SG & Cut SFT normalised by removing the ambient rail temperature at the time of the measurement. As shown the data all falls within a tight band. It is considered that the sources of the small errors contained within this data did not necessarily result from the VERSE® measurement and could equally have resulted from the strain measurements.

4 Conclusions

- The new VERSE® method gives improved accuracy over the original VERSE® method when compared with the strain gauge and cut results.
- The accuracy of the new VERSE® method gives a mean accuracy when compared with strain gauge and cut of 0.2°C with a standard deviation of 1.3°C.

5 Recommendations

1 The new VERSE® method with the Vortok frame should be adopted as the preferred method for non-destructive stress free temperature measurement once Railtrack approval has been obtained.

2 Based on the success of this trial, AEA Technology Rail should make an application to Railtrack for the discontinuation of the need for supporting strain gauge and cut verification measurements on a 1 in 10 basis during future VERSE® service work.

6 References

1 I Banton, An Operator's Guide to VERSE® - A non-destructive method of SFT measurement. TCE-D059-US-003, 8 February 1998.

Date	Rail State	Rail temp(°C)	Strain (με)
06-10-98	Before cut	16	888
06-10-98	After cut	16	808
06-10-98	rail cut	16	808
06-10-98	6mm pull	15	786
07-10-98	after night	9	833
07-10-98	20mm pull	11	964
07-10-98	as above	10	964
07-10-98	unstressed	12	728
07-10-98	5mm pull	16	776
07-10-98	as above	16	779
07-10-98	unstressed	16	736
07-10-98	9mm pull	14	852
07-10-98	as above	13	856
07-10-98	unstressed	13	730
07-10-98	15mm pull	13	905
07-10-98	as above	12	904
08-10-98	after night	11	840
08-10-98	unstressed	10	860
08-10-98	7mm pull	10	801
08-10-98	clips & blocks	10	801
08-10-98	11mm pull	12	850
08-10-98	unstressed	12	730
08-10-98	19mm pull	12	1004
08-10-98	clips & block	12	1003
08-10-98	blocks out	15	976
08-10-98	unstressed	15	733
08-10-98	3mm pull	15	762
08-10-98	unstressed	15	730
08-10-98	23mm pull	15	966
08-10-98	clips & blocks	15	972
08-10-98	unstressed	15	731
08-10-98	13mm pull	15	876
Mean unstressed strain			731

Table 1 Strain measurement results

File Name	Date	Rail	Equip & Method	State of rail	Rail Temp(°C)	VERSE® SFT Estimate (°C above ambient)	SG&C (°C above ambient)
BEV1.DAT	5.10.98	Right	MkI new	as found	12	4.82 (+0.39)	4.43
BEV2.DAT	5.10.98	Left	MkI new	as found	12	5.89 (-1.00)	6.89
AA000062.DAT	6.10.98	Right	MkII orig	as found	10	25.9 (+12.25)	13.65
AA000063.DAT	6.10.98	Right	MkII new	as found	11	16.88 (+3.23)	13.65
AA000064.DAT	6.10.98	Right	MkII new	6mm pull up	15	5.99 (+1.21)	4.78
AA000065.DAT	7.10.98	Right	MkII new	left overnight tensors off	10	8.36 (-0.51)	8.87
AA000066.DAT	7.10.98	Right	MkII new	20mm pull up	12	20.14 (-0.12)	20.26
AA000068.DAT	7.10.98	Right	MkII new	5mm Pull up	15.5	3.5 (-0.67)	4.17
AA000069.DAT	7.10.98	Right	MkII new	9mm pull up	13.5	10.32 (-0.55)	10.87
AA000070.DAT	7.10.98	Right	MkII new	15mm pull up	13.5	14.11 (-1.02)	15.13
AA000071.DAT	8.10.98	Right	MkII new	Left overnight tensors off	10	9.33 (-0.15)	9.48
AA000072.DAT	8.10.98	Right	MkII new	7mm pull up	11	4.76 (-1.33)	6.09
AA000073.DAT	8.10.98	Left	Vortok orig	as found	13.5	26.72	No reading
AA000074.DAT	8.10.98	Right	MkII new	11mm pull up	12.5	9.76 (-0.59)	10.35
AA000075.DAT	8.10.98	Left	Vortok new	as found	13.5	16.62	No reading
AA000076.DAT	8.10.98	Right	MkII new	19mm pull up	13	22.73 (-1.01)	23.74
AA000077.DAT	8.10.98	Right	Vortok new	Repeat of above	13	24.84(+1.1)	23.74
AA000078.DAT	8.10.98	Right	Vortok new	3mm pull up	15.5	3.73 (+1.03)	2.70
AA000079.DAT	8.10.98	Right	Vortok new	23mm pull up	15	22.40 (+1.97)	20.43
AA000080.DAT	8.10.98	Right	Vortok new	13mm pull up	14	14.17 (+1.56)	12.61

Table 2 Bevercotes VERSE® Measurement

AEA TECHNOLOGY RAIL		
PROJECT TITLE: Verse Trials TITLE: ROOT1 REV: 1.0 AUTHOR: P S Brown DRAWING NO:		DATE: 11-Nov-98 REVISED: 16-Nov-98 PAGE:
DRAWN:	CHECKED:	APPROVED:

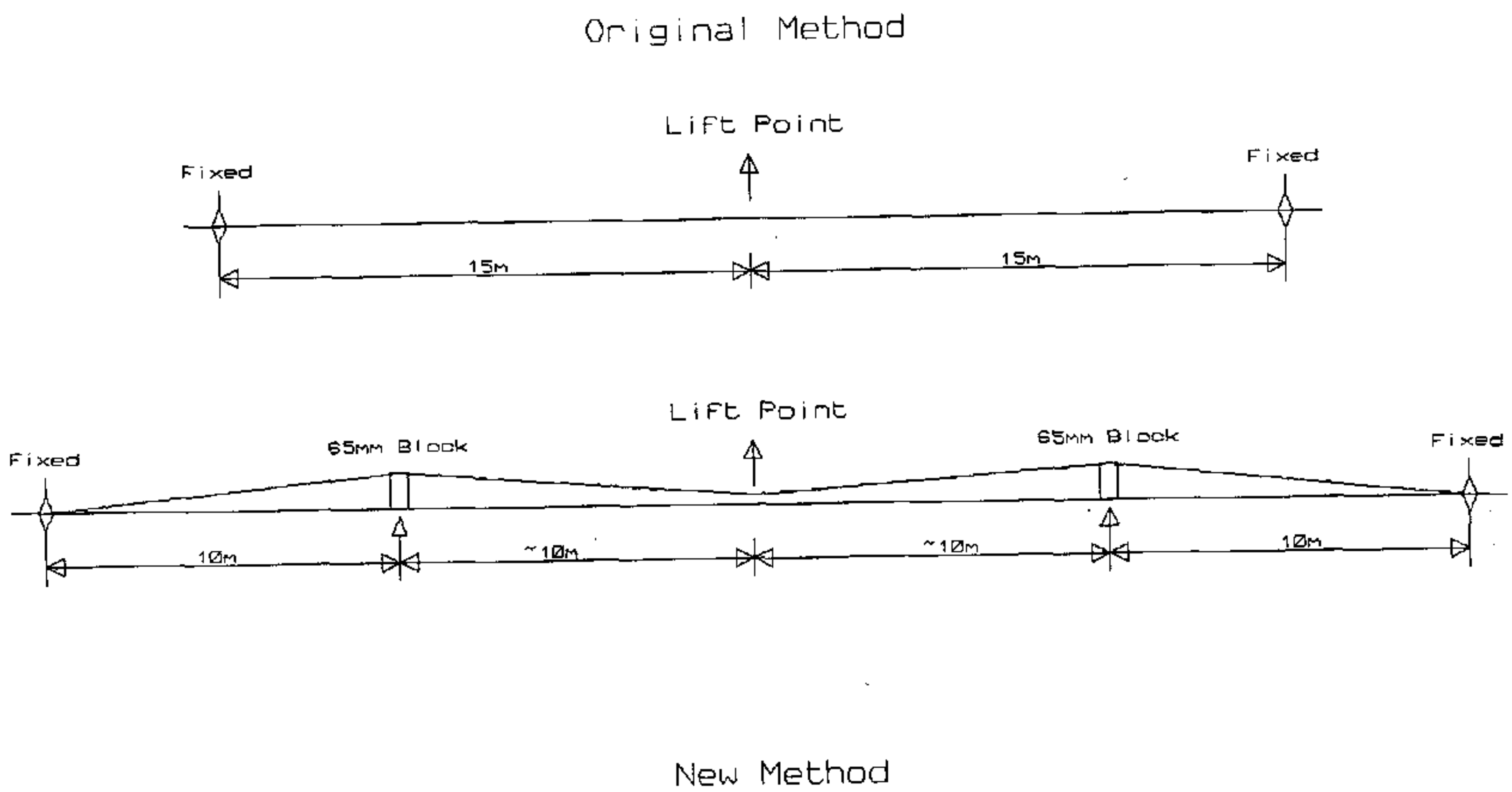
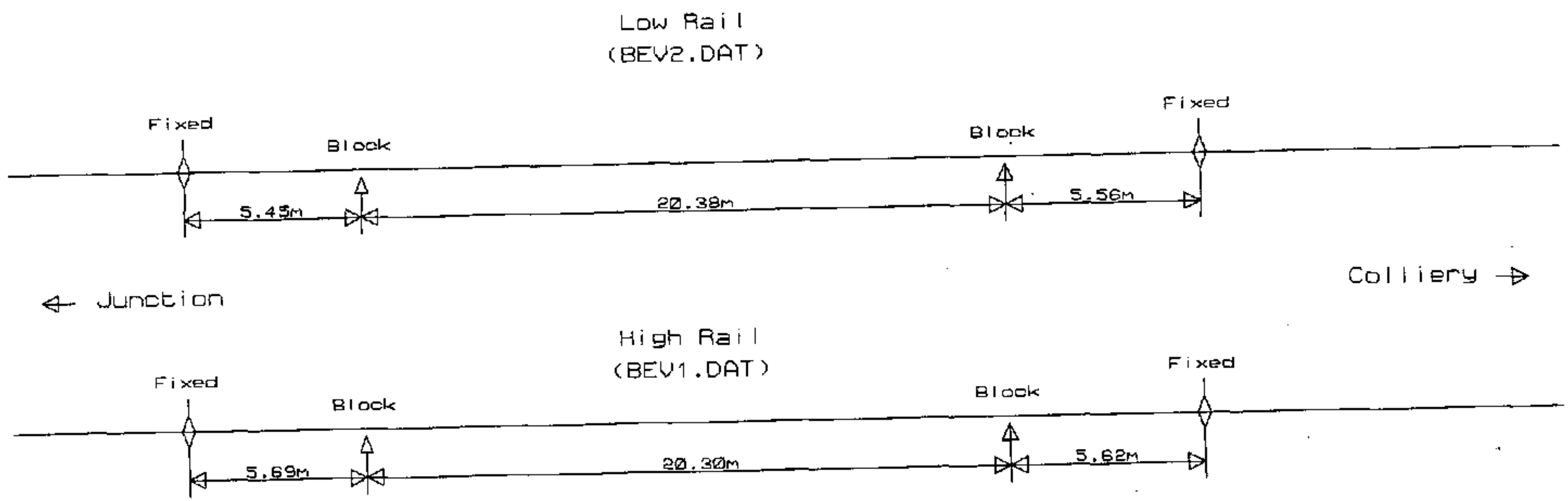


Figure 1: Rail Set-Up for VERSE Measurements

AEA TECHNOLOGY RAIL		
PROJECT TITLE: Verse Trials TITLE: ROOT1 REV: 1.0 AUTHOR: P S Brown DRAWING NO:		DATE: 11-Nov-98 REVISED: 16-Nov-98 PAGE:
DRAWN:	CHECKED:	APPROVED:

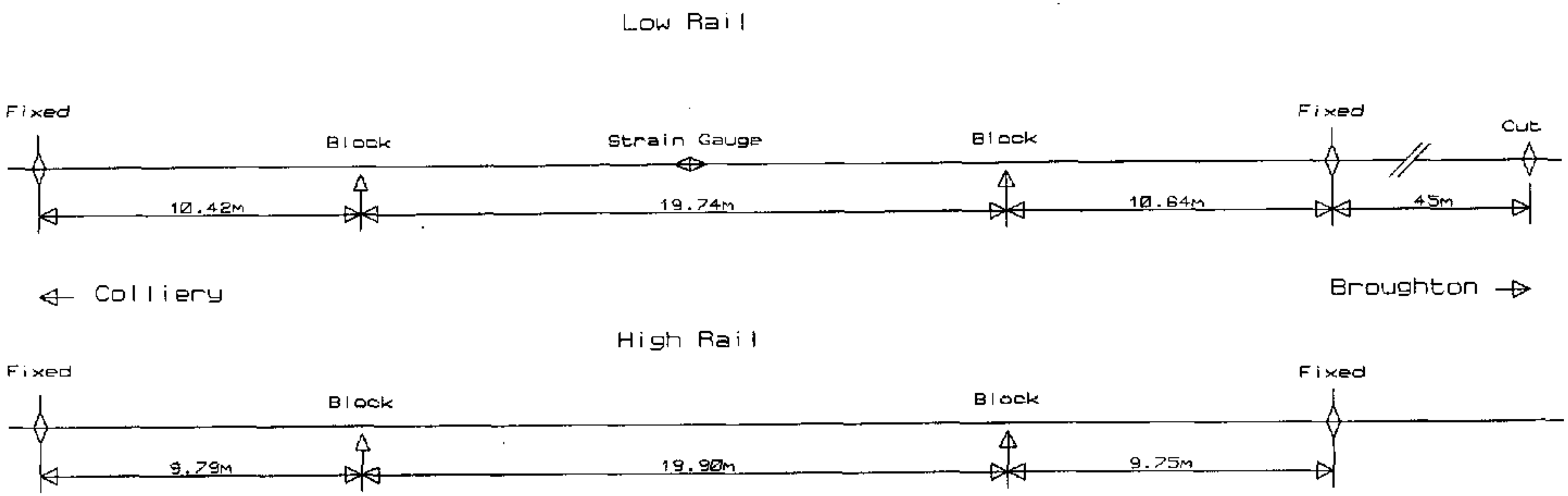


Rail Section BR 98lb Fb

Radius of Curvature 1136m

Figure 2: Bevercotes - Junction End

AEA TECHNOLOGY RAIL		
PROJECT TITLE: Verse Trials TITLE: ROOT1 REV: 1.0 AUTHOR: P S Brown DRAWING NO:		DATE: 11-Nov-98 REVISED: 16-Nov-98 PAGE:
DRAWN:	CHECKED:	APPROVED:

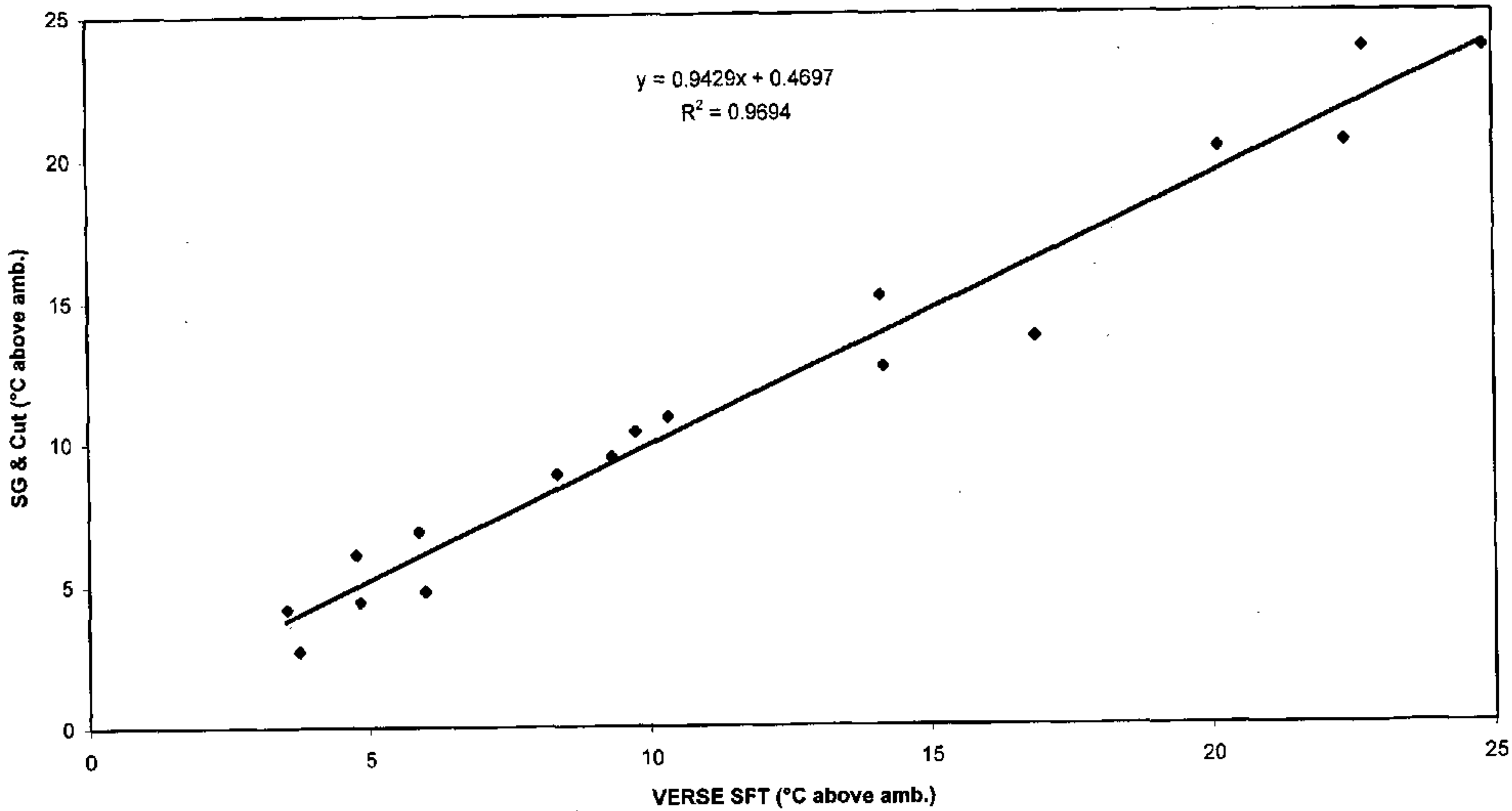


Rail Section BS11 113A Fb

Radius of Curvature 2600m

Figure 3: Broughton - Colliery

Figure 4: VERSE SFT estimate versus SG & Cut



Appendix 1

Two examples of processed Bevercotes data files

V1.00

* User Name
* Date and Time
07/10/1998 14:33

* VERSE Equipment Identity
AA

* VERSE Software Version Number
0.90

* Last Successful Calibration Filename
AA000034.SUC

* Last Calibration Filename
AA000034.SUC

* SITE INFORMATION

* Location
"bevercote"

* ELR TID Mileage Yardage
BEV1 1100 4 0

* Rail
Right

* Rail Section
FB113A

* Rail Heights (mm)
157.19 157.19

* Rail Temperatures (C)
13.50 13.50 13.50

* Track Curvature (m)
2600.000000

* Track Cant (mm)
25.00

* Rail Fastening
Pandrol

* Sleeper type
F23

* Stressing Date
Unknown

* Comment
""

* SCRAGGING RUNS

* Number of Runs
3

* Run 1

* Time
14:35

* Number of Data Points
2

* Load (kN) Displacement (mm)
0.06 15.98
7.16 16.27

* Run 2

* Time
14:35

* Number of Data Points
2

* Load (kN) Displacement (mm)
0.04 16.26
1.09 16.27

* Run 3

* Time
14:35

* Number of Data Points
2

* Load (kN) Displacement (mm)
0.06 16.23
7.16 16.26

* Scragging Runs Status (0=Fail, 1=Success)
1

* MEASUREMENT RUNS

* Number of Runs
3

* Run 1

* Time
14:38

* Number of Data Points
50

* Load (kN)	Displacement (mm)
0.22	17.45
0.39	19.30
0.63	21.35
0.81	23.00
0.96	24.73
1.22	27.47
1.41	28.78
1.59	30.51
1.78	32.21
2.03	34.49
2.23	36.38
2.42	38.01
2.62	39.87
2.80	41.75
3.04	43.98
3.23	45.67
3.41	47.55
3.60	49.40
3.81	51.06
3.97	52.99
4.21	55.21
4.42	56.99
4.61	58.81
4.82	60.88
5.02	62.64
5.20	64.50
5.38	66.06
5.61	68.20
5.79	70.16
5.99	72.27
6.19	74.01
6.41	75.80
6.62	77.22
6.80	79.30
7.02	81.25
7.19	82.86
7.42	85.17
7.60	86.98
7.79	88.91
8.01	90.78
8.19	92.26
8.40	93.79
8.60	96.29
8.79	97.68
9.01	99.88
9.19	101.47
9.40	103.17
9.60	105.28
9.79	107.14
10.00	108.81

* Run 2

* Time

14:40

* Number of Data Points
51

* Load (kN)	Displacement (mm)
0.06	16.73
0.18	17.48
0.36	19.45
0.66	21.89
0.82	23.85
1.01	25.61
1.22	27.31
1.44	29.13
1.60	30.77
1.82	33.18
2.01	34.72
2.18	36.05
2.40	38.38
2.64	40.59
2.80	41.98
2.99	43.93
3.20	45.64
3.40	48.09
3.58	49.37
3.80	51.65
4.00	53.79
4.19	55.25
4.39	57.23
4.61	59.00
4.82	60.45
5.01	62.88
5.21	64.55
5.40	66.22
5.61	68.35
5.79	70.20
5.99	71.88
6.19	73.49
6.41	76.04
6.58	77.52
6.83	79.66
7.00	81.37
7.20	83.12
7.38	84.96
7.60	86.99
7.82	88.90
8.00	90.69
8.18	92.58
8.40	94.10
8.58	95.90
8.79	97.60
9.00	99.67
9.19	101.52
9.40	103.20
9.58	104.99
9.78	106.70

10.00 108.84

* Run 3

* Time
14:42

* Number of Data Points
51

* Load (kN)	Displacement (mm)
0.09	16.85
0.18	17.84
0.45	19.72
0.62	21.72
0.78	23.60
1.00	25.13
1.19	26.76
1.42	29.46
1.61	31.06
1.79	32.61
2.05	34.95
2.22	36.52
2.43	38.51
2.64	40.53
2.83	42.44
3.05	44.01
3.22	46.01
3.43	48.20
3.61	49.71
3.79	51.10
4.00	53.32
4.22	55.09
4.42	57.03
4.59	58.97
4.80	60.67
4.98	62.18
5.20	64.33
5.41	66.32
5.59	68.16
5.82	70.27
6.02	71.86
6.19	73.39
6.39	75.32
6.60	77.68
6.81	79.14
7.00	81.08
7.17	82.90
7.40	85.00
7.61	86.71
7.79	88.35
7.99	90.39
8.21	92.01
8.40	93.67
8.60	95.48
8.80	97.33

9.00 99.24
9.21 101.34
9.43 102.87
9.60 104.92
9.79 106.54
10.00 108.19

* POST TEST TEMPERATURES
13.50 13.50 13.50

* Temperature within limits status (0=Fail, 1=Success)
1

* RESULTS

* Status (0=Not Calculated, 1=Calculated)
1

* SFT

NOT CALCULATED

* Run 2 SFT

Low stress, May be in compression. (10.23 10.23 10.23)

* Run 3 SFT

Low stress, May be in compression. (10.38 10.38 10.38)

* Mean SFT

10.32

V1.00

* User Name
* Date and Time
08/10/1998 09:32

* VERSE Equipment Identity
AA

* VERSE Software Version Number
0.90

* Last Successful Calibration Filename
AA000035.SUC

* Last Calibration Filename
AA000035.SUC

* SITE INFORMATION

* Location
"bevercote"

* ELR TID Mileage Yardage
BEV1 1100 4 0

* Rail
Right

* Rail Section
FB113A

* Rail Heights (mm)
157.19 157.19

* Rail Temperatures (C)
10.00 10.00 10.00

* Track Curvature (m)
2600.000000

* Track Cant (mm)
25.00

* Rail Fastening
Pandrol

* Sleeper type
F23

* Stressing Date
Unknown

* Comment
""

* SCRAGGING RUNS

* Number of Runs
3

* Run 1

* Time
09:35

* Number of Data Points
3

* Load (kN) Displacement (mm)
0.05 14.12
0.12 13.99
6.16 13.98

* Run 2

* Time
09:36

* Number of Data Points
2

* Load (kN) Displacement (mm)
0.06 13.95
1.08 14.04

* Run 3

* Time
09:36

* Number of Data Points
3

* Load (kN) Displacement (mm)
0.06 14.02
0.11 14.11
2.10 14.09

* Scragging Runs Status (0=Fail, 1=Success)
1

* MEASUREMENT RUNS

* Number of Runs
3

* Run 1

* Time
09:38

* Number of Data Points
51

* Load (kN)	Displacement (mm)
0.09	14.07
0.19	14.98
0.40	16.82
0.63	18.96
0.80	20.79
0.98	22.60
1.20	24.52
1.43	26.48
1.61	28.52
1.79	30.04
2.01	32.30
2.20	34.01
2.41	35.88
2.60	37.70
2.80	39.59
2.99	41.79
3.22	43.99
3.38	45.65
3.60	47.56
3.79	49.53
4.01	51.47
4.20	53.46
4.43	55.74
4.59	57.08
4.77	58.85
5.03	60.77
5.23	63.38
5.42	65.19
5.62	67.03
5.78	68.33
5.99	70.86
6.20	72.58
6.40	74.32
6.57	76.50
6.81	78.58
6.98	80.27
7.21	82.17
7.39	84.23
7.62	86.24
7.79	87.92
7.99	89.99
8.19	91.50
8.44	93.60
8.59	95.46
8.78	97.11
8.99	99.14
9.20	101.21
9.39	102.90
9.60	104.68
9.80	106.20
9.98	108.19

* Run 2

* Time
09:41

* Number of Data Points
51

* Load (kN)	Displacement (mm)
0.07	14.00
0.23	15.11
0.43	16.98
0.64	19.02
0.79	20.61
1.02	22.99
1.19	24.43
1.40	26.55
1.62	28.27
1.83	30.39
1.99	32.03
2.17	34.01
2.37	35.90
2.60	37.96
2.80	39.77
2.99	41.54
3.18	43.63
3.40	45.64
3.64	47.78
3.80	49.83
4.00	51.50
4.19	53.32
4.42	55.46
4.63	57.64
4.82	59.18
5.02	60.95
5.18	62.99
5.39	64.90
5.61	67.10
5.80	68.69
5.98	70.66
6.21	72.84
6.41	74.56
6.60	76.65
6.83	78.49
7.01	80.28
7.20	82.19
7.39	84.02
7.62	86.20
7.81	87.95
8.01	90.05
8.20	91.85
8.38	93.52
8.57	95.21
8.78	97.35
8.99	99.10
9.19	100.74

9.38 102.84
9.61 104.44
9.82 106.44
9.99 108.20

* Run 3

* Time
09:43

* Number of Data Points
51

* Load (kN) Displacement (mm)
0.04 13.95
0.20 14.81
0.42 16.85
0.62 18.62
0.80 20.74
0.97 22.04
1.22 24.45
1.42 26.44
1.63 28.34
1.79 30.03
1.97 31.81
2.21 33.97
2.37 35.66
2.63 38.11
2.80 39.77
2.98 41.42
3.22 43.83
3.38 45.46
3.60 47.74
3.77 49.47
4.03 51.70
4.18 53.21
4.40 55.43
4.60 57.06
4.81 58.93
5.04 61.44
5.21 62.95
5.40 64.81
5.58 66.76
5.81 68.89
6.01 70.91
6.20 72.62
6.40 74.77
6.59 76.66
6.81 78.70
7.00 80.27
7.19 82.39
7.39 84.26
7.65 86.11
7.80 88.18
8.02 90.01
8.19 91.92

8.40 93.86
8.58 95.48
8.77 97.43
9.01 99.46
9.20 100.82
9.39 102.92
9.59 105.03
9.80 106.64
9.99 108.25

* POST TEST TEMPERATURES
10.00 10.00 10.00

* Temperature within limits status (0=Fail, 1=Success)
1

* RESULTS

* Status (0=Not Calculated, 1=Calculated)
1

* Run 1 SFT

Low stress, May be in compression. (9.37 9.37 9.37)

* Run 2 SFT

Low stress, May be in compression. (9.39 9.39 9.39)

* Run 3 SFT

Low stress, May be in compression. (9.28 9.28 9.28)

* Mean SFT

9.33

APPENDIX B

VERTICAL RAIL STIFFNESS EQUIPMENT (VERSE®) TRIALS

Letter Report for Vortok International

Prepared by
John Tunna

TTCI
Transportation
Technology Center, Inc.
...a subsidiary of the Association of American Railroads
Pueblo, Colorado

P-00-048

AUGUST 2000

Table of Contents

1.0 INTRODUCTION

Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads (AAR), conducted tests on VERSE® (Vertical Rail Stiffness Equipment) to determine the accuracy of its measurements. VERSE is a system, developed by AEA Technology Rail, for non-destructively measuring the neutral temperature of continuously welded rail or CWR. The tests were conducted on July 18, 2000 at the Federal Railroad Administration's Transportation Technology Center, near Pueblo, Colorado.

When CWR is installed, it is normally stressed to a state of tension so that in hot weather there is a reduced risk of buckling. The temperature at which the rail moves from tension to compression is known as the neutral temperature. After a period of time in service, movement in the track and maintenance operations can change the neutral temperature. A means of monitoring the neutral temperature is required to successfully manage the risk of buckling (sun kinking). VERSE is the name given to a set of proprietary equipment that measures the neutral temperature in the rail.

1.1 BACKGROUND

The process of non-destructively measuring the neutral temperature of CWR involves unclipping a nominal 130 feet of rail at its joints, lifting the rail at the center of the unclipped length, and measuring the applied load and rail vertical displacement. The load/displacement data are recorded on a portable computer, along with details of the rail section, temperature, and site location. This information is then downloaded to a personal computer and analyzed to give the neutral temperature of the rail. The analysis uses the relationship between the rail's vertical stiffness and the axial force in the rail.

Before the VERSE lift is made, the rail is unclipped and supported on packing pieces 32 feet either side of the lifting point. An accurate result is achieved by averaging the readings from three successive lifts. The whole process typically takes 30 minutes to obtain a result for a single rail.

The VERSE equipment that was tested by TTCI is shown in Figure 1. The frame is fabricated from aluminum alloy with stainless steel pins at the points of rotation. The unit packs away into a box that fits into the trunk of a car.

Within the UK, VERSE has been established as an industry-approved method of non-destructive stress-free temperature (SFT) measurement. Railtrack, the UK track authority, approved the original VERSE method for carrying out SFT measurements on track with curvature less than 1.75 degrees.

Figure 1. VERSE Equipment in Operation

2.0 OBJECTIVE

The objective of the VERSE trials at TTCI was to provide independent verification of the accuracy of VERSE. The tests were designed so that the neutral temperature in the rail could be varied in a controlled manner. The neutral temperature was measured by VERSE and calculated independently from instrumentation installed and operated by TTCI.

3.0 PROCEDURES

The following subsections describe the test site, instrumentation, test procedure, and method of data analysis.

An important requirement for the test was that no rapid changes to the temperature of the rail should occur during the VERSE measurements. Figure 2 shows the rail temperature at the site for the three days prior to the tests. It can be seen that the rail temperature is most stable between 4 a.m. and 8 a.m. and between 12 p.m. and 4 p.m.. For this reason the tests were divided into two sessions, morning and afternoon. The procedures were slightly modified for the afternoon session. The differences are described in the next section.

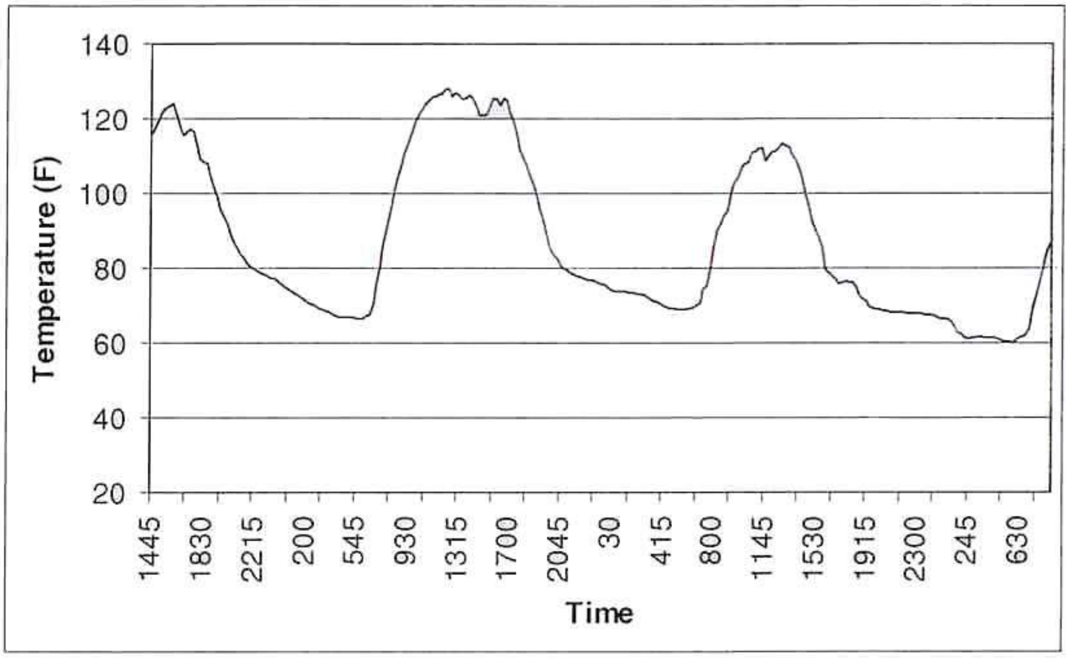


Figure 2. Variation of Temperature, Three Days Prior to Trials

3.1 SITE DESCRIPTION

The trials were carried out on the inside rail of the west tangent of TTC's Balloon Loop. This loop is mainly used to turn trains that are being tested on the Railroad Test Track. The Balloon Loop's west tangent is approximately 2,000 feet long. The rail there is 136RE section supported on Rockla concrete ties with Pandrol fastenings.

Figure 3 shows a schematic of the test site giving the relative positions of the strain gages and thermocouples. The rail was cut to provide a gap of 2 inches at one end of the site. Hydraulic rail tensors were set up over the cut gap to enable a range of neutral temperatures to be superimposed above the ambient rail temperature.

The site was measured out and marked up for the trials. Two positions (D and F in Figure 3) were marked up 32 feet either side of the VERSE lift point (E) at the center of the site. These were the positions for the rail support pieces. Two further positions (C and G) were marked up. These were the extremities of the VERSE lifted length, beyond which the rail was re-clipped after each load had been applied to the rail.

At positions A and H white paint was sprayed around the plastic insulator and the upper surface of the rail foot to provide a telltale. This would indicate if any relative movement took place between the rail and the tie once the rail was tensioned.

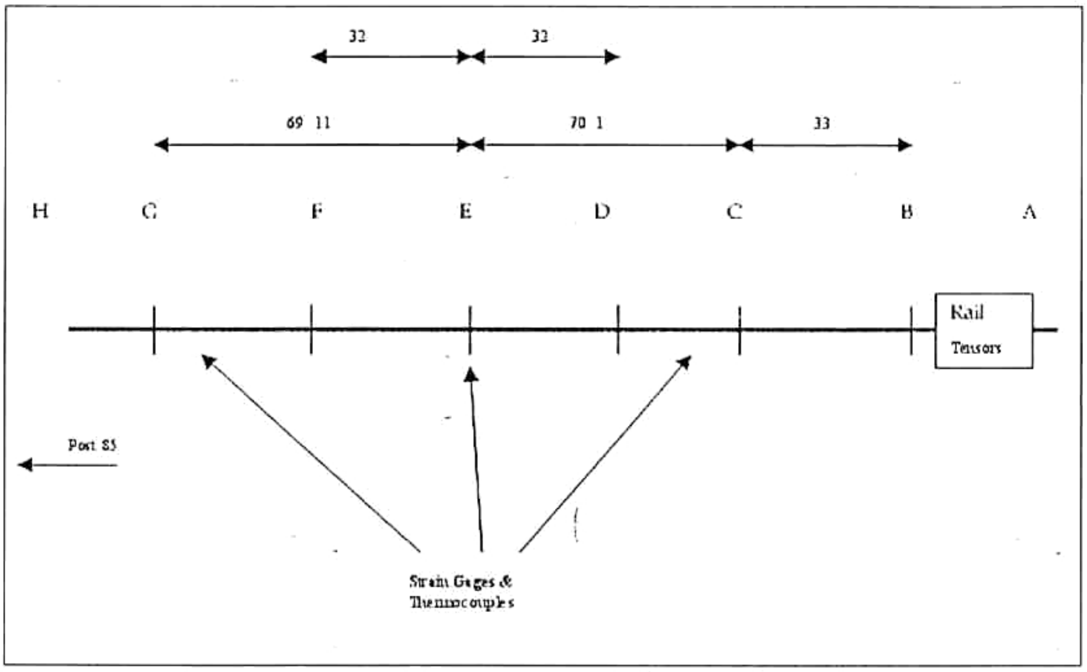


Figure 3. Schematic Site Diagram

3.2 INSTRUMENTATION

The instrumentation comprised the following channels:

- Three strain gage bridges measuring rail axial strain at locations C, E and G in Figure 3.
- Three thermocouples fixed under the foot of the rail at locations C, E and G in Figure 3.

An 8-channel, Campbell 21X data logger was used to record the signals from the instrumentation. During the morning session the data was logged at 1-minute intervals. In the afternoon the sampling frequency was increased to once every 15 seconds.

The most important strain and temperature location was at the center of the site (location E in Figure 3) where the VERSE measurements were taking place. The values at this location were used in the analysis. The strains and temperatures at the other locations were used to check that the rail was in a uniform stress and temperature state over the site length.

The VERSE equipment comes with its own portable data logger and results were downloaded to a desktop computer after each testing session. VERSE did not use any information from the rail tensors or strain gages; thus, independence of measurements was assured.

3.3 TEST PROCEDURE

The typical test procedure involved the following four steps:

1. Unclip the rail over the complete length of the test site and place the rail on rollers at every tenth tie.
2. Apply a set load on the rail with the rail tensors.
3. Remove the rollers between B and C, and between F and G (see Figure 3), and re-clip the rail over these lengths.
4. Make the VERSE measurements (as described previously) and start again at Step 1.

3.4 METHOD OF ANALYSIS

The VERSE results and the data files from the strain gages and thermocouples were transferred to a personal computer for analysis. The data analysis was performed using Microsoft Excel.

4.0 RESULTS

4.1 TEMPERATURE

The variation of temperature over the morning and afternoon testing sessions is shown in Figures 4 and 5. It can be seen that the objective of testing while the rail temperature was stable was not achieved during the morning tests. The temperature started to rise rapidly after 6:20 a.m. This needs to be taken into account when interpreting the test results. During the afternoon session, the temperature, although high, was more stable.

The three thermocouples gave reasonably similar reading, but by the afternoon the one at location C was reading 4 degrees Fahrenheit lower than the others were.

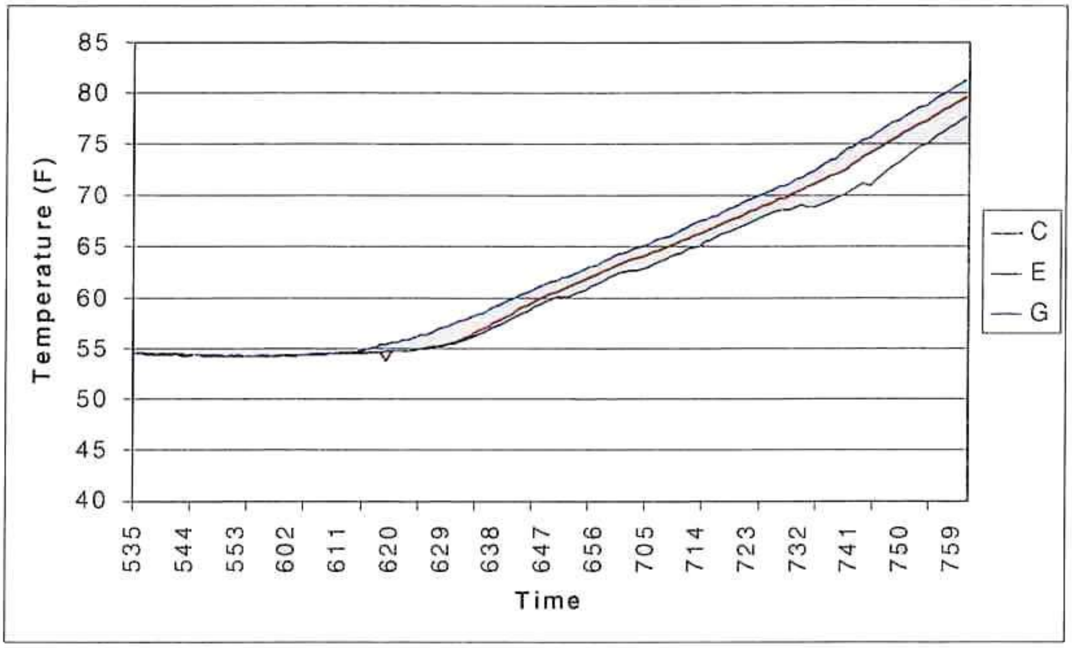


Figure 4. Variation of Temperature during Morning Session

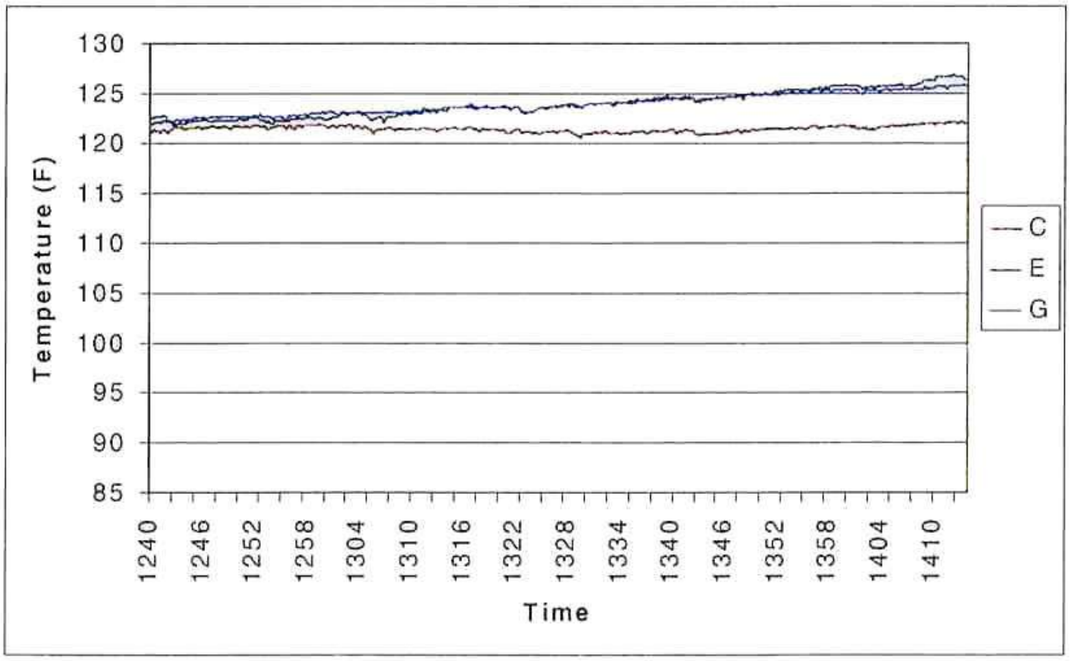


Figure 5. Variation of Temperature during Afternoon Session

4.2 RAIL LOAD

The variation of load in the rail during the tests is shown in Figures 6 and 7 where tension in the rail is shown as a negative load. It can be seen how the force in the rail dropped off after each load was applied by the tensors. In Figure 6, for example, a load of 40 tons (-80 kips) from zero was applied to the rail at 6:45 a.m. Over the next 10 minutes, during which time the VERSE measurements were made, the load went down to 20 tons (-40 kips).

This relaxation in load is thought to be due to the ties moving in the ballast over the anchor lengths. The telltales showed that the rail was not moving relative to the ties at the anchor lengths.

The reason why the data was sampled more frequently in the afternoon session was to ensure that the force could be obtained at the time of each of the three VERSE lifts.

Since the VERSE measurement involves lifting and lowering the rail, if the strain gages were not on the neutral axis of the rail, they would pick up the resulting bending strain. No sign of this behavior can be seen in Figures 6 and 7, giving confirmation that the strain gages are reading only axial strain.

The three strain gages gave similar readings at the start of the tests, but by the afternoon the one at location G was showing a compressive offset compared to the other two. This could be attributed to the relative movement that was thought to be occurring between the ties and the ballast at this end of the site.

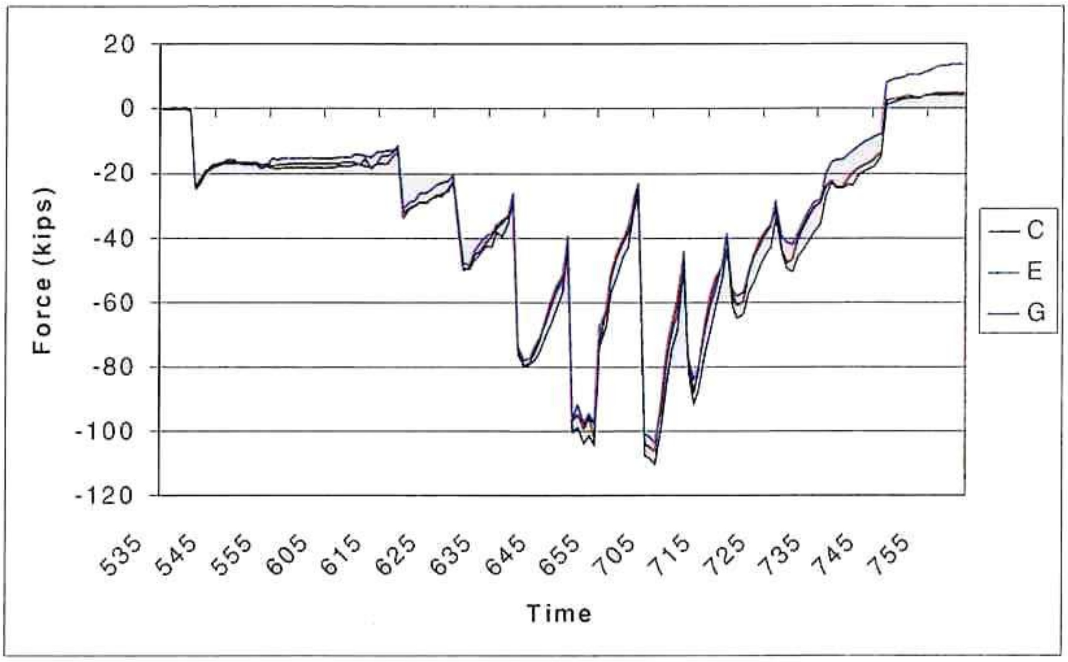


Figure 6. Variation of Rail Force during Morning Session

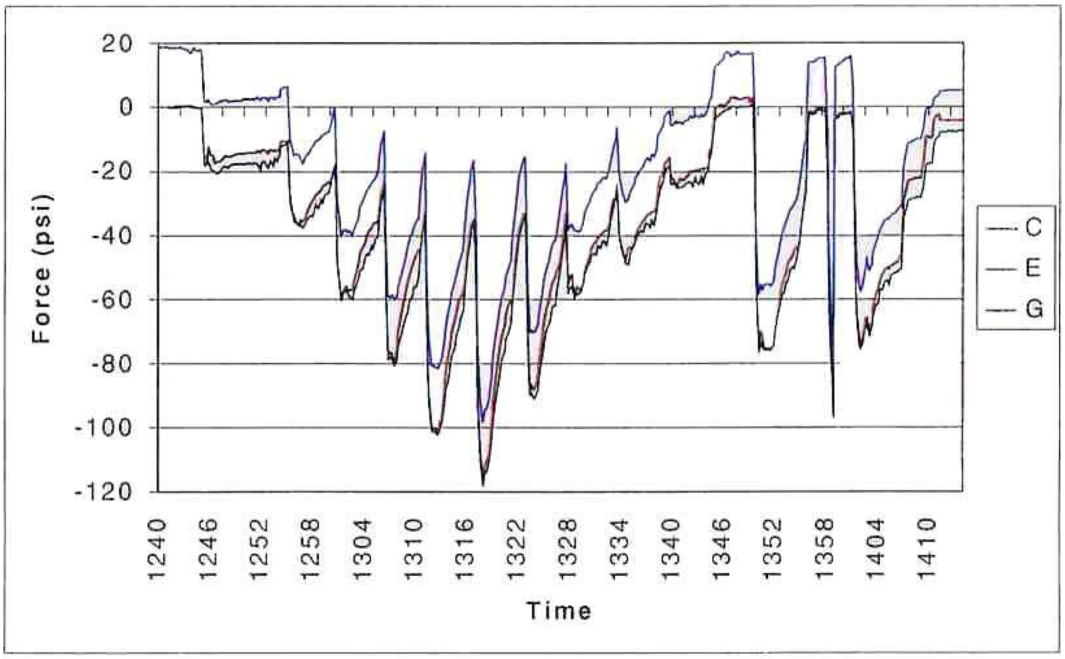


Figure 7. Variation of Rail Force during Afternoon Session

4.3 NEUTRAL TEMPERATURE

The neutral temperature of the rail for each test was calculated using the following formula:

$$T_n = \frac{(P_{start} + P_{end})}{2AE\alpha} + T_a$$

where: T_n = neutral temperature (°F), T_a = ambient temperature (°F), P_{start} = rail load at the start of the VERSE measurements (kips), P_{end} = rail load at the end of the VERSE measurements (kips), A = cross-sectional area of the rail (in^2), E = Young's modulus (psi) and α = coefficient of linear expansion (in/in/°F).

The results of these calculations are shown in Tables 1.

4.4 COMPARISONS

Table 1 also shows the neutral temperatures measured by VERSE and the differences (or errors) between VERSE and the calculated neutral temperatures (from TTCI measurements).

It can be seen from Table 1 that the range of the error is from 0°F to 5°F. This is shown more clearly in Figure 8, which shows the distribution of the errors. The statistics of this distribution are as follows (all values in °F):

Mean	2.79
Standard Error	0.28
Median	2.75
Standard Deviation	1.32
Range	4.84
Minimum	0.13
Maximum	4.97

The mean error is approximately 3°F. This could be explained by the cross sectional properties of the rail being different to those entered into the VERSE equipment. The rail height was measured and found to be 7.24 inches. This is less than the new rail height of

7.31 inches indicating that wear and/or grinding has taken place. VERSE uses the vertical, second moment of area of the rail section in its calculations. The small difference in rail height can make a significant difference to the second moment of area. VERSE tries to compensate for this effect, but the rules it uses are currently only calibrated for rail sections used in the UK. It is expected that a suitable compensation could be derived for North American rails.

Table 1. VERSE Neutral Temperature Test Results Compared to Calculated Results

Test	Start Load (kips)	End Load (kips)	Ambient Temp (°F)	Neutral Temp (°F)	VERSE Result (°F)	Error (°F)
No.	P_{start}	P_{end}	T_a	T_n	T_v	$T_v - T_n$
1	16.44	16.95	54.50	60.91	64.90	4.0
2	26.24	24.50	55.50	65.25	70.00	4.8
3	44.97	35.03	56.80	72.17	76.64	4.5
4	79.90	61.81	58.50	85.72	88.52	2.8
5	73.80	31.40	61.06	81.27	85.30	4.0
6	108.50	74.60	63.30	98.47	98.60	0.1
7	91.60	68.80	65.30	96.11	97.97	1.9
8	64.71	45.38	67.00	88.14	91.17	3.0
9	50.49	40.57	68.90	86.39	88.59	2.2
10	23.28	19.08	70.70	78.84	83.80	5.0
11	17.33	16.13	122.30	128.73	131.77	3.0
12	34.11	27.21	122.50	134.28	137.62	3.3
13	52.81	44.31	122.80	141.45	143.73	2.3
14	68.07	56.11	122.90	146.75	150.71	4.0
15	93.10	69.53	123.50	154.74	156.18	1.4
16	91.70	70.80	123.50	154.71	155.57	0.9
17	77.40	62.17	123.50	150.31	151.50	1.2
18	46.35	43.00	124.00	141.16	145.27	4.1
19	39.36	36.82	124.40	139.03	141.73	2.7
20	23.21	23.82	124.20	133.23	135.39	2.2
21	59.06	50.45	125.30	146.33	148.78	2.5
22	62.00	55.51	125.70	148.27	149.95	1.7

A comparison between the neutral temperature measured by VERSE and that derived from TTCI's instrumentation is shown in Figure 9. The morning session's results are the cluster in the lower left-hand corner. The afternoon session's results are in the top right-hand corner. Ideally all the results should lie on the solid, diagonal line. The two dashed lines are at 10°F either side of the solid line.

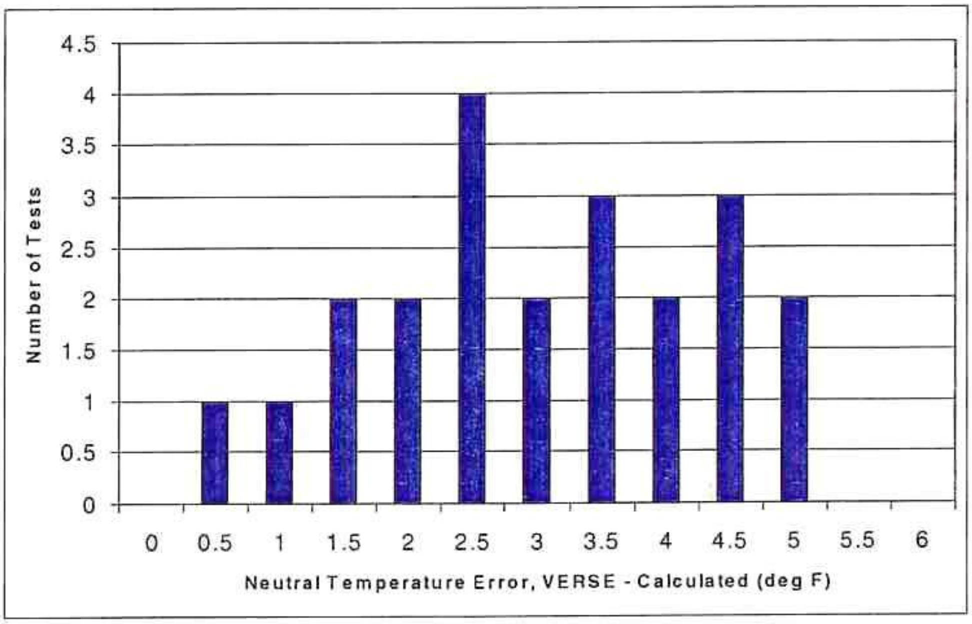


Figure 8. Distribution of VERSE Errors

Figure 9 clearly shows the bias error of approximately 3°F. All the results lie comfortably within +10°F of the calculated values. The results from the afternoon session are slightly more accurate than those from the morning session. This can be explained by the more frequent data sampling in the afternoon and the fact that the rail temperature was more stable then.

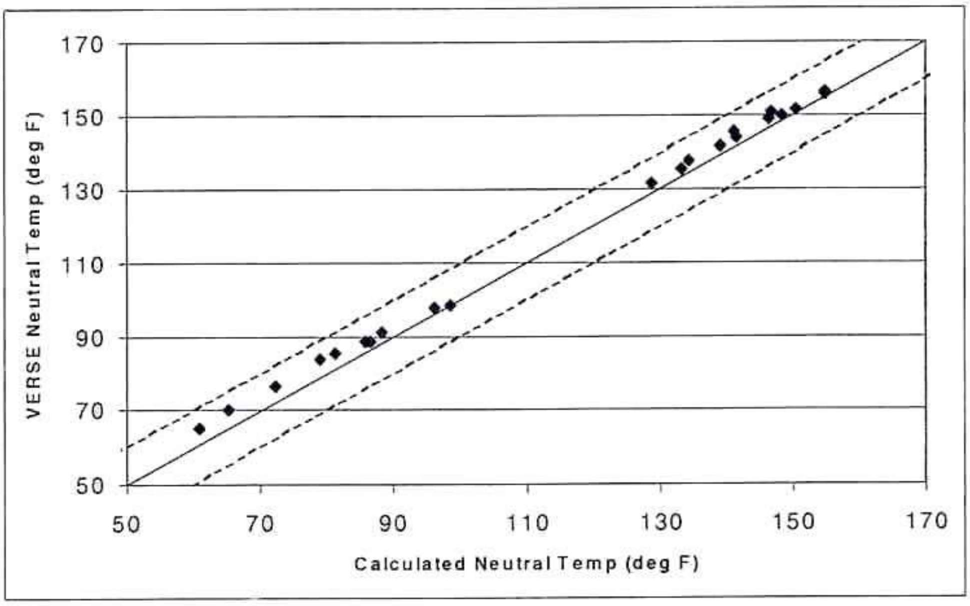


Figure 9. Neutral Temperature Comparisons

5.0 CONCLUSIONS

The VERSE equipment supplied by Vortok International has been tested at the TTCI in a series of controlled experiments designed to demonstrate its accuracy.

The tests involved applying a series of loads to a rail installed in track. For each load, the neutral temperature was measured by VERSE and independently checked by TTCI's instrumentation.

The results show that VERSE measured neutral temperatures that were consistently within 5°F of that calculated by TTCI. The VERSE results displayed a bias to be approximately 3°F higher than TTCI's results. It is thought that this bias could be due to incorrect section properties for the rail being entered into the VERSE calculations. If this bias error can be removed then the agreement between the two methods of measurement will be less than ±2.5°F.

Better results were achieved when the rail temperature was reasonably constant. The standard process of averaging the VERSE measurements over three lifts gives confidence that the stress in the rail is not changing significantly.

Tests were only made when the rail was in tension. VERSE cannot measure the neutral temperature when the rail is in compression.

Disclaimer:

APPENDIX C

Railway Research Institute, Section of Railway Track Service
Hlaváčova 206, 530 29 Pardubice

Research Task Letter Report

Empirical Assessment of Accuracy of Neutral Temperature Measurements of Continuously Welded Rail by means of VERSE Equipment.

Pardubice, April 2001

TABLE OF CONTENTS

1 INTRODUCTION

The Railway Research Institute Prague (VUZ), a subsidiary of Czech Railways (CD), carried out tests on VERSE (Vertical Rail Stiffness Equipment) for the purpose of empirical determination of its measurement accuracy. VERSE is a method for non-destructive measuring the true neutral temperature of continuously welded rails (CWR).The tests were conducted on 20 March 2001 on the Small Test Circuit of the Railway Research Institute at Cerhenice.

When CWR is installed, the long welded rails are clipped at temperature ensuring its stability at higher temperatures as well as its reliability in winter period (rail cracks risks). CWR should, be at the time of clipping, tension-free (unless the tension is simulated, e.g. by rail tensors)i.e. the „clipping“ temperature is identical to the neutral one. It is not always easy to reach the above mentioned conditions (existence of so called inner tensions of rails which appear during the manufacturing process etc.). Operation influences too may cause the tension „moving“ which is followed by variations in the recorded neutral temperature.

The knowledge of the neutral temperature is a significant factor for ensuring reliability and safety of CWR installation. Frequently applied destructive methods are too time-consuming and expensive (CWR must be cut) and require more extra-works and on top of that this method can be unreliable because the exactness of the measurement can be influenced by the sleepers moving in the ballast at the anchor lengths. In service operation, each introduced method enabling to determine the neutral temperature of CWR in a non-destructive way is welcome.

VERSE is a patented name of an equipment able to measure a true neutral temperature of a jointless track.

2 VERSE TAKING MEASUREMENTS PROCEDURE

The non-destructive measuring of CWR neutral temperature include :

- unclipping the 30m length of rail
- lifting the lose rail at its center
- measuring the applied force and the vertical deflection

The force and deflection data is downloaded to a portable PC together with the site information, its geography and temperature of the rail. This data is then transferred to a PC, analysed, and finally the neutral temperature is calculated. The analysis is based on the relations between the rail vertical stiffness and its axial force.

The rail is, prior to its lifting by means of VERSE, unclipped and placed on sliding pads 10m either side from the lifting point. The exact result is achieved by averaging the measured values from 3 successive lifting operations. The whole operation, during which the results of 1 rail are obtained, usually takes about 30 min.

The VERSE equipment tested by VUZ is shown on photographs in the appendix to this report. The frame is made from aluminium alloy with stainless pins at the points of rotation. The equipment can be put into a box the dimensions of which enable car transport.

VERSE method has been introduced in the UK as an industry-approved way of measuring the neutral temperature.

3 PURPOSE OF TESTS

The purpose of VERSE tests carried out by VUZ was an independent empirical assessment of the accuracy of the equipment. The test methodology was intended so that the axial force in the rail could be varied in a controlled manner.

The neutral temperature was measured by VERSE independently of the instrumentation operated by VUZ engineers.

4 TESTS METHODOLOGY

The site, instrumentation, test procedures and data analysis are described in the following paragraphs.

An important precondition of gaining relevant values was a continual course of rail temperature without fluctuation. The variation of the rail temperature of the test section during measuring is shown in figure 4.1. There were stable climatic condition with minimum temperature fluctuations on the Small Test Circuit Cerhenice in this period. For this reason, splitting measuring process into the morning and afternoon sessions, or adapting standard test procedure, were not necessary.

4.1 SITE DESCRIPTION

The tests were conducted on the outer rail, kilometrage 5.2 of the Small Test Circuit staight section of the Railway Research Institute at Cerhenice. Its total length is 724m. This track is particularly used for testing heavy-duty railway vehicles.

The railway superstructure consists of UIC-60 rails supported on SNCF bi-block sleepers with NABLA rail fastening.

A schematic drawing of the site, with strain gauge bridges positioning, is shown in figure 4.2. The rail was cut, and the gap of 18mm was formed at one end of the test section. A rail tensor was installed in this point to apply the load and so simulate CWR neutral temperatures higher than those at the time of taking measurements.

The site was measured out and marked up for testing. On either side of the VERSE measuring point (E position in figure 4.2) two further positions (D and F) were marked up in 10m distances. In this section the rollers were installed. Two more points (C and G) set the limits for the maximum length of rail which is to be lifted by the VERSE equipment. After each axial force had been applied, the rail was re-clipped. The rail of the test section was at its quarters chalkmarked on the upper surface of its foot to provide a telltale. This would indicate any relative movement between the rail and the sleepers once the rail was tensioned.

4.2 INSTRUMENTATION

The following instrumentation was used during the VUZ measuring :

- 3 pieces of strain gauges measuring the axial forces of the rail in C, E and G positions (see figure 4.2)
- a digital contact thermometer to measure the rail temperature in above mentioned points.

The strain gauges used for measurements were of HBM type 10/120 LY 41, length 10mm K-factor 2. Having ground and cleaned the defined spots on the neutral axis of the rail, opposing strain gauges were stuck on in pairs. On supplying 2 compensation strain gauges a complete measuring bridge was thus completed. To process the signals from the strain-gauges, the measuring bridge HBM KWS 673, response set to 1m V/V, was used. The values were recorded by the data logger and analysed by PC.

The data on the axial forces intensity was sampled in 1min. intervals.

The rail temperature was measured in 5min. intervals during the whole process of measurements (see figure 4.1). The development of temperature, as well as the axial force at successive measurements, was stable with minimum fluctuation.

The data obtained in the middle if the section (E position – see figure 4.2), where VERSE measurements were taken, were used for analysis. The data of other positions were used to assess stability of temperature and strain conditions on site.

VERSE equipment has its own portable data logger from which the values were transferred to a deskop computer after each test session. No information from the rail tensors or strain gauges was used during VERSE measurements.

4.3 TEST PROCEDURE

The test procedure comprises the following steps :

- Unclip the rail over the complete length of the test site and place the rail on rollers at every tenth sleeper.
- Apply a set load on the rail with the rail tensors.
- Remove the rollers between B and C positions and between F and G (see figure 4.2), and re-clip the rail over the lengths.
- Make the VERSE measurements; on completion, the whole procedure is repeated.

4.4 DATA ANALYSIS

The VERSE measurements results and strain gauges data files were downloaded to the PC to be analysed. The data analysis was performed using Microsoft Excel.

5 RESULTS

5.1 TEMPERATURE

The variation of temperature during the measurements is shown in figure 4.1. It can be seen that the temperature of rail was stable with maximum variation of 2°C during the whole process of measurement. This value is influenced by a lower temperature early in the morning; after 11a.m. the temperature was more stable showing the variation of 1,0°C over the remaining period of measuring.

5.2 VARIATION OF AXIAL STRAIN IN RAIL

The variation of load in the rail is shown in figure 5.1. The axial force in the rail increased after each controlled extension of the rail by the tensors. No considerable decrease in axial force, e.g. due to the relative movement of the rail to the sleepers, was observed during a session of measurement (neither the relative movement of the rail to the sleepers nor the movement of the whole rail-sleepers-frame).

Since the VERSE measurement involves lifting and lowering the rail, it is necessary to position the strain gauges on the neutral axis of the rail, otherwise the obtained values would be influenced by the bending strain corresponding to the time of lifting the rail. No sign of this phenomenon is, according to figure 5.1 evident, which confirms that it is only axial forces data obtained by means of the strain gauges.

The strain gauges values are in fact identical without many differences; during the repeated loading of the rail neither the relative movement of the rail to the sleepers nor the shift of the whole rail frame were observed.

5.3 CALCULATION OF NEUTRAL TEMPERATURE

The neutral temperature of the rail for each test was calculated using the following formula :

$$t_u = \frac{P_p + P_k}{2 \, . \, E \, . \, F \, . \, \alpha} + t_k \quad [°C] \qquad [1]$$

where : t_u = neutral temperature [°C]
t_k = ambient temperature (rail temperature) [°C]
E = Young´s modulus (modulus of elasticity) [Pa]
F = cross-sectional area of the rail [m^2]
P_p = axial force (rail load) at the start of the VERSE measurements [N]
P_k = rail load at the end of the VERSE measurements [N]
α = coefficient of linear expansion [K^{-1}]

The results of these calculations are shown in table V.1

Test	Start Load	End Load	Ambient Temp.	VUZ Neutral Temp.	VERSE Neutral Temp.	Difference t_{U2}- t_{U1}
No.	P_P [N]	P_K [N]	t_K [°C]	t_{U1} [°C]	t_{U2} [°C]	[°C]
1	317,30	313,68	5,0	21,997	22,604	0,6
2	86,40	88,06	5,5	10,199	10,080	- 0,1
3	129,60	129,00	7,0	13,966	13,106	-0,9
4	193,30	191,08	7,0	17,354	17,269	-0,1
5	283,50	274,45	7,0	22,030	21,056	-1,0
6	317,30	313,68	7,0	23,997	24,321	0,3
7	60,00	67,24	6,5	9,927	8,476	-1,5
8	132,13	132,13	6,0	13,118	14,412	1,3
9	255,80	255,80	6,0	19,781	19,733	0,0
10	302,40	302,40	6,0	22,292	22,590	0,3

Table V.1 Results of calculations

5.4 COMPARISON OF TEST RESULTS

Table V.1 shows the neutral temperatures measured by VERSE and the differences between these values and the values from the VUZ strain gauge measurements.

The range of the differences is from -1,5°C to +1,3 °C. The figure 5.2 shows the distribution of the differences.

Statistics of the distribution :

- minimum :	-5
- maximum :	1,3
- arithmetic mean :	-0,1014
- weighted arithmetic mean :	-0,1268
- median :	-0,0666
- modus :	-0,1 or 0,3
- harmonic mean :	-0,2862
- geometric mean :	0,3677
- variation range :	2,7
- average deviation :	0,5998
- relative average deviation :	-5,9121
- dispersion :	0,5951
- standard deviation :	0,7714

The rails of the test site did not show any wear, and so the rail cross sections were comparable to standard profiles measured by the VERSE equipment. This is the reason why the range of the differences of this statistic set is comparatively small. This fact is extremely important because VERSE uses the value of the cross-sectional moment of inertia with respect to vertical rail axis [J_y]. It is very useful that the VERSE computer is programmed to také rail wear into account. The VERSE procedure includes its measurement and its input into the computer. The values of differences would have probably been lower, if both the test teams used synchronized thermometers to determine the rail temperatures. With regard to the independence of making measurements and obtaining the data, it was impossible to be carried out.

Figure 5.3 shows a graphical comparison of the results measured by the VERSE equipment and by the VUZ strain gauges. If the results of the measurements were ideal, all the dots should lie on the solid diagonal line. The measured results lie comfortably within 3°C either side of the solid line. The mentioned interval is a range of the neutral temperature differences (±3°C) allowed according to CD specifications for installing long-welded rails.

The graph shows that all the results measured by the VERSE equipment lie within the mentioned interval.

6 CONCLUSIONS

The VERSE equipment owned by VORTOK International was tested by the Railway Research Institute Prague in a series of controlled experiments with the aim to prove its accuracy. During the tests, the rail was loaded by applying varied axial forces to the rail by means of the rail tensors. After each load, the simulated neutral temperatures were measured by the VERSE equipment and independently by the VUZ instrumentation. The results show that the VERSE equipment measured the neutral temperatures within the maximum error from −1,5°C to +1,3°C. These values lie within the allowed range of errors according to CD regulations for installing CWR.

Comparatively low values of the errors reflex the fact that the rails of the site did not show much wear which means that the rail cross-section areas were comparable to the ones measured by VERSE before (see par.5.4). Even fairly stable ambient temperature contributed undoubtedly to the favourable results. The constant course of tension during the period of successive measurements is a consequence of this fact.

The tests were only carried out when the rail was in tension, it means that only tension axial forces were in action in rail, and the simulated neutral temperature was higher than the rail ambient temperature. VERSE cannot measure the neutral temperature when the rail is in compression (i.e. when the neutral temperature is lower than the ambient temperature at the time of making measurements).

Vortok International Verse Equipment

VUZ Strain Gauges

Time	Temp.
10:45	5.5
10:50	6.0
10:55	7.0
11:00	7.0
11:05	7.0
11:10	7.0
11:15	7.0
11:20	7.0
11:25	7.0
11:30	7.0
11:35	7.0
11:40	7.0
11:45	7.0
11:50	7.0
11:55	7.0
12:00	7.0
12:05	7.0
12:10	7.0
12:15	7.0
12:20	7.0
12:25	7.0
12:30	7.0
12:35	7.0
12:40	7.0
12:45	7.0
12:50	7.0
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13:05	7.0
13:10	6.5
13:15	6.5
13:20	6.5
13:25	6.5
13:30	6.5
13:35	6.5
13:40	6.5
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13:55	6.5
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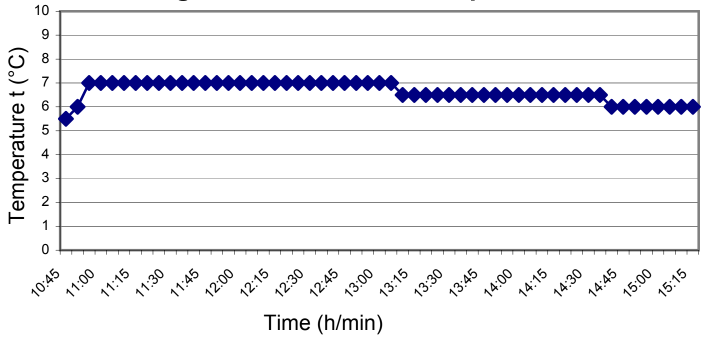
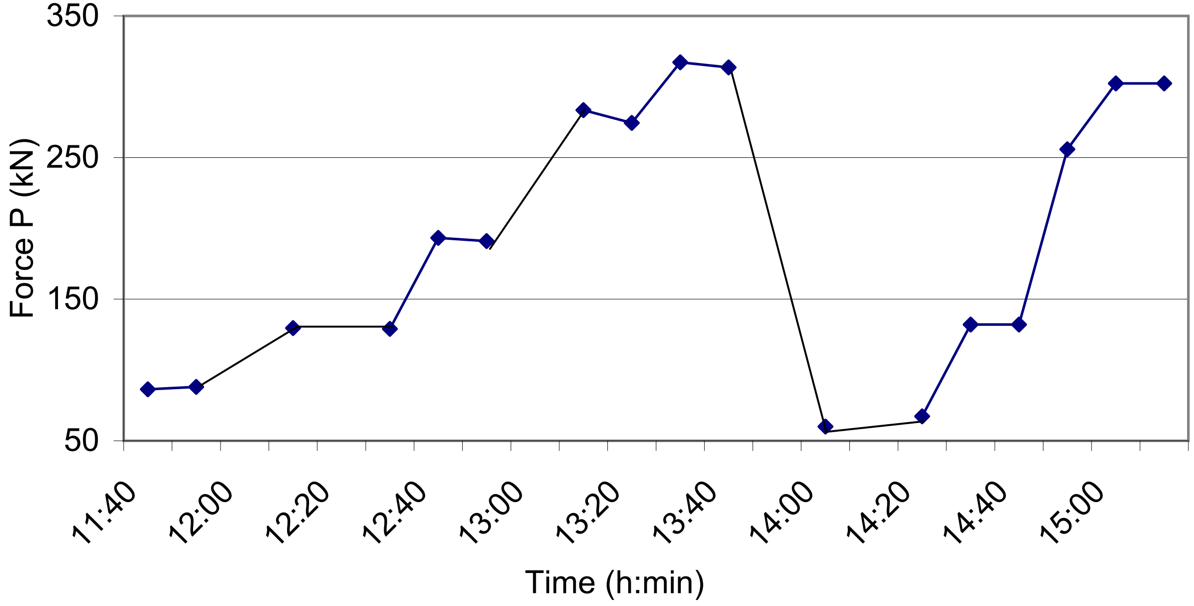
14:05	6.5
14:10	6.5
14:15	6.5
14:20	6.5
14:25	6.5
14:30	6.5
14:35	6.5
14:40	6.0
14:45	6.0
14:50	6.0
14:55	6.0
15:00	6.0
15:05	6.0
15:10	6.0
15:15	6.0

Fig.4.1 Rail Ambient Temperature

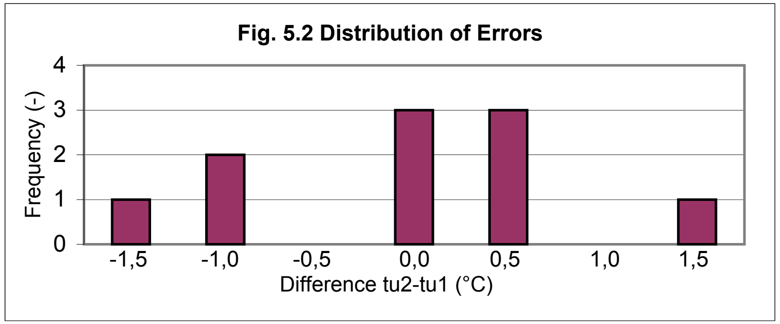


TIME	FORCE
11:40	86.4
11:50	88.06
12:00	
12:10	129.6
12:20	
12:30	129
12:40	193.3
12:50	191.08
13:00	
13:10	283.5
13:20	274.45
13:30	317.3
13:40	313.68
13:50	
14:00	60
14:10	
14:20	67.24
14:30	132.13
14:40	132.13
14:50	255.8
15:00	302.4
15:10	302.4

Fig. 5.1 Variation of Rail Force during Simulation of Neutral Temperature



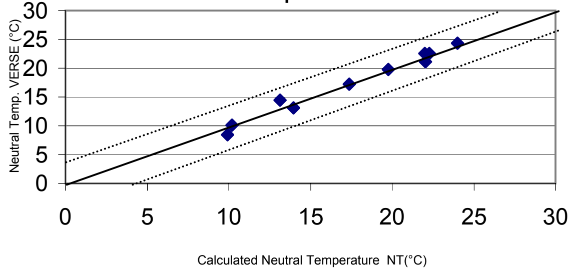
Error	Frequency
-1.5	1
-1.0	2
-0.5	0
0.0	3
0.5	3
1.0	0
1.5	1



Test	Start Load	End Load	Ambient Rail Temp	VUZ NT	VERSE NT	Error t_{u2}-t_{U1}	¦xi-x¦	(xi-x)2
č.	Pp [N]	Pk [N]	t_k [°C]	t_{U1} [°C]	t_{U2} [°C]	[°C]		
1	317.30	313.68	5.0	21.997	22.604	**0.6**	0.7086	0.502125
2	86.40	88.06	5.5	10.199	10.080	**-0.1**	0.0180	0.000325
3	129.60	129.00	7.0	13.966	13.106	**-0.9**	0.7585	0.575348
4	193.30	191.08	7.0	17.354	17.269	**-0.1**	0.0163	0.000266
5	283.50	274.45	7.0	22.030	21.056	**-1.0**	0.8722	0.760677
6	317.30	313.68	7.0	23.997	24.321	**0.3**	0.4256	0.181142
7	60.00	67.24	6.5	9.927	8.476	**-1.5**	1.3500	1.822624
8	132.13	132.13	6.0	13.118	14.412	**1.3**	1.3950	1.946077
9	255.80	255.80	6.0	19.781	19.733	**0.0**	0.0534	0.002848
10	302.40	302.40	6.0	22.292	22.590	**0.3**	0.3998	0.159859
suma						-1.0		6.0
minimum						-1.5		
maximum						1.3		
arithmetic mean						-0.1014		
weighted arithmetic mean						-0.1268		
median						-0.0666		
modus						either -0,1 or 0,3		
harmonic mean						-0.2862		
geometric mean						0.3677		
variation range						2.7		
average deviation						0.5998		
realative average deviation						-5.9121		
dispersion						0.5951		
standard deviation						0.7714		

TEST	VUZ NT	VERSE NT
č.	t_{U1} [°C]	t_{U2} [°C]
1	21.997	22.604
2	10.199	10.080
3	13.966	13.106
4	17.354	17.269
5	22.030	21.056
6	23.997	24.321
7	9.927	8.476
8	13.118	14.412
9	19.781	19.733
10	22.292	22.590

Fig. 5.3 Graphic Comparsion of Neutral Temperatures



APPENDIX D

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°. 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 Kenkyujo 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:
11.5×10^{-6}
As the readings are $m \times 10^{-6}$ the readings and coefficient of expansion are in the same units.

SFT = Strain change/ coefficient of expansion + actual temperature of rail

((176 – 172)/2 +172)/ 11.5 + 12.4°C = 27.53°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 usual 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.

ii. 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.
iii. 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.

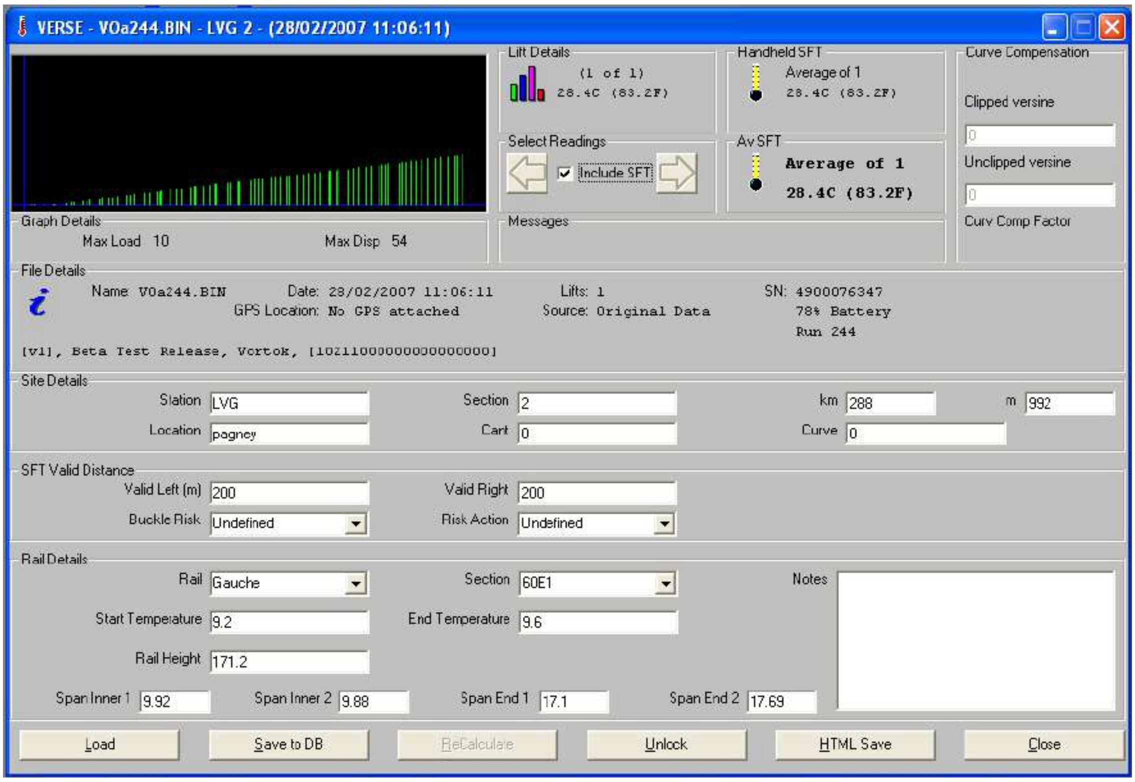
c. The tests demonstrate conclusively that the apparent change in SFT seen by SNCF during their measurements was due to a rapidly changing rail surface temperature and that the measurements were not taken under recommended conditions.

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.

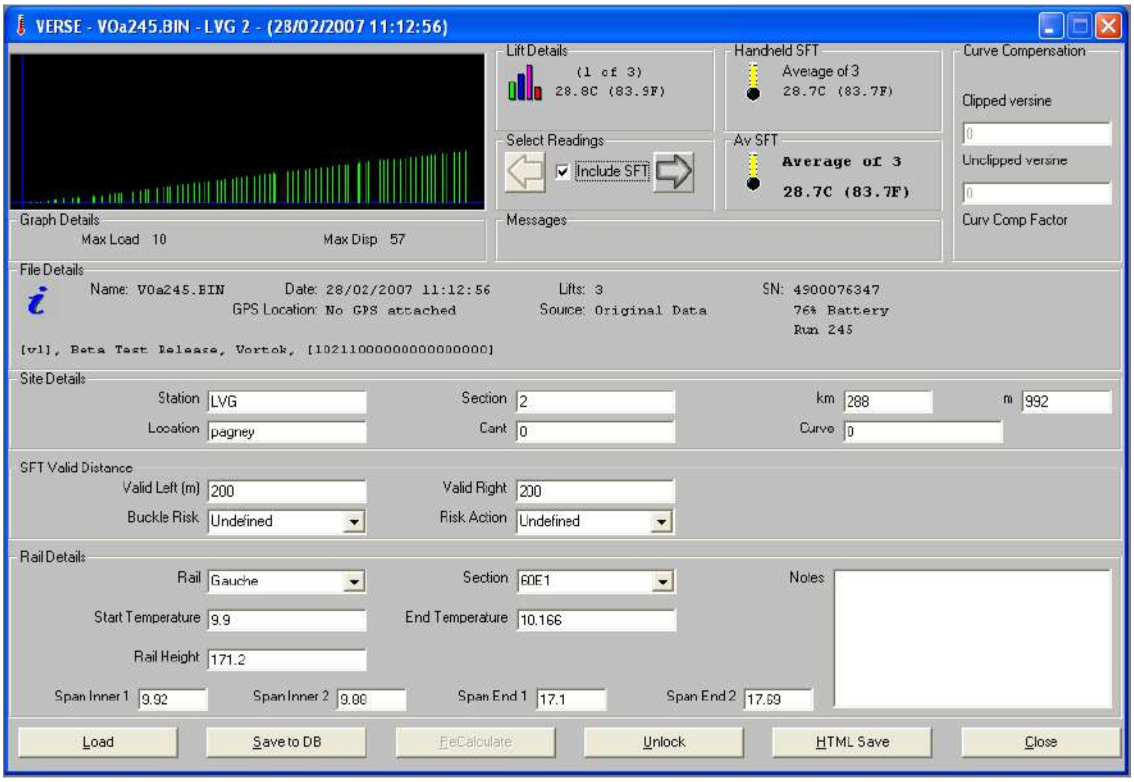
Appendix

Measurement 1

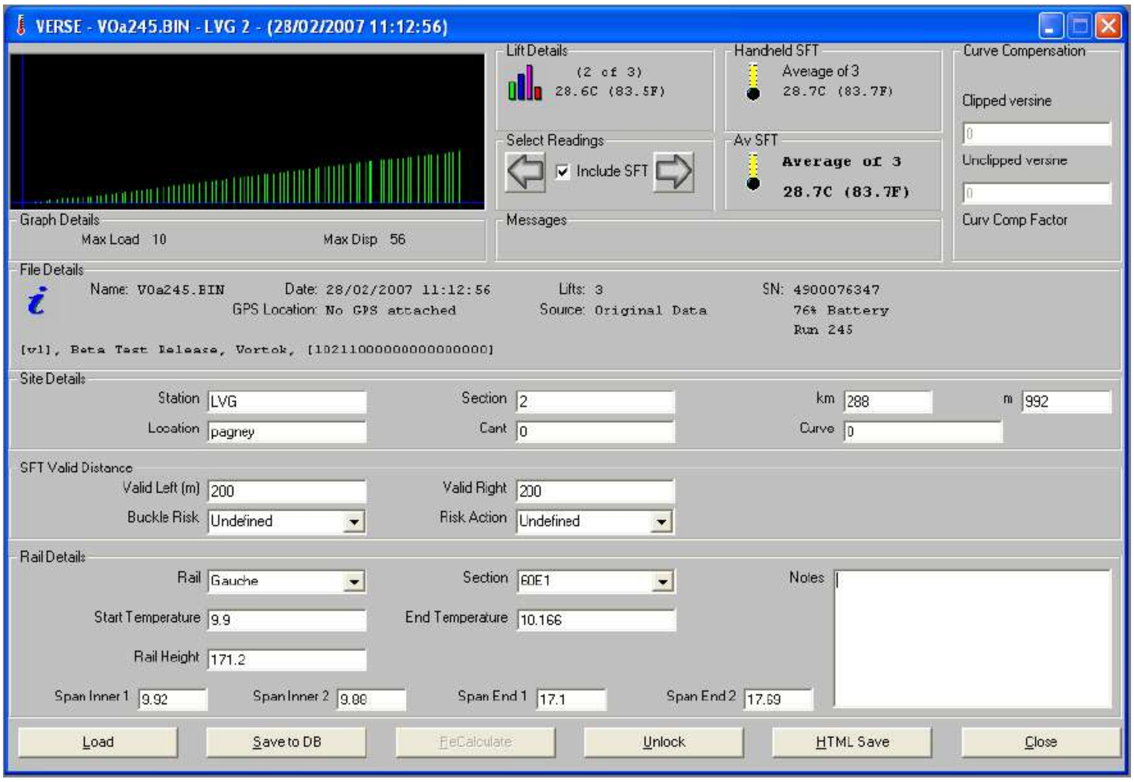


Measurement 2

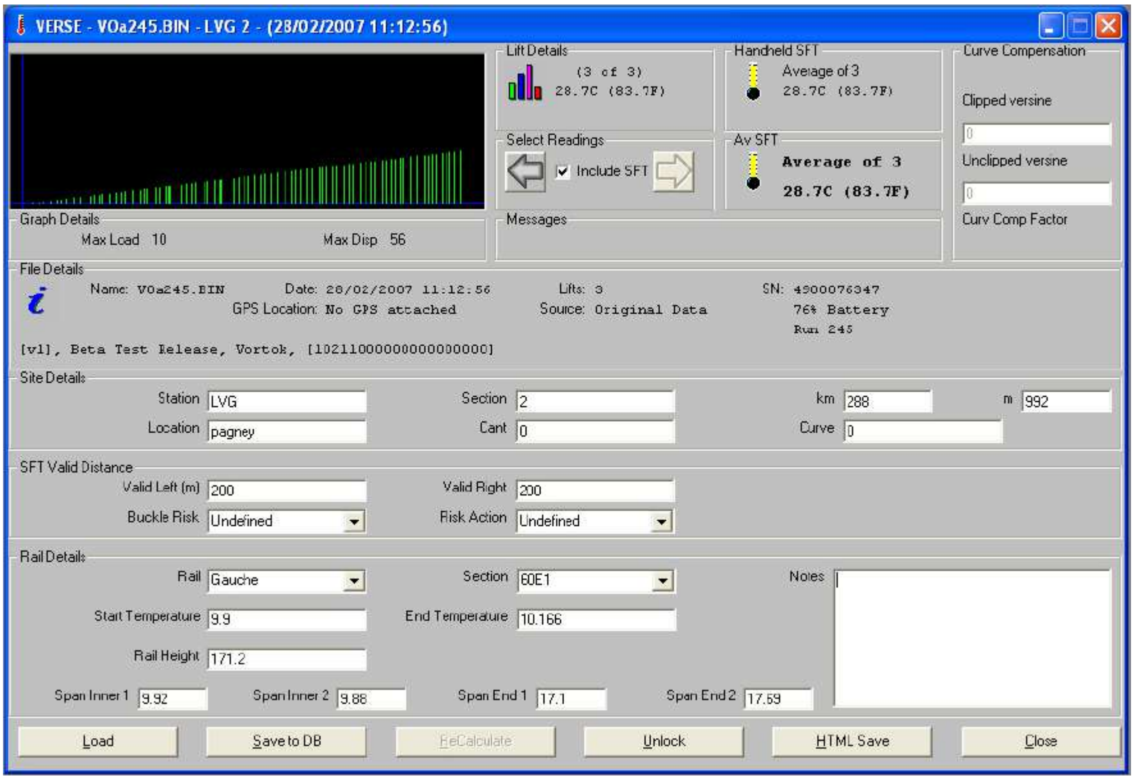
Lift 1



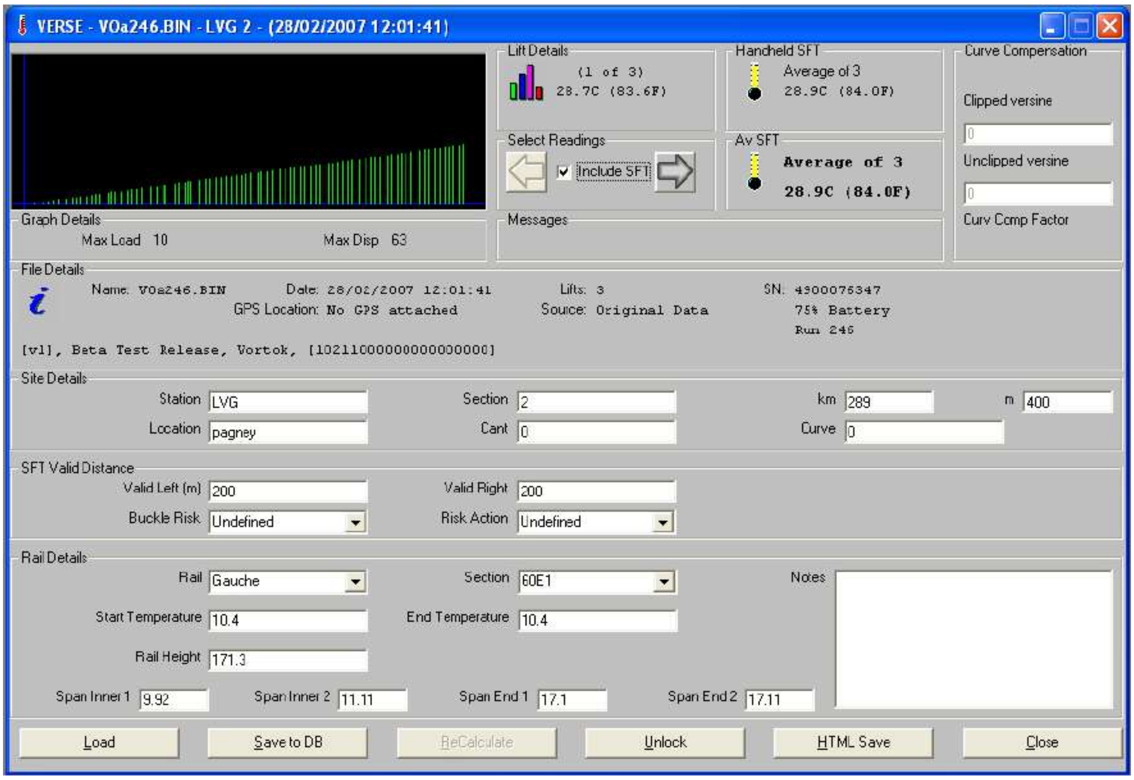
Measurement 2
Lift 2



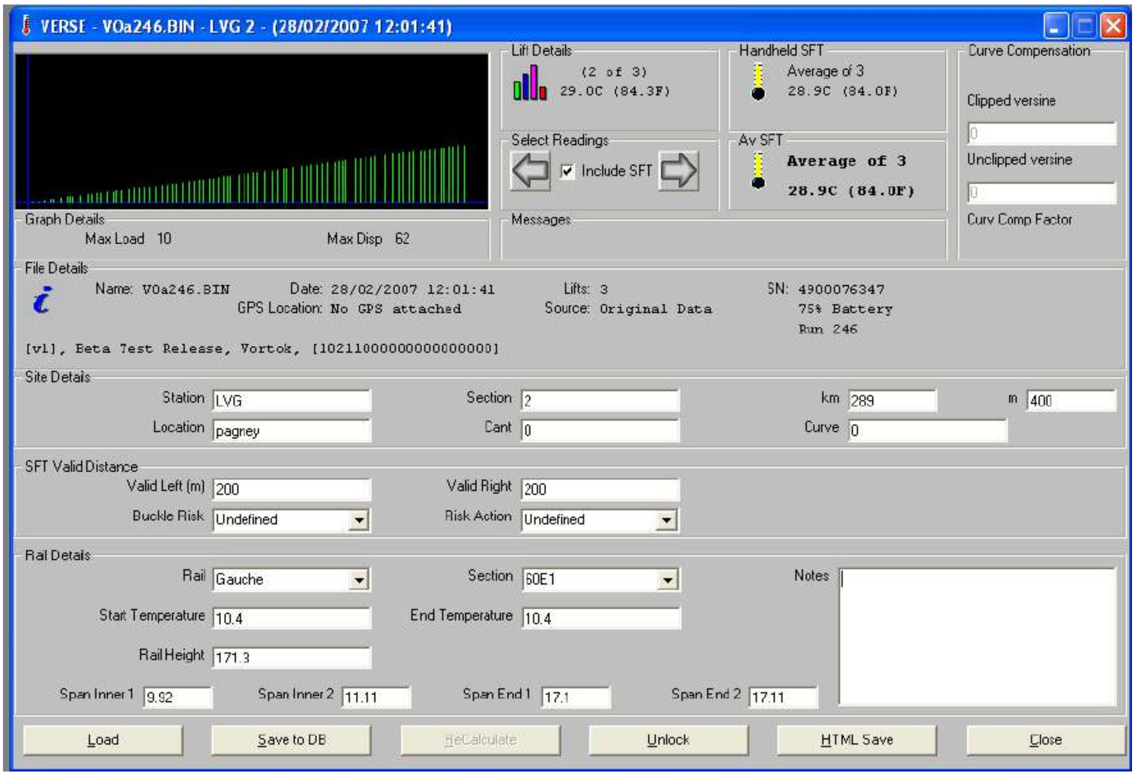
Measurement 2
Lift 3



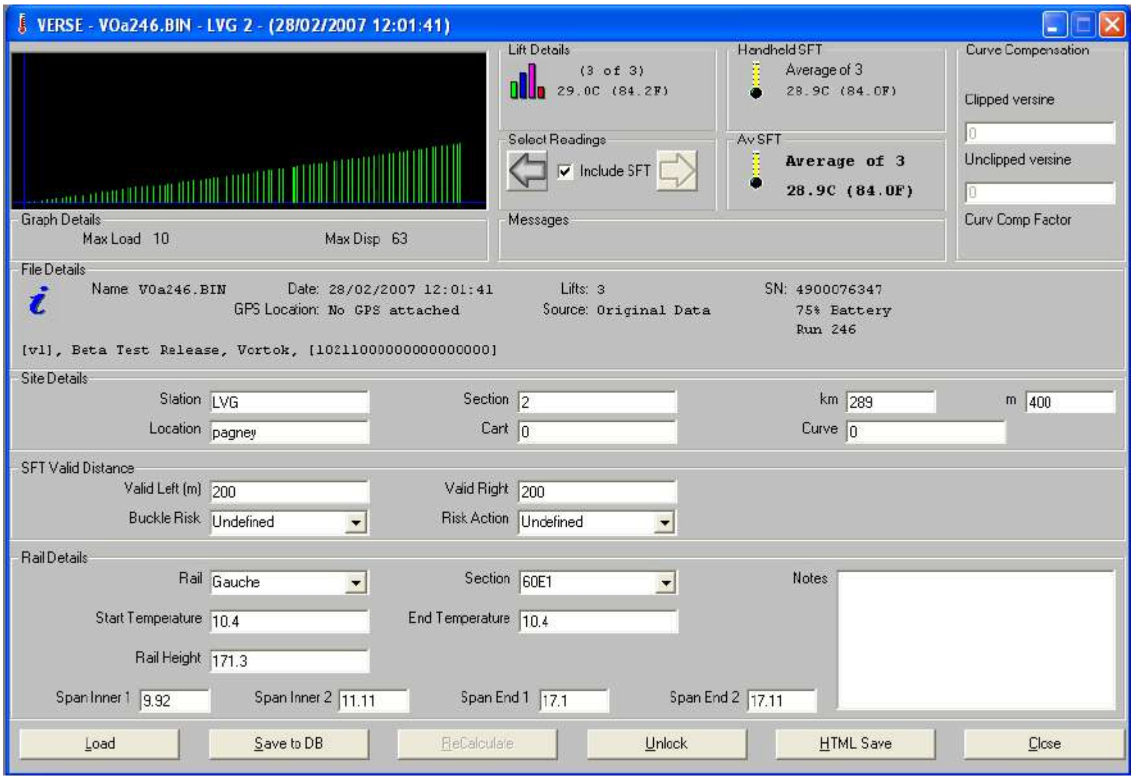
Measurement 3
Lift 1



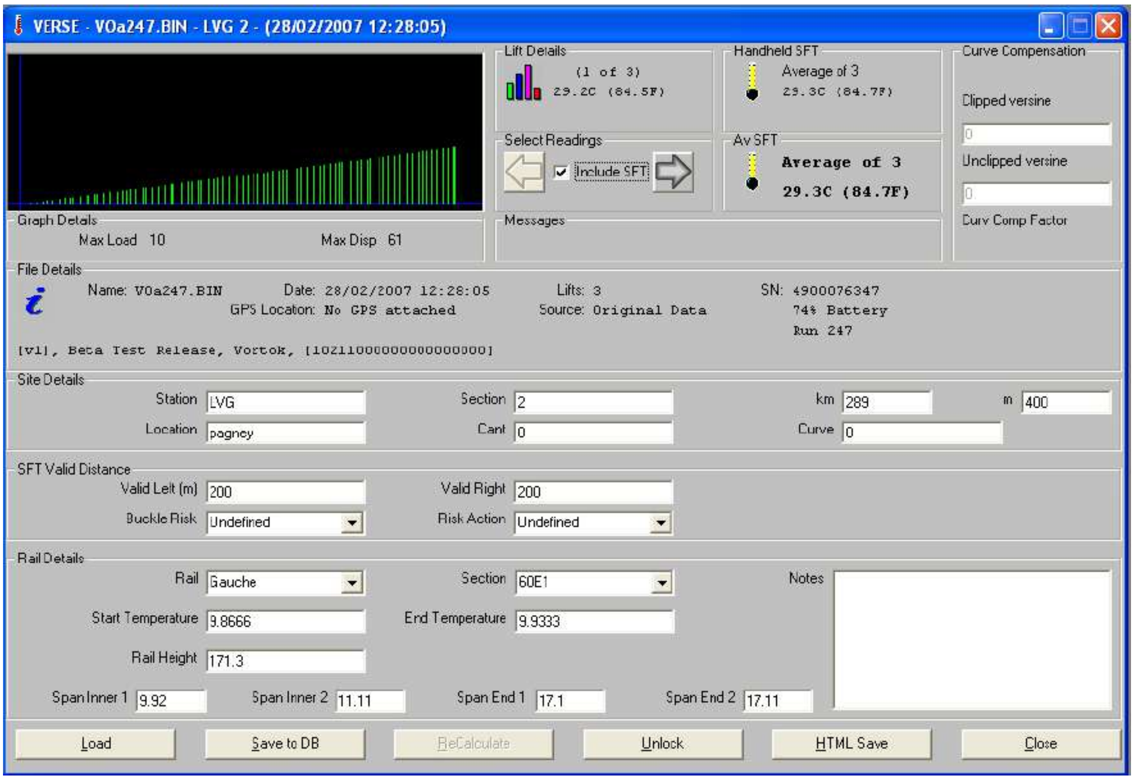
Measurement 3
Lift 2



Measurement 3
Lift 3



Measurement 4
Lift 1



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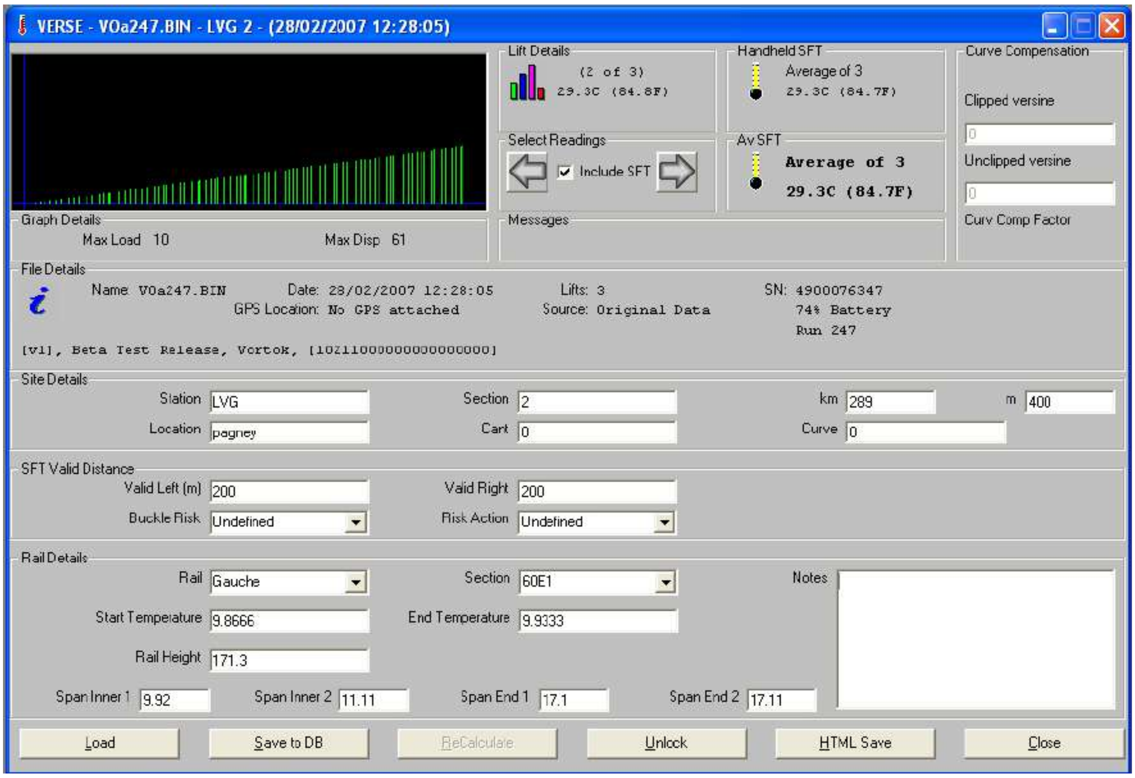
Lift 2



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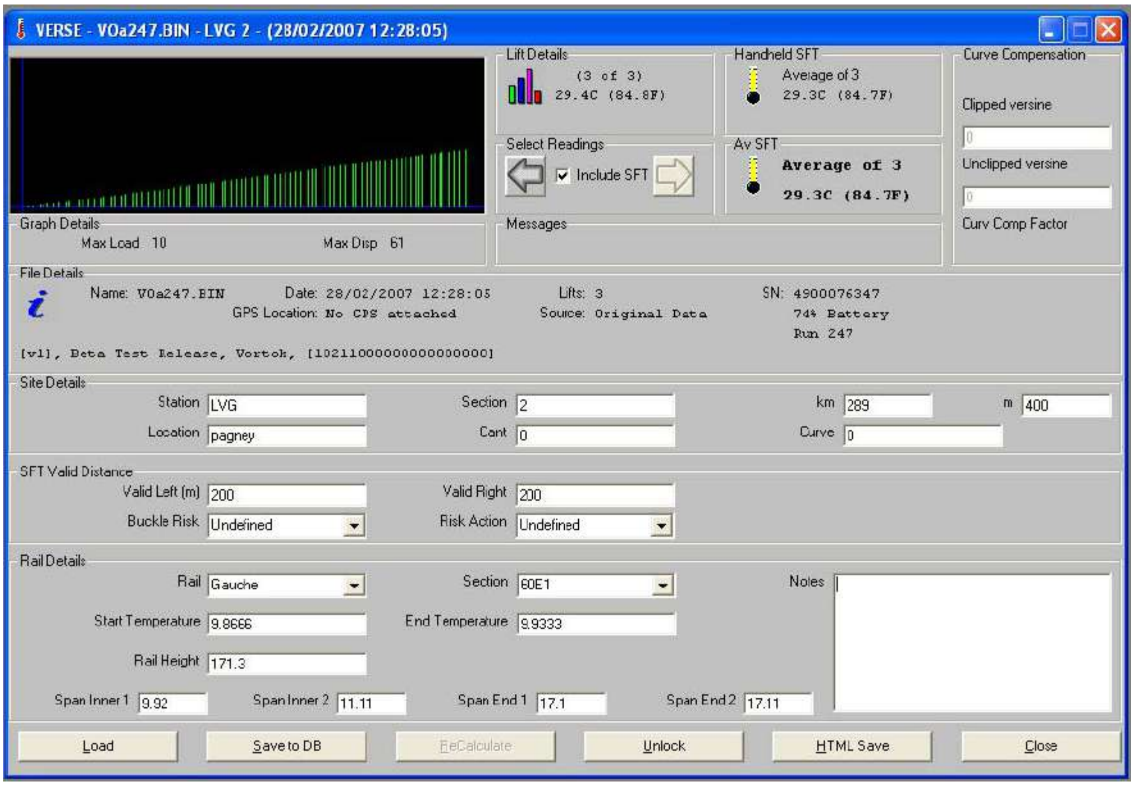
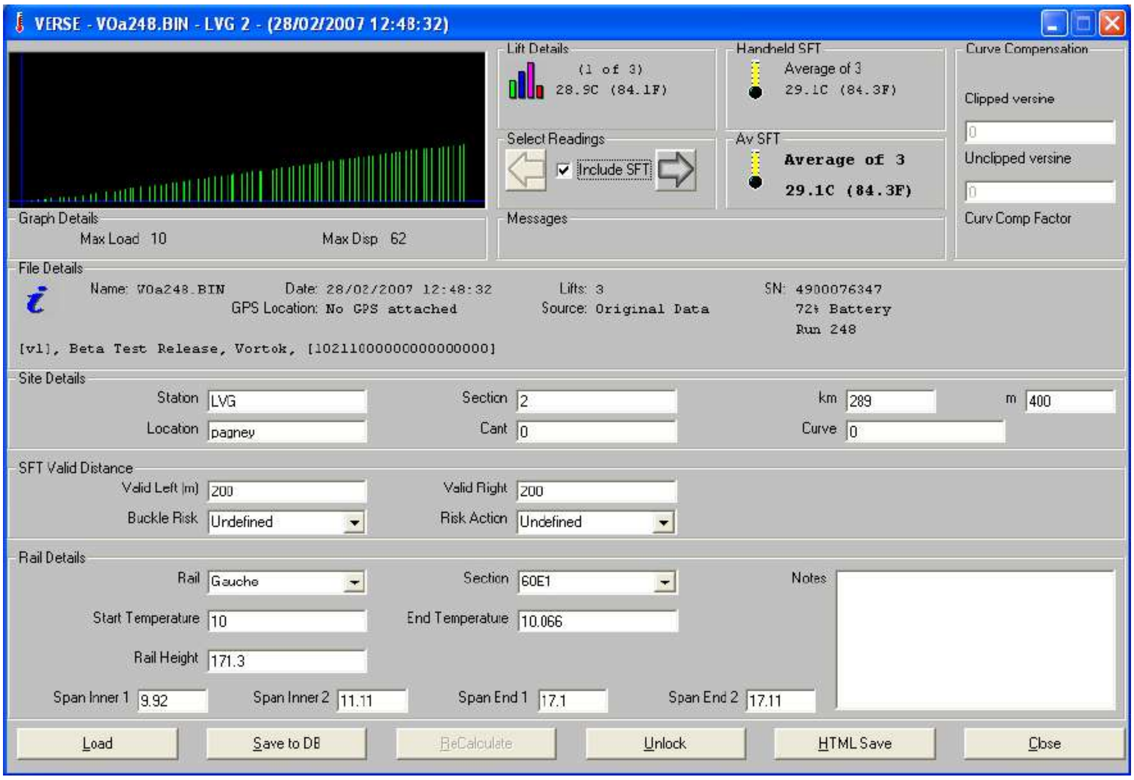
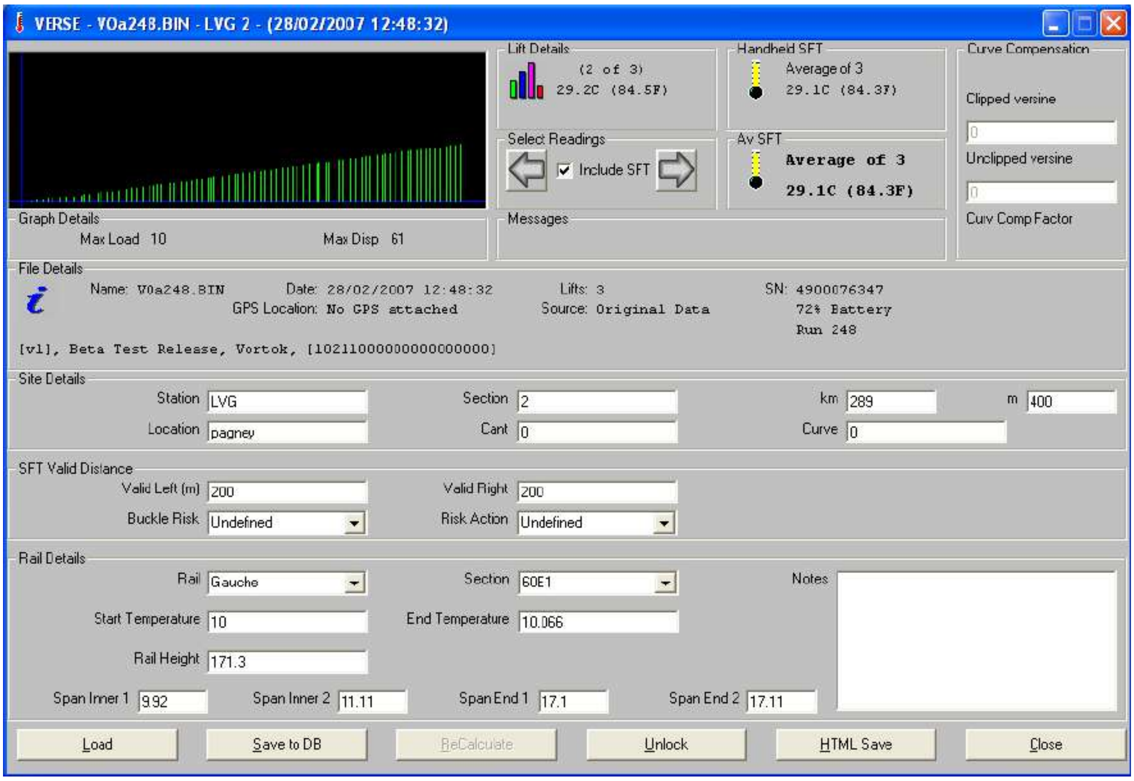
Lift 3



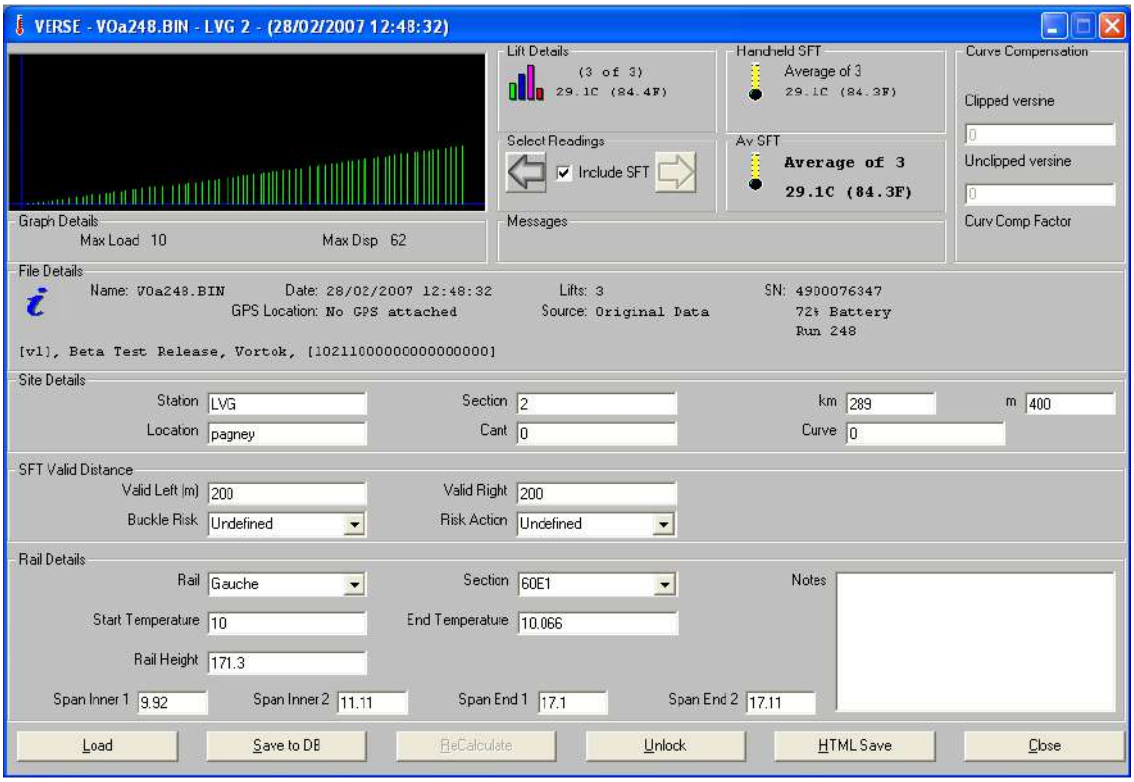
Measurement 5
Lift 1



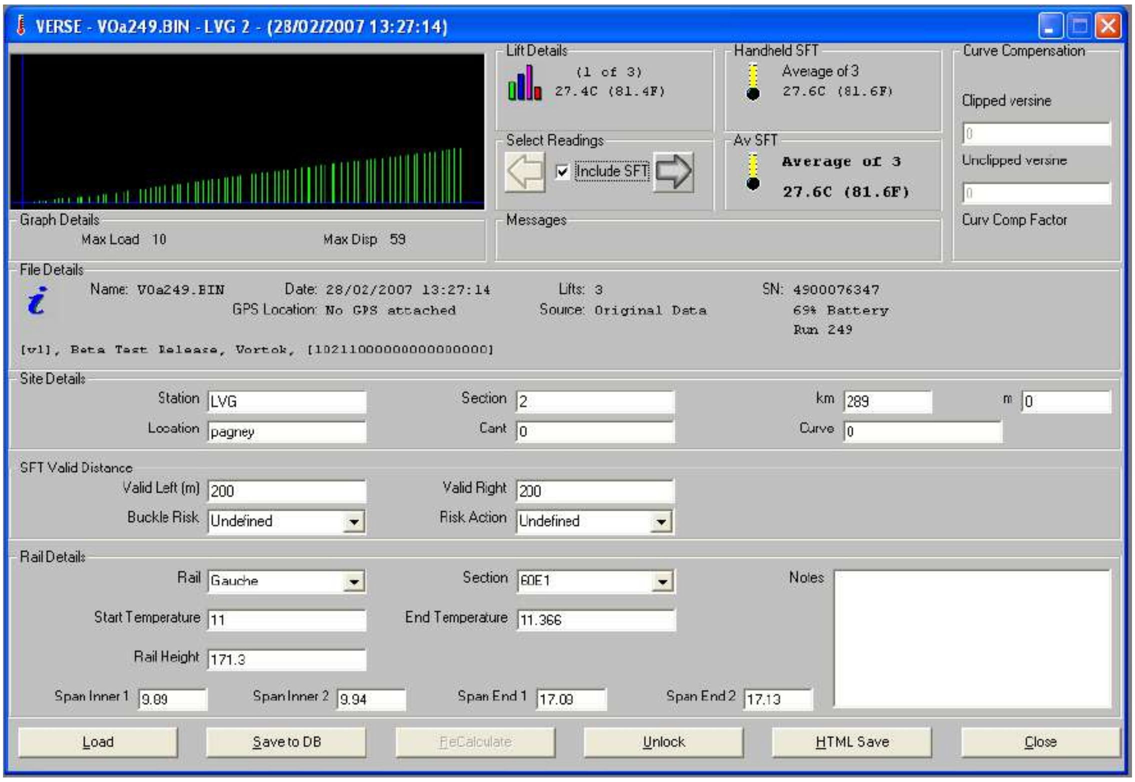
Measurement 5
Lift 2



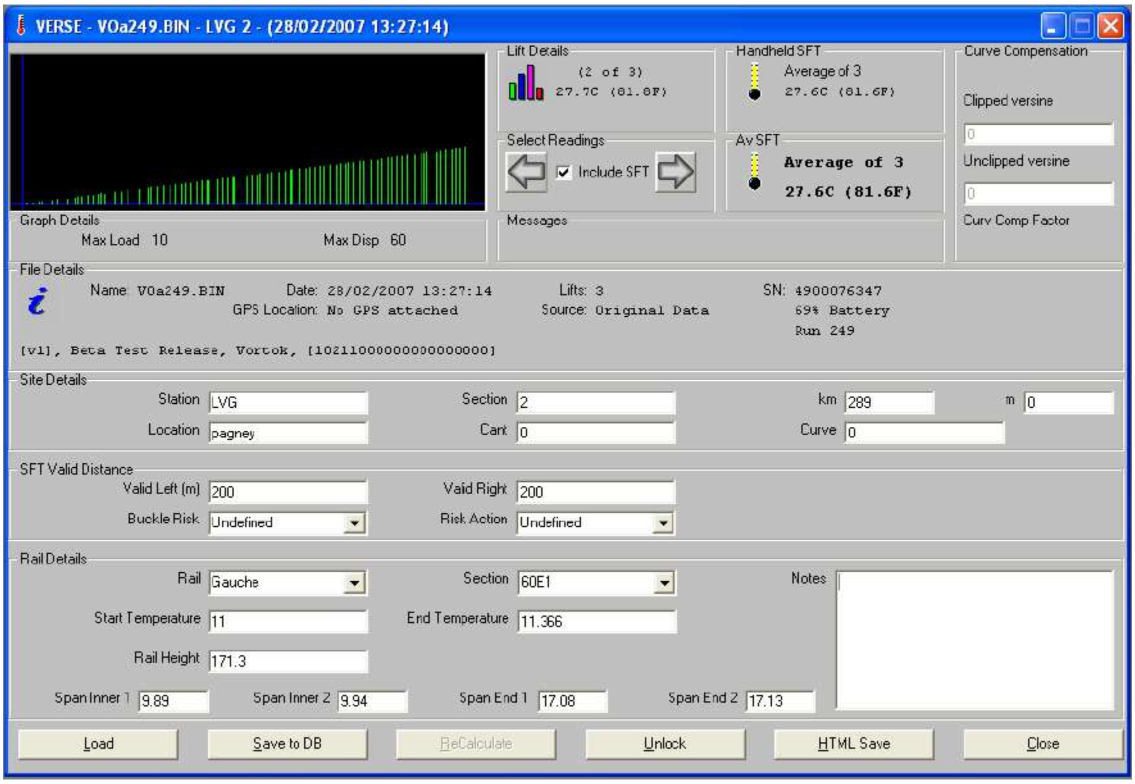
Measurement 5
Lift 3



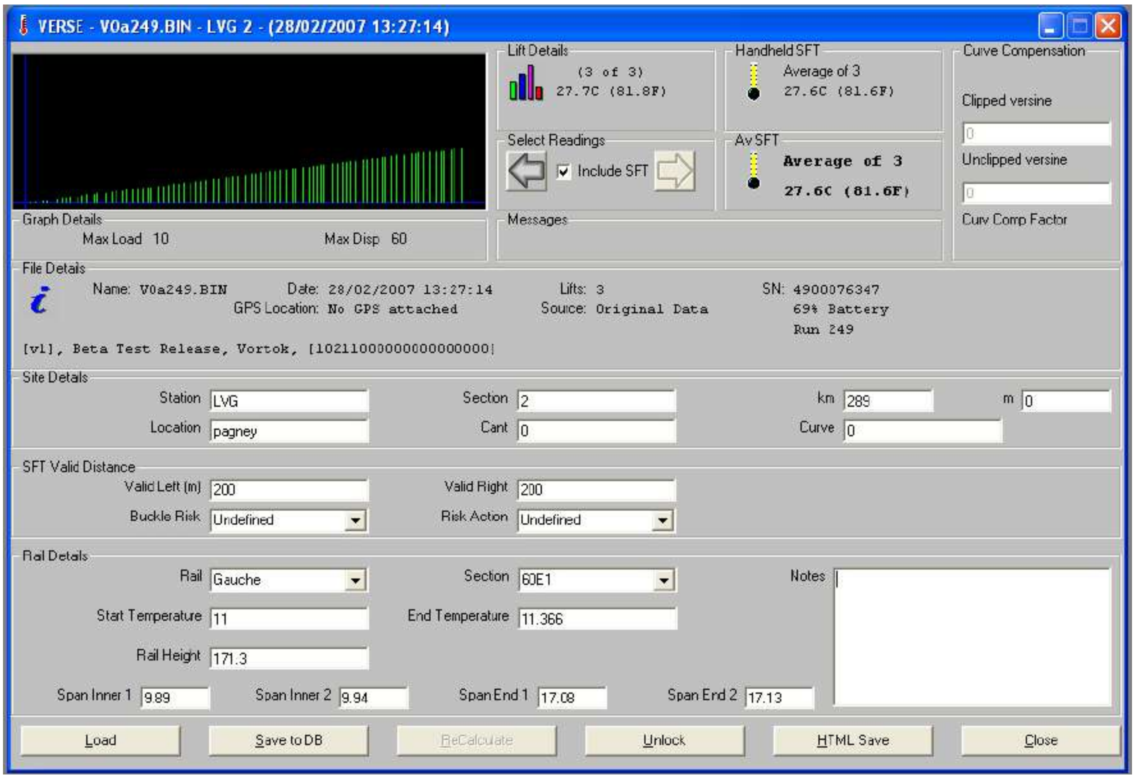
Measurement 6
Lift 1



Measurement 6
Lift 2



Measurement 6
Lift 3



APPENDIX E

VERSE® Trials

Mito 107 Km North of Tokyo Japan

29th – 30th January 2008

Richard Robertson
Export Sales and Marketing Manager
Vortok International

Background

Japan Railways East is planning to cover its network with sensors to measure changes to the stress free temperature. Sumitomo Metals are acting as consultants to the project and it is through them that contact was made, as a system to calibrate or benchmark such sensors will be required.

Currently JR East has small sections of track monitored by a Japanese made device that is very accurate, at least for the first few months after installation. After this time then the units begin to suffer from significant and erratic drift and therefore require an annual calibration.

This calibration process requires that the units are removed from track and this in itself is not a practical solution across an entire network. In addition they are benchmarked against their last known reading even though that will not necessarily be accurate.

JR East has therefore begun trials of the Salient system that can apparently be in track for a minimum of 10 years without the need for calibration. The interest in VERSE is threefold;

a) To establish the accuracy of the Salient sensors.
b) To calibrate the Salient sensors upon installation.
c) Assess possible problem areas in which to place Salient sensors.

In this first trial JR East and Sumitomo were testing VERSE to establish;

a) The Accuracy of VERSE readings.
b) Ease of use and time to take a measurement.
c) Feasibility of unclipping shorter sections of track and the effect upon the accuracy of the reading.
d) Compatibility with Japanese network and conditions.

The trials took place over the nights of the 29th and 30th of January close to the outskirts of the town of Mito 107 km north of Tokyo.

The rail type was JIS50KgN and the fastenings were predominantly Pandrol e-clip.

Test 1 & 2 - Establishing the accuracy and ease of use of VERSE.

Both Sumitomo and JR East were impressed with how quick and easy it is to set the VERSE equipment up ready to take a measurement. It was agreed that both rails could be measured within 30 – 40 minutes.

.

Test 1 Comprising 2 lifts with regular spans (30m total)

Rail temperature 4.9°C

Lift number	1	2	3	Average
Result	32.0°C	32.3°C	-	32.2°C

Test 2 Comprising 3 lifts with regular spans (30m total)

Rail temperature = beginning 5°C end 4.9°C

Lift number	1	2	3	Average
Result	32.5°C	32.6°C	32.2°C	32.4°C

Strain gauges manufactured by the Kaneko Company were calibrated and fitted to the recently stressed rail shortly before the trial. The readings from these gauges taken soon after installation are accepted by JR East as being almost as accurate as a measurement taken by cutting the rail.

The measurement provided by the Kaneko sensor was 32.1°C

VERSE within 0.1°C and 0.3°C

Kaneko sensor pictured above.

Tests 2, 3 & 4 – Establish accuracy with smaller spans

Test 3 Comprising 3 lifts at a 25m span.

Rail temperature = 4.7°C

Lift number	1	2	3	Average
Result	31.9°C	32.0°C	32.4°C	32.1°C

VERSE measurement equal to that of strain gauge at 25m

Test 4 Comprising 4 lifts at a 20m span.

Rail Temperature = 4.7°C

Lift number	1	2	3	4	Average
Result	30.6°C	User error	31.7°C	31.8°C	31.4°C

VERSE within 0.8°C of strain gauge at 20m

Test 5 Comprising 3 lifts at a 20m span

Rail temperature = 4.7°C

Lift number	1	2	3	Average
Result	31.2°C	31.6°C	31.6°C	31.5°C

VERSE within 0.7°C of strain gauge at 20m

Summary

JR East certainly had reservations as to the accuracy of VERSE and the location of the trial was carefully selected so as to include freshly calibrated strain gauge sensors. Their reservation was not whether VERSE could be accurate to 0.2°C but whether it would be able to measure within 2 or 3°C and be a viable calibration and validation tool.

The result of the tests at the proper span of 30m were received very well and accepted by both JR East and Sumitomo to be in line with the test reports previously submitted to them. It was confirmed that VERSE can be used for measuring SFT, outside of wintertime restrictions, without any changes to the JR rule book.

The third test was to see how VERSE would react if the maximum unclipped span was reduced toward the ideal of JR East of 20m. At 25m both VERSE and the strain gauge were in agreement with an SFT reading of 32.1°C and tasting continued to the ideal of 20m that JR were looking for.

Whilst the accuracy dropped to average variances of 0.8°C and 0.7°C this was deemed as acceptable given the restrictions VERSE was working under. All concerned were pleased with the result.

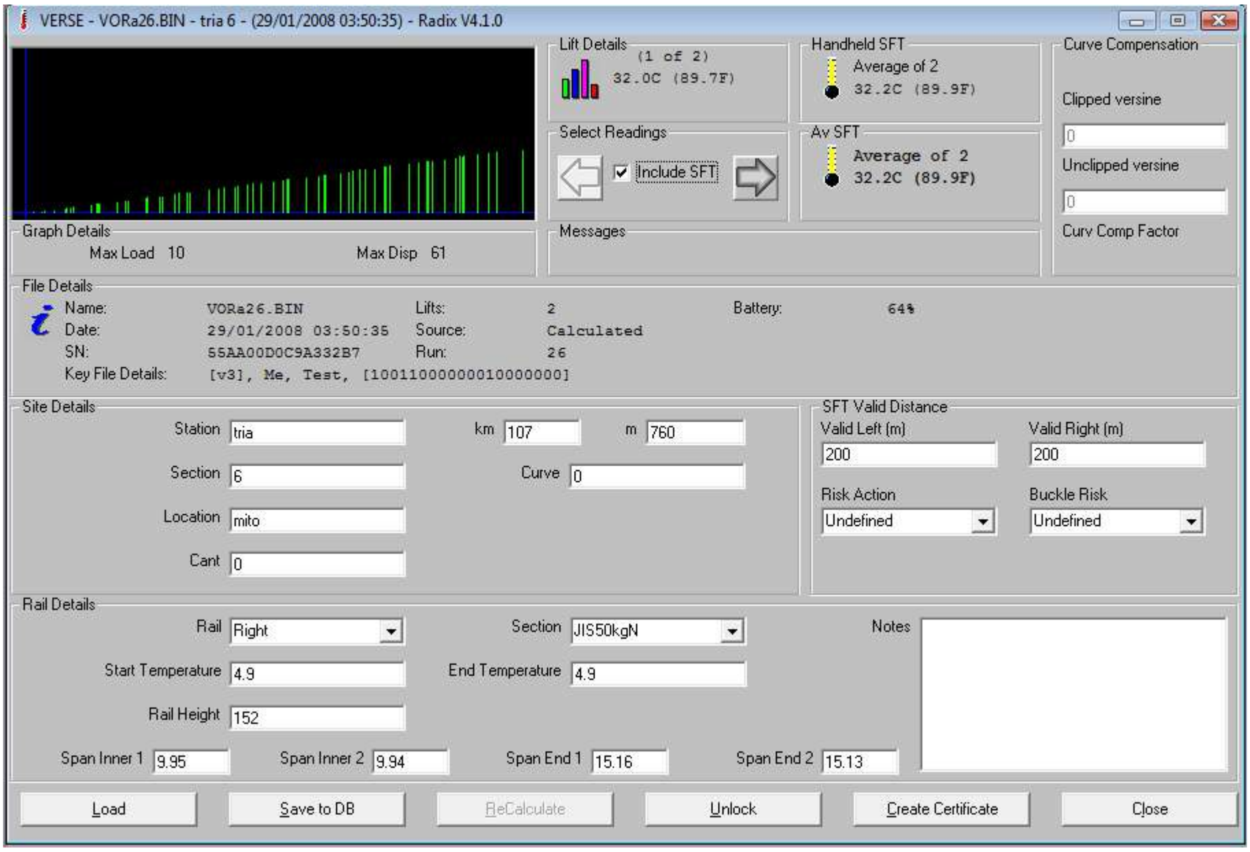
Conclusion

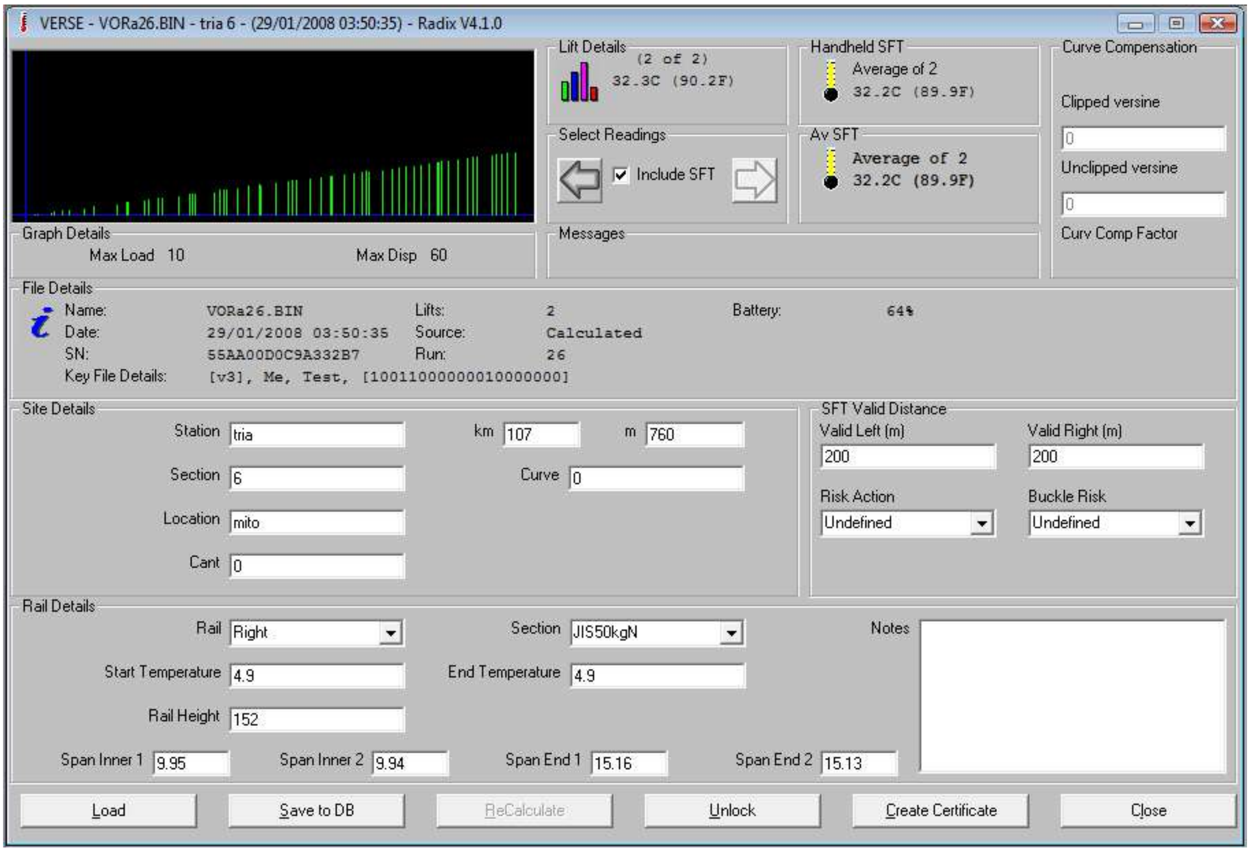
This demonstration proved not only VERSE's ease of use and accuracy but also the flexibility afforded to the user of the system. With the accuracy of VERSE at the proper unclipped span of 30m accepted, the purpose of the testing at shorter spans was not to establish a new method of working but to see what VERSE would be capable of providing during exceptionally cold weather. To that end an accuracy of 0.7°C to 0.8°C at a span reduced by a third to 20m was an exceptional result.

VERSE was deemed to be the most accurate way of establishing the correct SFT and therefore the most cost effective method of calibrating the Salient, or similar, sensors that look likely to be used in a network roll out in the near future.

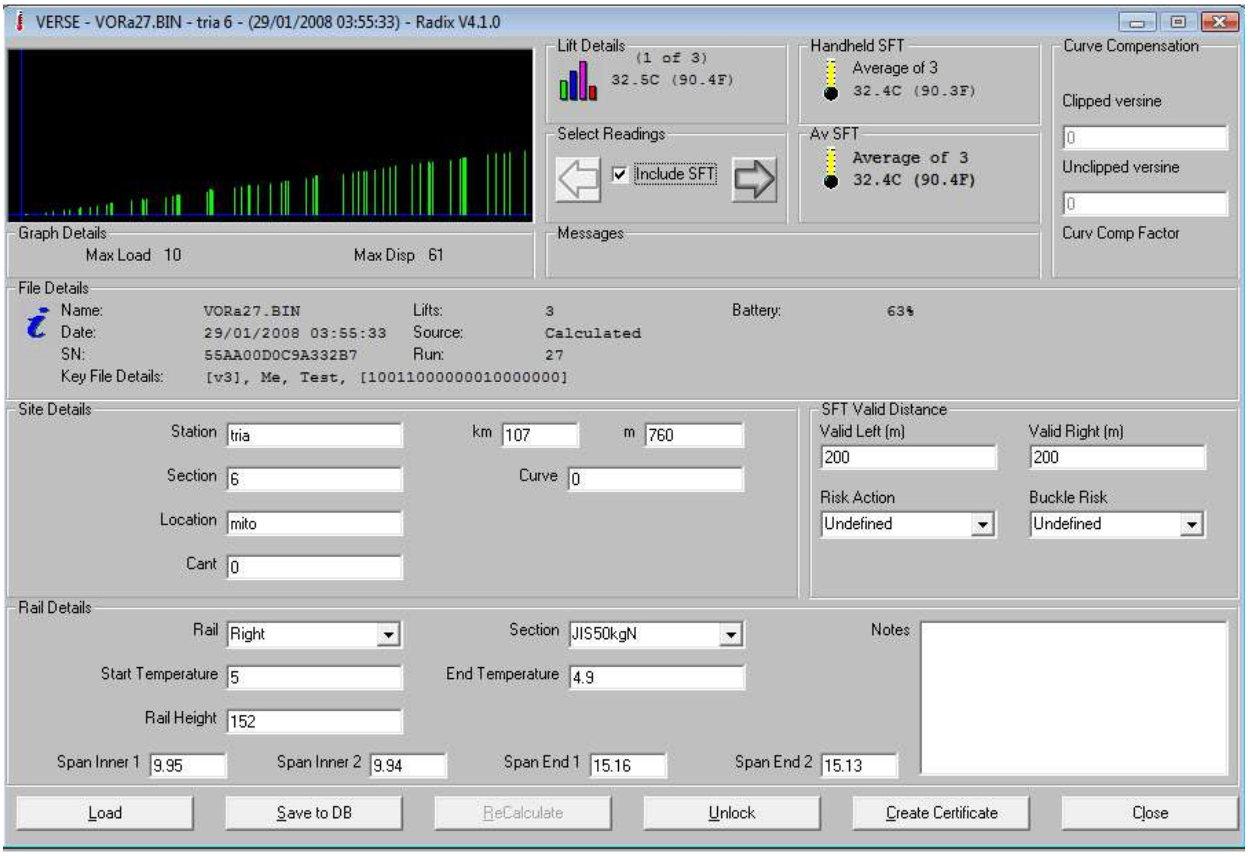
Appendix

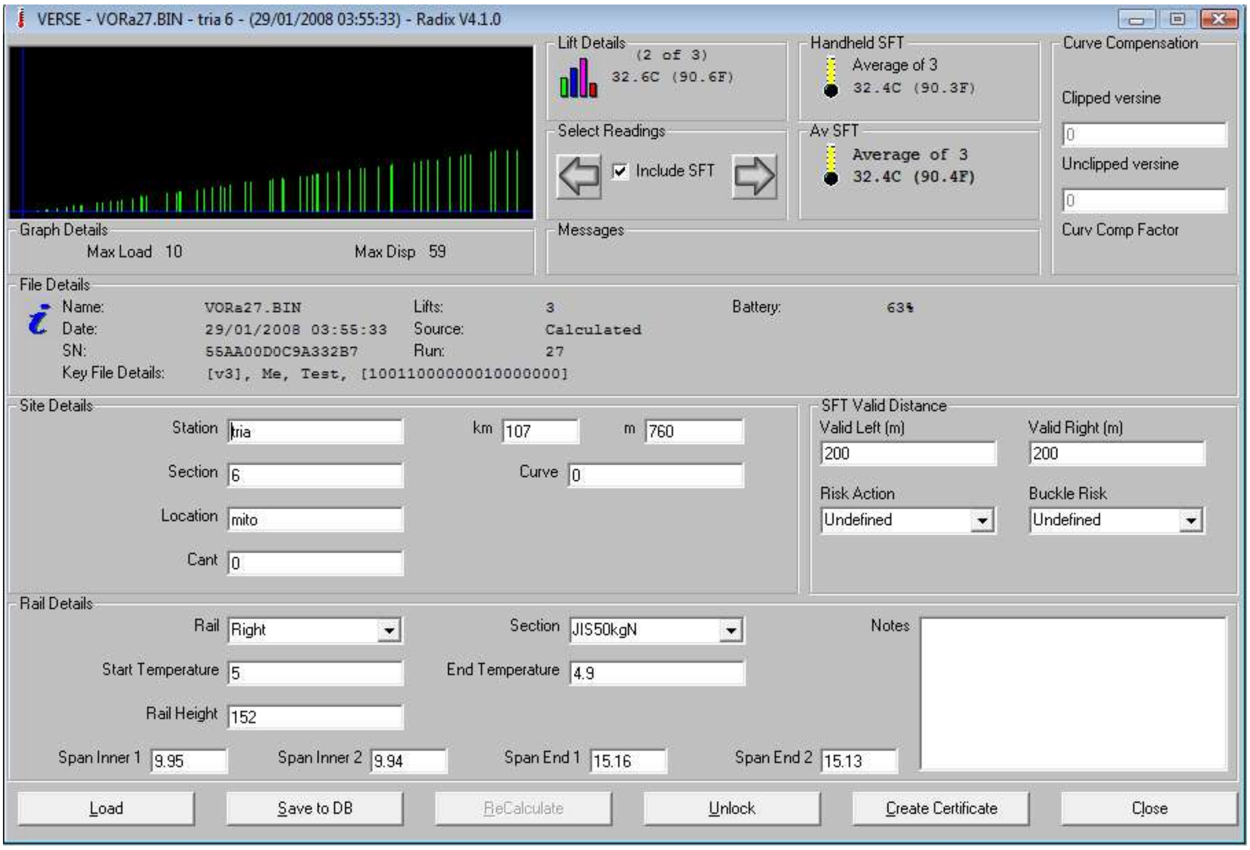
Test 1 (30m)

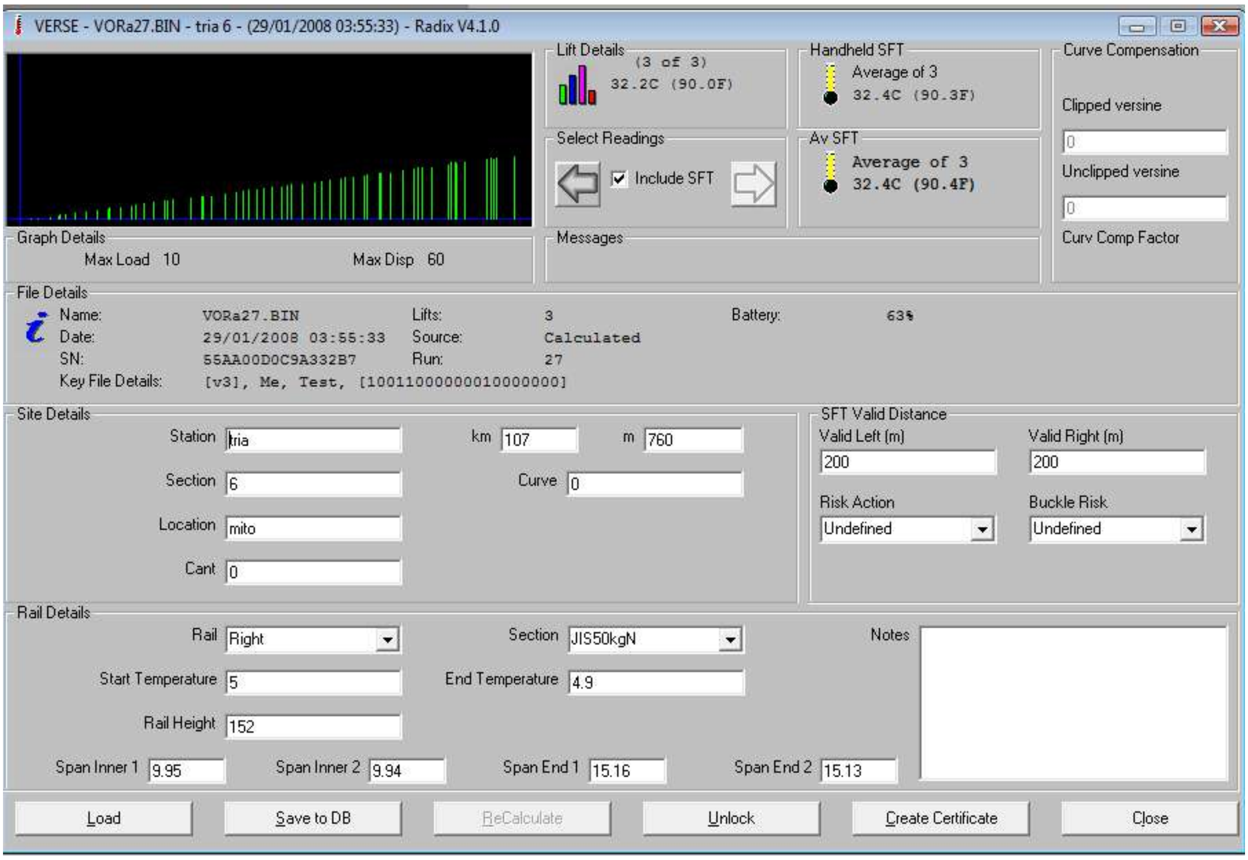




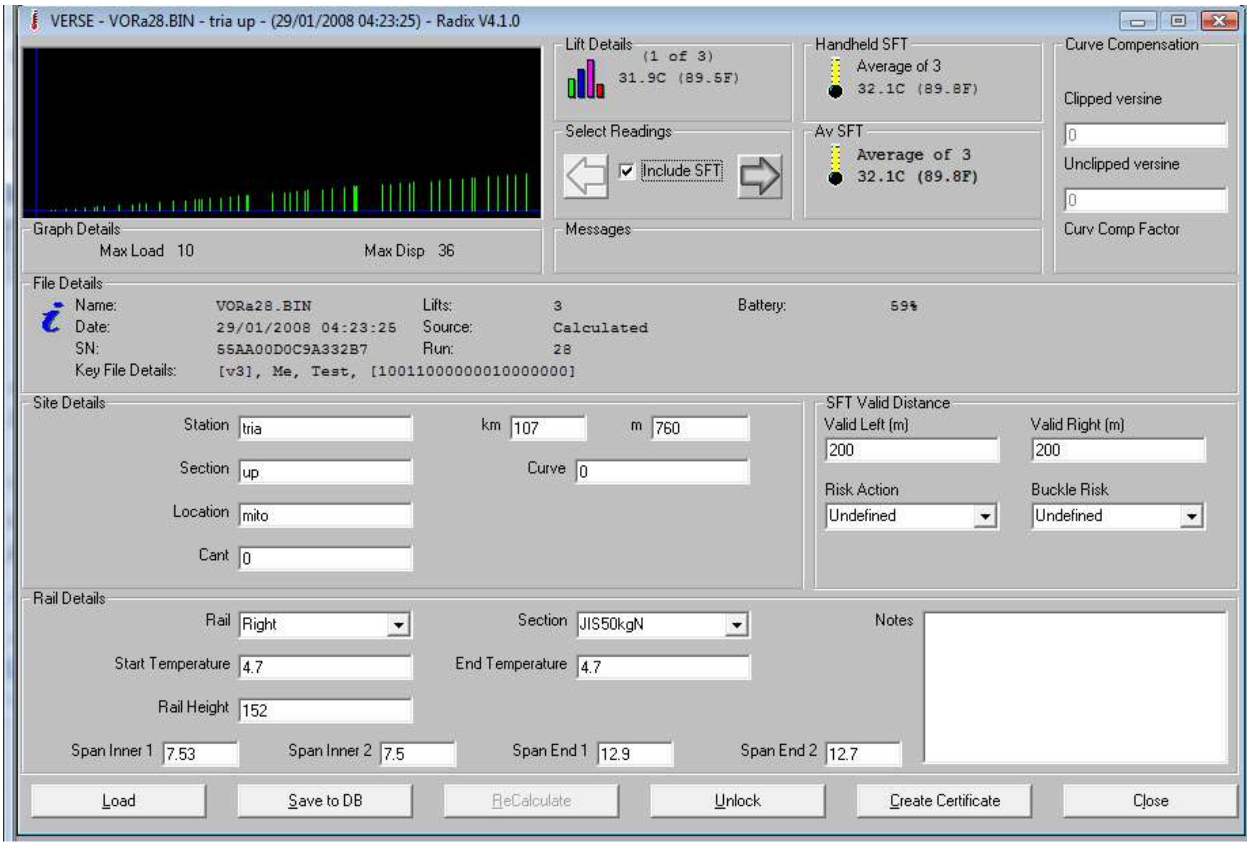
Test 2 (30m)

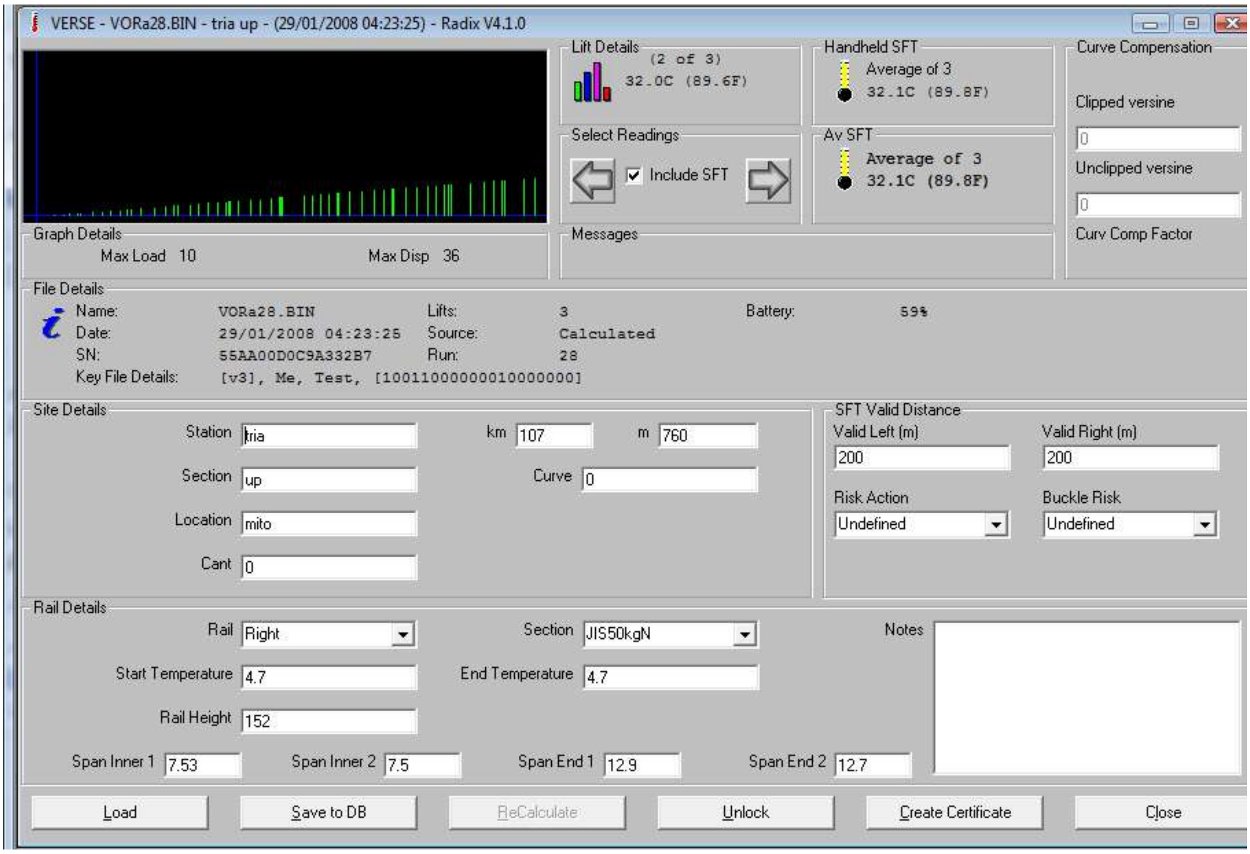

VERSE - VORa27.BIN - tria 6 - (29/01/2008 03:55:33) - Radix V4.1.0
Lift Details
(1 of 3)
32.5C (90.4F)
Handheld SFT
Average of 3
32.4C (90.3F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.4C (90.4F)
Graph Details
Max Load 10
Max Disp 61
Messages
File Details
Name: VORa27.BIN
Date: 29/01/2008 03:55:33
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 27
Battery: 63%
Site Details
Station tria
Section 6
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Start Temperature 5
Rail Height 152
Section JIS50kgN
End Temperature 4.9
Notes
Span Inner 1 9.95
Span Inner 2 9.94
Span End 1 15.16
Span End 2 15.13
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

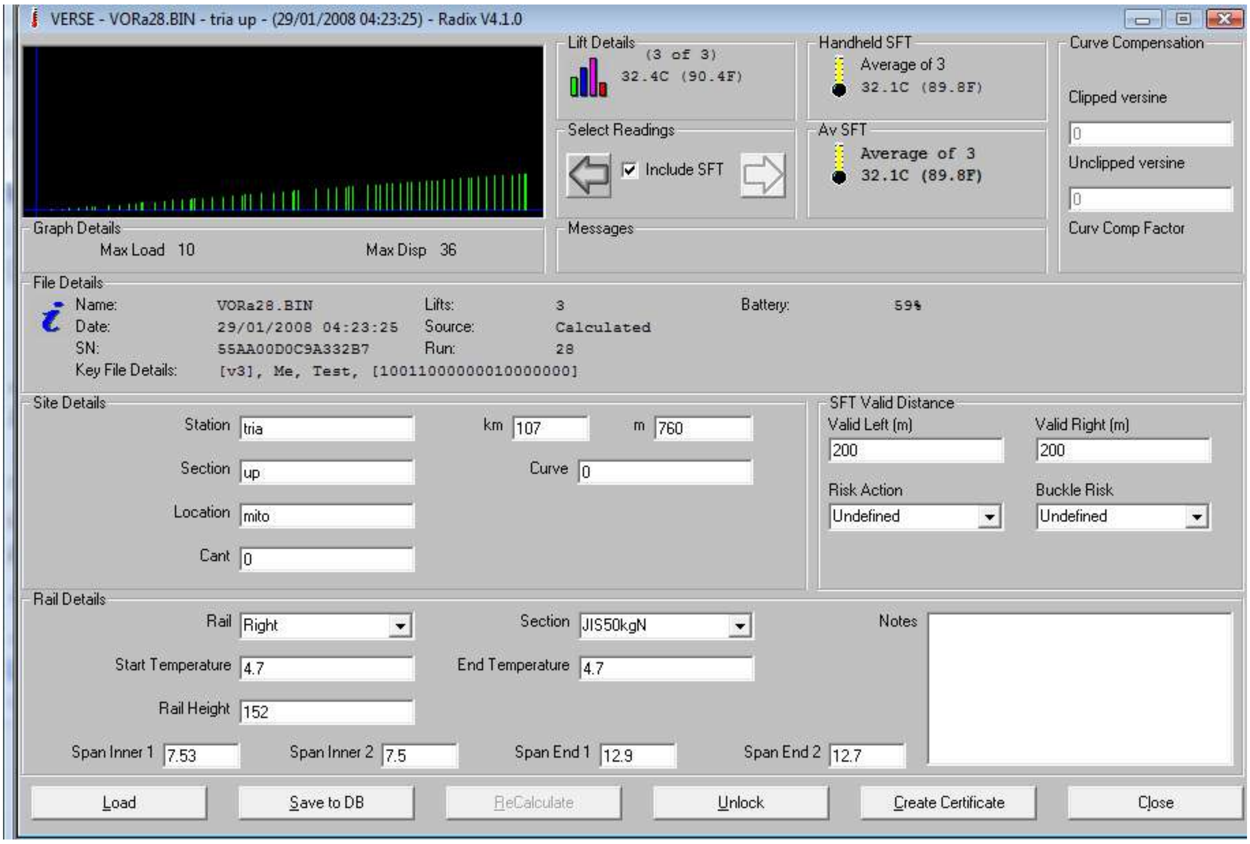

VERSE - VORa27.BIN - tria 6 - (29/01/2008 03:55:33) - Radix V4.1.0
Lift Details
(2 of 3)
32.6C (90.6F)
Handheld SFT
Average of 3
32.4C (90.3F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.4C (90.4F)
Graph Details
Max Load 10
Max Disp 59
Messages
File Details
Name: VORa27.BIN
Date: 29/01/2008 03:55:33
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 27
Battery: 63%
Site Details
Station tria
Section 6
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Start Temperature 5
Rail Height 152
Section JIS50kgN
End Temperature 4.9
Notes
Span Inner 1 9.95
Span Inner 2 9.94
Span End 1 15.16
Span End 2 15.13
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close


VERSE - VORa27.BIN - tria 6 - (29/01/2008 03:55:33) - Radix V4.1.0
Lift Details
(3 of 3)
32.2C (90.0F)
Handheld SFT
Average of 3
32.4C (90.3F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.4C (90.4F)
Graph Details
Max Load 10
Max Disp 60
Messages
File Details
Name: VORa27.BIN
Date: 29/01/2008 03:55:33
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 27
Battery: 63%
Site Details
Station tria
km 107
m 760
Section 6
Curve 0
Location mito
Cant 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 5
End Temperature 4.9
Rail Height 152
Span Inner 1 9.95
Span Inner 2 9.94
Span End 1 15.16
Span End 2 15.13
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

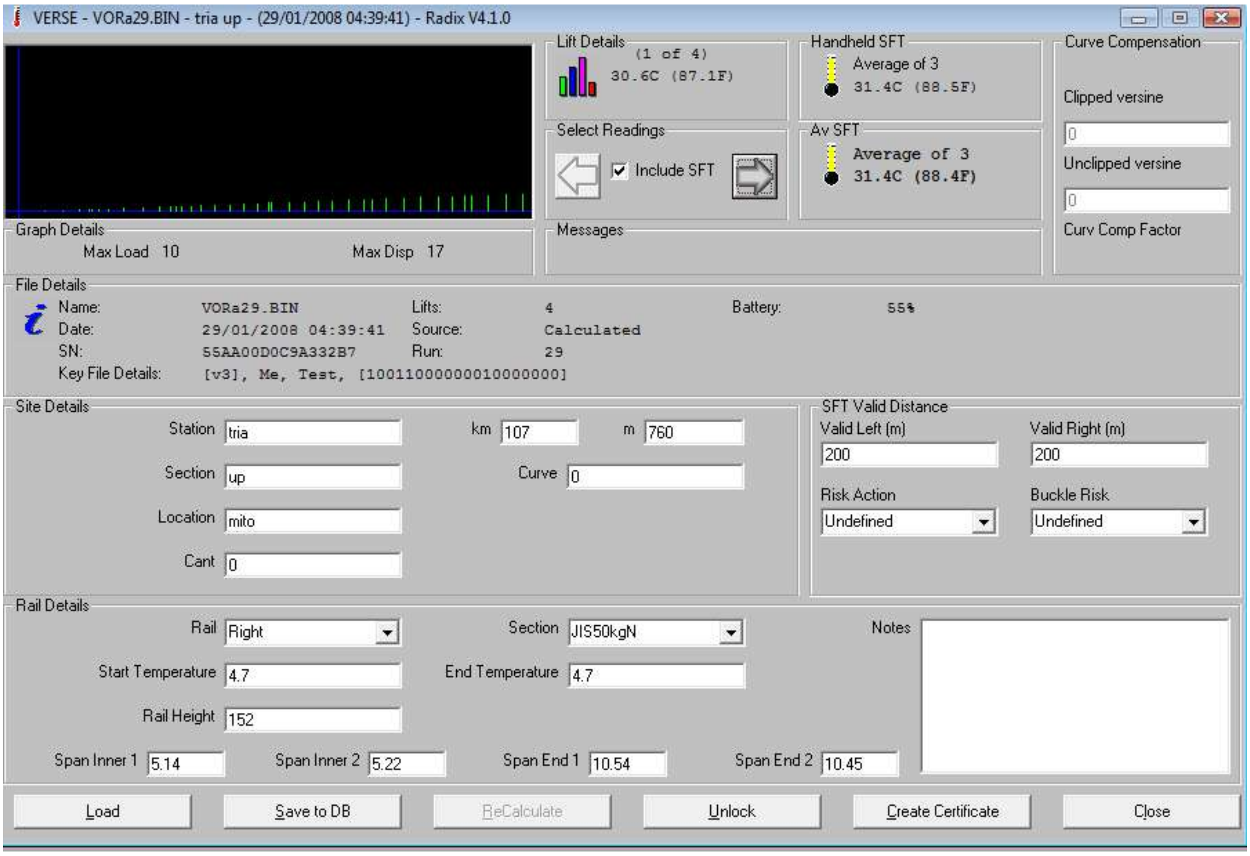
Test 3 (25m)

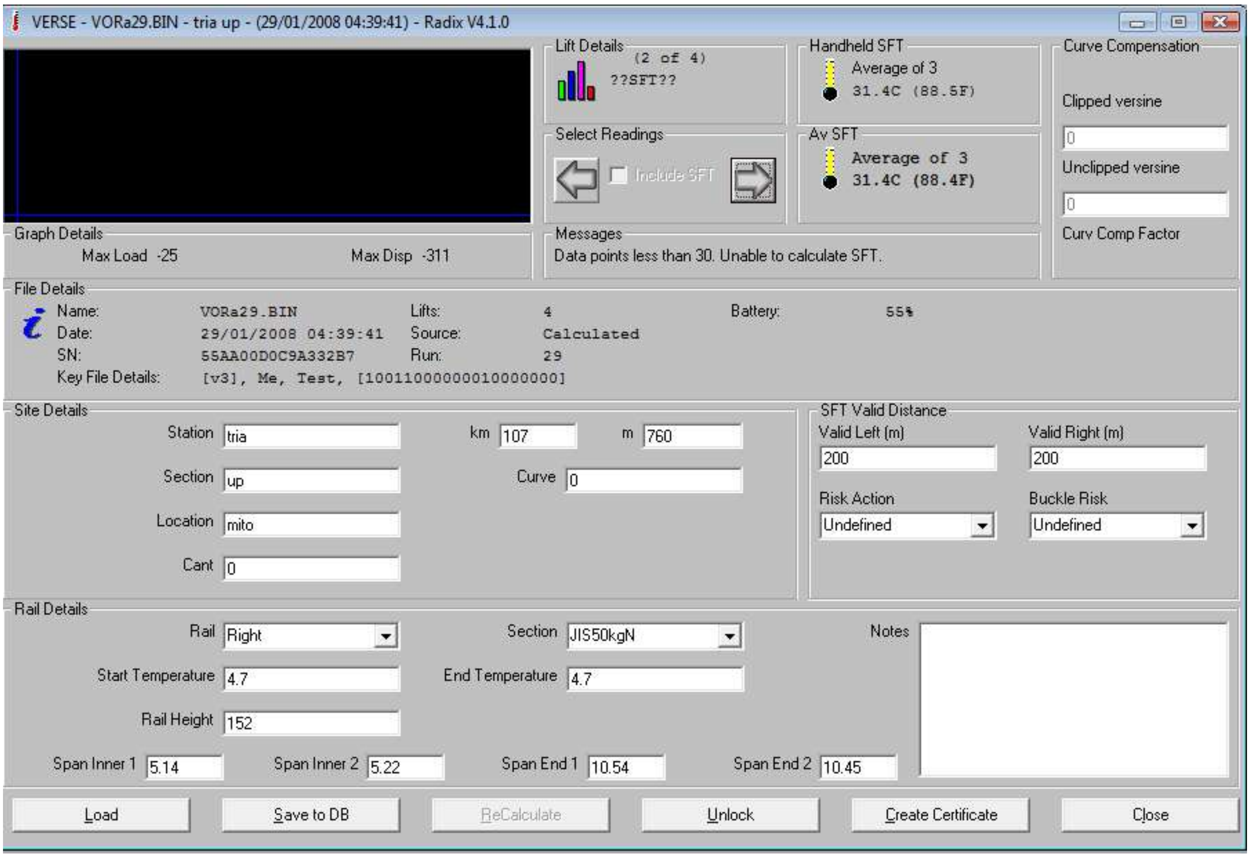

VERSE - VORa28.BIN - tria up - (29/01/2008 04:23:25) - Radix V4.1.0
Lift Details
(1 of 3)
31.9C (89.5F)
Handheld SFT
Average of 3
32.1C (89.8F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.1C (89.8F)
Graph Details
Max Load 10
Max Disp 36
Messages
File Details
Name: VORa28.BIN
Date: 29/01/2008 04:23:25
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 28
Battery: 59%
Site Details
Station tria
km 107
m 760
Section up
Curve 0
Location mito
Cant 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 7.53
Span Inner 2 7.5
Span End 1 12.9
Span End 2 12.7
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close


VERSE - VORa28.BIN - tria up - (29/01/2008 04:23:25) - Radix V4.1.0
Lift Details
(2 of 3)
32.0C (89.6F)
Handheld SFT
Average of 3
32.1C (89.8F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.1C (89.8F)
Messages
Graph Details
Max Load 10
Max Disp 36
File Details
Name: VORa28.BIN
Date: 29/01/2008 04:23:25
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 28
Battery: 59%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 7.53
Span Inner 2 7.5
Span End 1 12.9
Span End 2 12.7
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

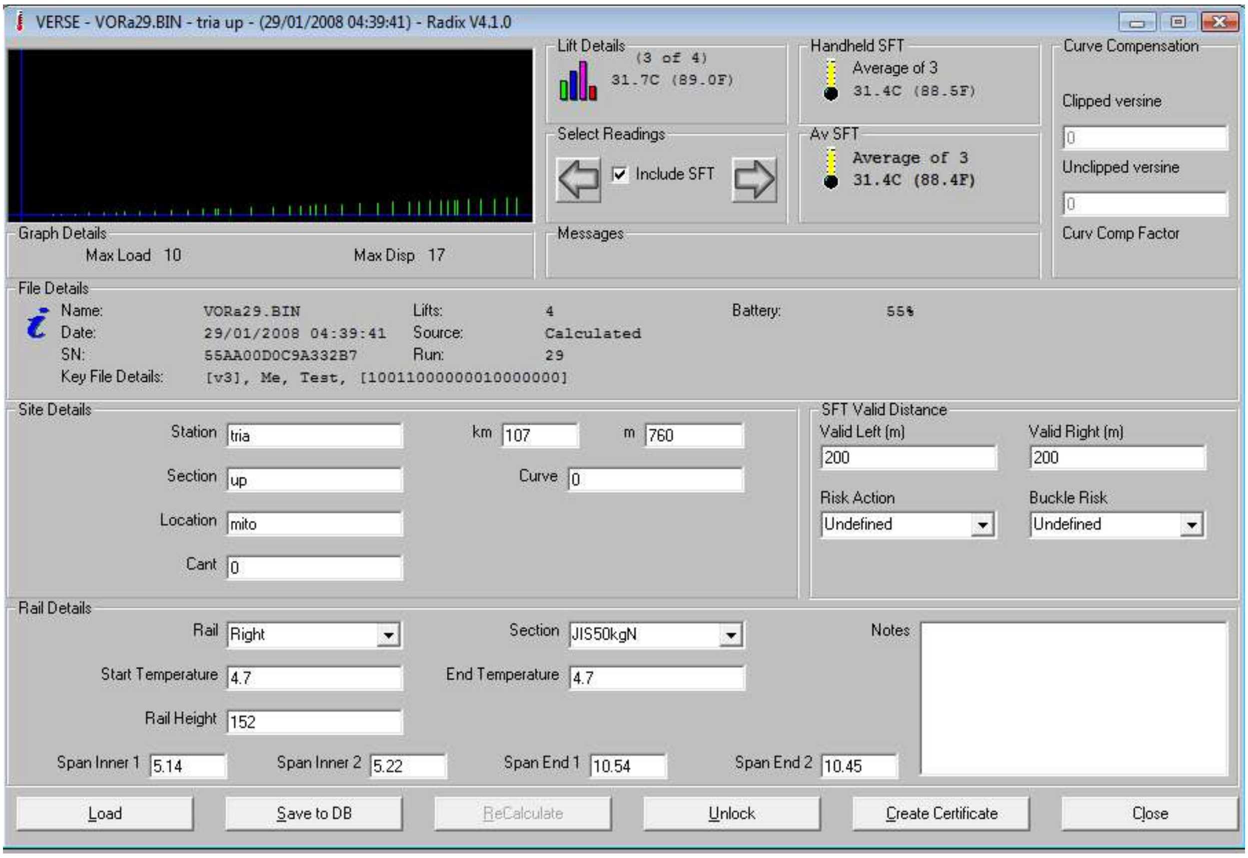

VERSE - VORa28.BIN - tria up - (29/01/2008 04:23:25) - Radix V4.1.0
Lift Details
(3 of 3)
32.4C (90.4F)
Handheld SFT
Average of 3
32.1C (89.8F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
32.1C (89.8F)
Messages
Graph Details
Max Load 10
Max Disp 36
File Details
Name: VORa28.BIN
Date: 29/01/2008 04:23:25
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 28
Battery: 59%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 7.53
Span Inner 2 7.5
Span End 1 12.9
Span End 2 12.7
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

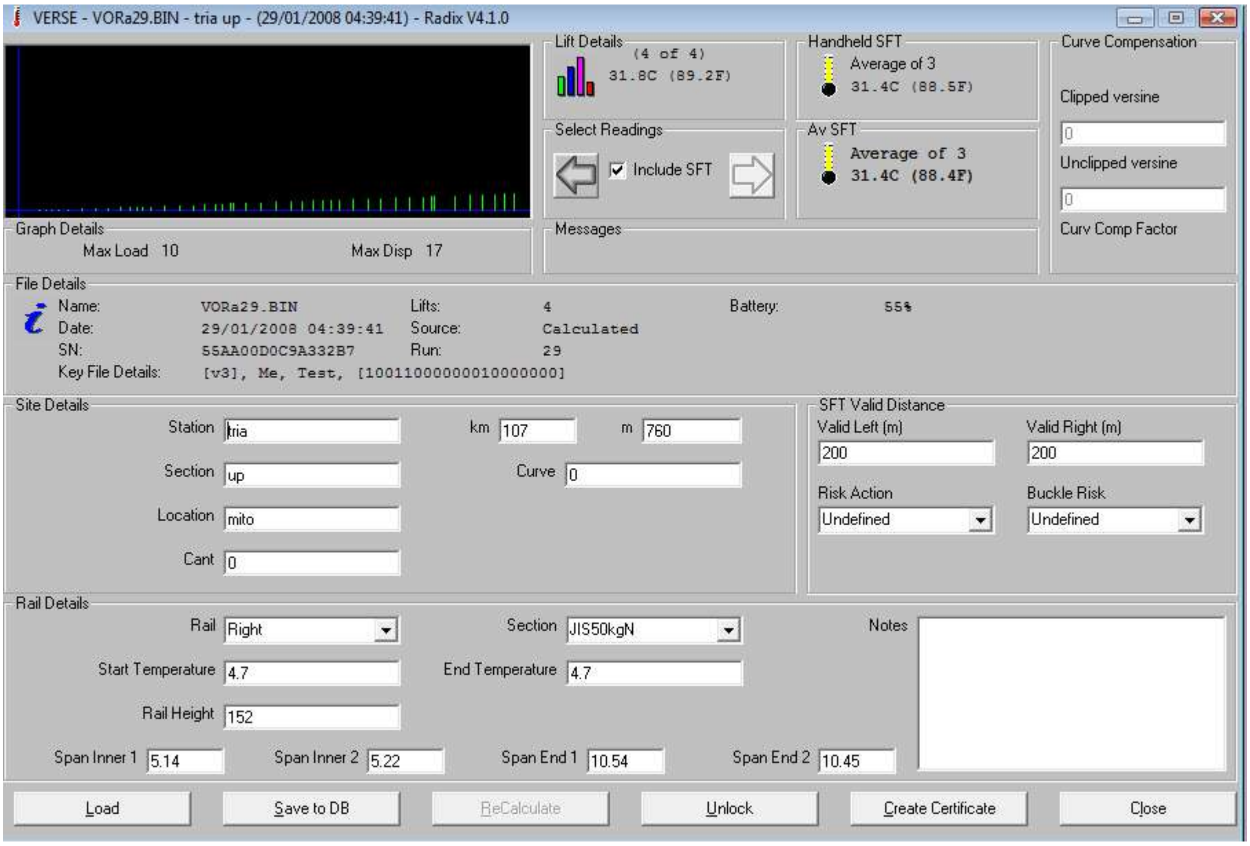
Test 4 (20m)



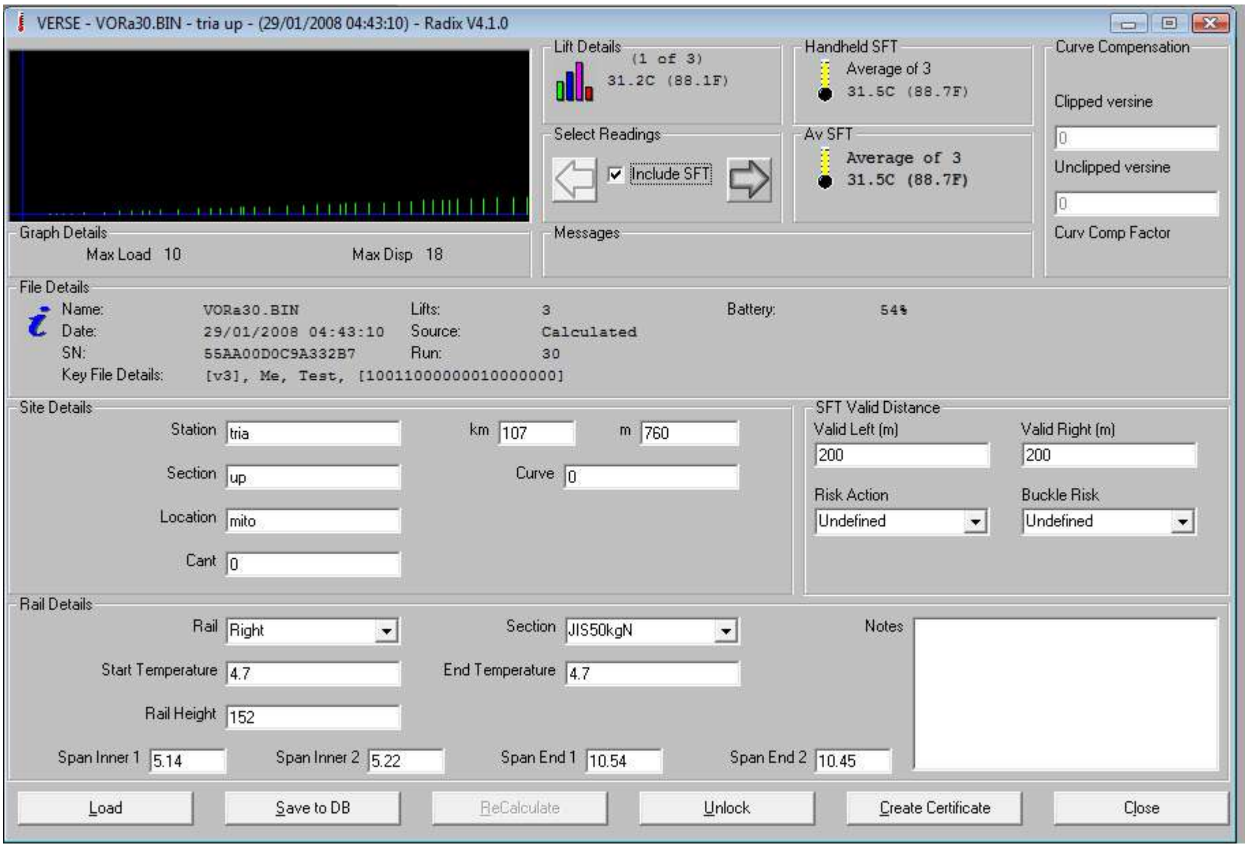


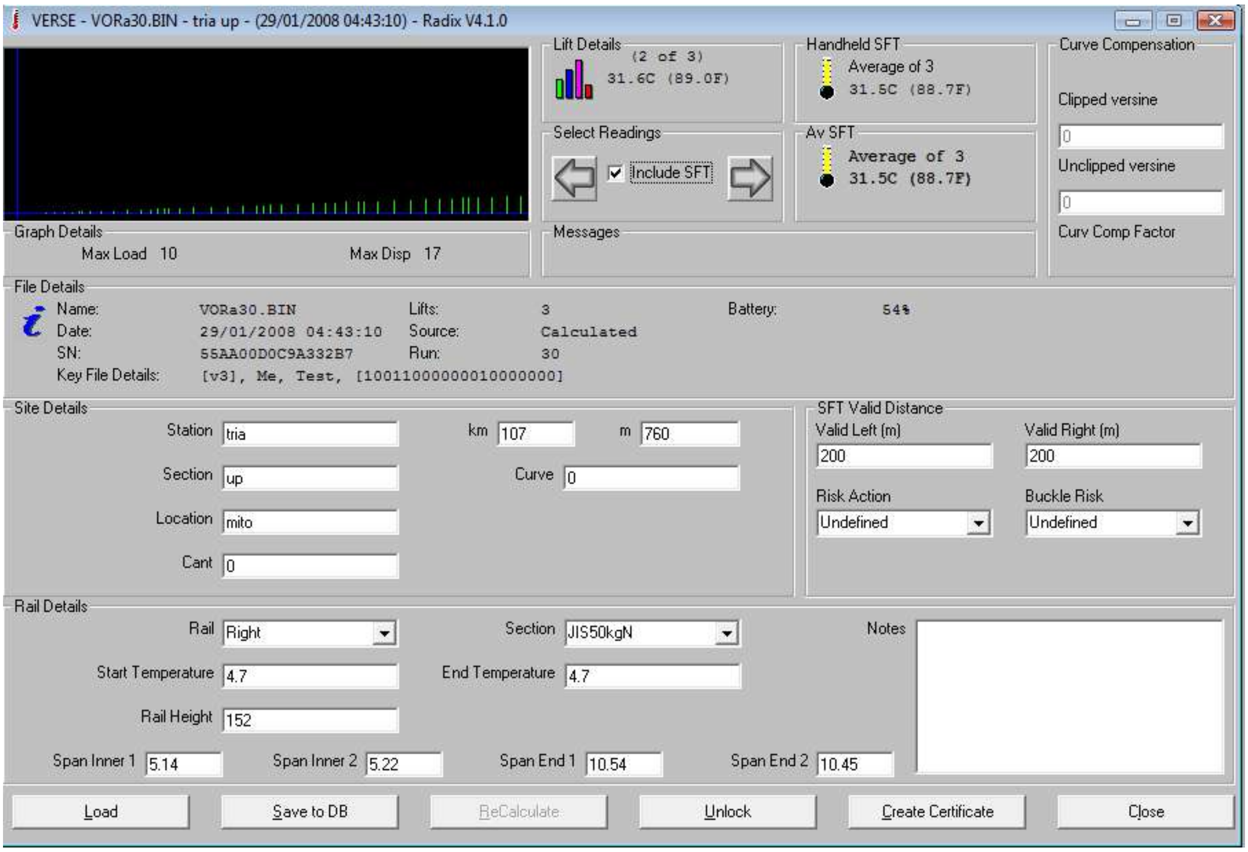
(Operator Error)

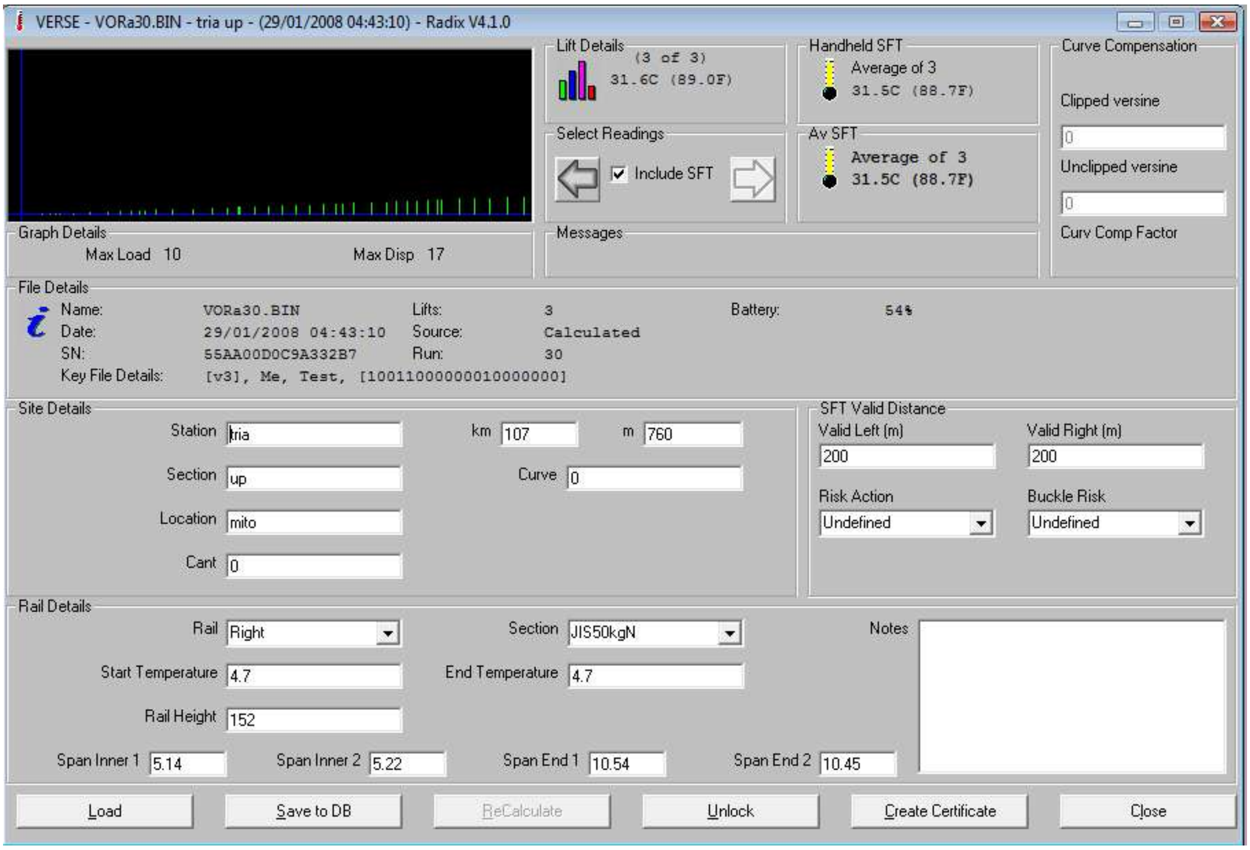

VERSE - VORa29.BIN - tria up - (29/01/2008 04:39:41) - Radix V4.1.0
Lift Details
(3 of 4)
31.7C (89.0F)
Handheld SFT
Average of 3
31.4C (88.5F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
31.4C (88.4F)
Graph Details
Max Load 10
Max Disp 17
Messages
File Details
Name: VORa29.BIN
Date: 29/01/2008 04:39:41
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 4
Source: Calculated
Run: 29
Battery: 55%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 5.14
Span Inner 2 5.22
Span End 1 10.54
Span End 2 10.45
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close


VERSE - VORa29.BIN - tria up - (29/01/2008 04:39:41) - Radix V4.1.0
Lift Details
(4 of 4)
31.8C (89.2F)
Handheld SFT
Average of 3
31.4C (88.5F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
31.4C (88.4F)
Graph Details
Max Load 10
Max Disp 17
Messages
File Details
Name: VORa29.BIN
Date: 29/01/2008 04:39:41
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 4
Source: Calculated
Run: 29
Battery: 55%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 5.14
Span Inner 2 5.22
Span End 1 10.54
Span End 2 10.45
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

Test 5 (20m)


VERSE - VORa30.BIN - tria up - (29/01/2008 04:43:10) - Radix V4.1.0
Lift Details
(1 of 3)
31.2C (88.1F)
Handheld SFT
Average of 3
31.5C (88.7F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
31.5C (88.7F)
Messages
Graph Details
Max Load 10
Max Disp 18
File Details
Name: VORa30.BIN
Date: 29/01/2008 04:43:10
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 30
Battery: 54%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 5.14
Span Inner 2 5.22
Span End 1 10.54
Span End 2 10.45
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close


VERSE - VORa30.BIN - tria up - (29/01/2008 04:43:10) - Radix V4.1.0
Lift Details
(2 of 3)
31.6C (89.0F)
Handheld SFT
Average of 3
31.5C (88.7F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
31.5C (88.7F)
Messages
Graph Details
Max Load 10
Max Disp 17
File Details
Name: VORa30.BIN
Date: 29/01/2008 04:43:10
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 30
Battery: 54%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 5.14
Span Inner 2 5.22
Span End 1 10.54
Span End 2 10.45
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close


VERSE - VORa30.BIN - tria up - (29/01/2008 04:43:10) - Radix V4.1.0
Lift Details
(3 of 3)
31.6C (89.0F)
Handheld SFT
Average of 3
31.5C (88.7F)
Curve Compensation
Clipped versine
0
Unclipped versine
0
Curv Comp Factor
Select Readings
Include SFT
Av SFT
Average of 3
31.5C (88.7F)
Graph Details
Max Load 10
Max Disp 17
Messages
File Details
Name: VORa30.BIN
Date: 29/01/2008 04:43:10
SN: 55AA00D0C9A332B7
Key File Details: [v3], Me, Test, [10011000000010000000]
Lifts: 3
Source: Calculated
Run: 30
Battery: 54%
Site Details
Station tria
Section up
Location mito
Cant 0
km 107
m 760
Curve 0
SFT Valid Distance
Valid Left (m) 200
Valid Right (m) 200
Risk Action Undefined
Buckle Risk Undefined
Rail Details
Rail Right
Section JIS50kgN
Notes
Start Temperature 4.7
End Temperature 4.7
Rail Height 152
Span Inner 1 5.14
Span Inner 2 5.22
Span End 1 10.54
Span End 2 10.45
Load
Save to DB
ReCalculate
Unlock
Create Certificate
Close

APPENDIX F

Thermit Welding (GB) Limited
87 Ferry Lane
Rainham
Essex
RM13 9YH

Telephone: Rainham (01708) 522626
Facsimile: (01708) 553806

FAO: Peter Shrubsall
Vortok International
Unit 607 Haxter Close
Belliver Industrial Estate
Roborough
Plymouth PL6 7DD

Direct Tel: 01332 366104
E-Mail: rsj@thermitwelding.co.uk

o/r: tws/rsj/pm/Vortok02.03
y/r:
Date: 2 March 2004

Dear Peter

Thermit Welding (GB) Ltd established a business providing VERSE measurement and training to the UK Railway Industry in 2000. Since then the business has continued to expand, such that we now deploy 4 measurement teams and are currently working in excess of 12 shifts / week- mainly on validation of SFT records for Network Rail.

On numerous occasions VERSE has successfully proven itself as a totally reliable and accurate method of measuring SFT and is currently the only non-intrusive method approved for use on Network Rail. We have used it on all categories of track on both timber and concrete supports, including curved track down to 700m radius and rail temperature down to -7 deg C (the lowest permitted by Network Rail for Track maintenance)

Our VERSE equipment was purchased in January 2002, since when it has been in constant use, deployed on sites throughout the U.K. Partly due to the elegantly simple principle of operation, and partly due to the design and quality of materials, the equipment has been extremely reliable and robust, having taken in excess of 1000 SFT measurements without any failure. The equipment requires very little maintenance other than regular calibration of the instrumentation and backing up of the data files, however we have taken the prudent decision to keep a small selection of strategic spares (e.g; spare hydraulic pump, and service kit, linear transducer) and have established our internal calibration procedure for the transducers and load cell.

The interest in the measurement of SFT using VERSE continues to grow in the U.K – alternative methods having been tested and found to be unreliable - and such is our confidence in its continued demand that we have just recruited an additional trainee, re-equipped all our operators and are investing in additional VERSE, and data recording equipment.

I should also take the opportunity of recording our appreciation of the high level of technical support provided by Vortok UK over the last four years. We look forward to our continuing to work together to promote the further expansion of SFT measurement using VERSE throughout the railway industry for the foreseeable future.

Best Regards

Richard Johnson
Director Technical Sales

CN

Use of VERSE – Non-destructive Stress Free Temperature Measurement on Canadian National Railway

In the past CN would destress ahead of a major program to ensure that the rail is at the preferred stress free temperature.
Once the work program was completed we would return to the work area and destress again to ensure no buckling.

This is a very costly and time-consuming process.

Productivity:
Maybe 1/2 mile per day destressing both sides.
A 40mile program would take about 80 days.
Crew generally consists of 12 people.

When using VERSE, checks can be made in about 20 minutes per rail with 4 men with no cutting, de-stressing, or welding!

The savings are huge.

The following data sampling came from 507 tested locations in 2002.
156 locations were at, or over, PRLT. (Preferred Rail Laying Temperature)
185 locations required monitoring because they were up to 10 degrees F. below the PRLT.
166 locations required distressing as they were greater than 10 degrees below the PRLT.

The testing was done with a crew of 4.

Had we not used non-destructive testing we would have required 1524 person days.
This figure is arrived at by assuming that each location is approximately ¼ mile long.
A crew of 12 people would be required for 127 days, if they do 4 locations a day.

Denis Morin
Manager - Engineering Programs
Canadian National
10004 - 104th Avenue, 18th Floor
Edmonton, Alberta T5J 0K2
Canada

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TELEFAX: +44 (0) 1752 702353
e-mail: sales@vortok.co.uk
www.vortok.co.uk

Verification of Newly Laid Track Using VERSE

The text below is an except from a St Louis Metro tender where the use of VERSE is specified in the CWR installation instructions to verify that the track has been laid correctly.

This is a common practice carried out by many other users of Verse including Network Rail, SNCF and VR (Finland)

3.10 NON DESTRUCTIVE STRESS FREE TEMPATURE MEASURING

Upon completion of CWR installation and thermal adjustments, the contractor shall verify that rails are at acceptable neutral stress temps by use of the VERSE non-destructive stress free measuring system, by VORTOK Int. and AEA Technology Rail or accepted equal.

Test using the VERSE equipment shall be performed per manufacture's recommendations on each rail at points no more than ½ mile apart, on tangent sections of track where curvature is no less than 2300' in radius.

Any sections of rail found by tests using the VERSE equipment to be at a neutral stress temp outside the range allowed by article 3.02.B.2 of this specification shall be readjusted in accordance with agency directives at no expense to the agency.

Section 3.02.B.2 states;
Clip rail at 105 degrees Fahrenheit minus 5 degrees to plus 15 degrees. When zero thermal stress temp is obtained and required quarter point movement has occurred, begin clipping immediately. Rail temp shall remain in specified zero thermal stress range until rail is fully clipped. If rail temp deviates from specified zero thermal stress range, cease clipping until rail returns to specified range.

Brian Sellers
Manager Track Maintenance
Metro St. Louis

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Vortok International is the Trading Name of Multiclip Company Limited, a member of the Pandrol Group of Companies
Registered Office: 63 Station Road, Addlestone, Surrey KT15 2AR. Registered No. 1212929 V.A.T. No. GB 232 6951 62
BS EN ISO 9001-2000
Certificate Number: 6901

Vortok International
David Townsend

VERSE-measurements, Finland

VR-TrackLtd has purchased three VERSE-units. Trials began in 2000, and our goal was to get an approval from Finnish Rail Administration to be able to do measurements on Finnish national network.

We got the approval and first unit came in august 2001. Measurements have been done after sleeper change work and geometrical changes of a track. The minimum curve radius, where we have measured is 600m according to approval from rail administration. That is in most cases the minimum radius in Finnish network.

Second unit came in may 2002 and the newest in September 2003. The total amount of measurements is up to now exceeds 1700.

Results have been satisfactory. We have compared with cut and reweld-method and accuracy has been within 2 degrees. VERSE has opened new ideas how to work and cut costs in track renewal works.

Pekka Rautanen
Production Manager
VR-Track Ltd

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APPENDIX J

NetworkRail

Certificate of Acceptance PA05/00901

Manufacturer:
Vortok International

Issue : 3
Valid From : 20.08.2018

VERSE (Vertical Rail Stiffness Equipment) incorporating DCCR bridge

Product Description

The Vortok VERSE (Vertical Rail Stiffness Equipment) (incorporating Direct Current Conductor Rail (DCCR) bridge) is a non-destructive method that can measure stress free temperature (SFT) of continuous welded rail (CWR). The VERSE kit is a combined mechanical/software system that can measure SFT on trackside.

The equipment consists of a portable loading frame, which is positioned over the rail to be measured. An upward vertical force is applied to the rail via the system hydraulics.

Transducers are used to measure the applied force with respect to the vertical displacement of the rail. This data is stored in a small robust handheld computer, which, along with a signal conditioning system, powers the transducers, captures their output signals and calculates the SFT.

Product Image

Scope of Acceptance

Full Acceptance

1) Accepted to measure and to indicate the stress state within continuous welded rail complying with NR/L2/TRK/001/mod3, issue 8, Clause 8.5 '*Stress unknown*' sites.

Safety, Technical and Engineering (STE) hereby authorises the product above for use and trial use on railway infrastructure for which Network Rail is the Infrastructure Manager under the ROGS regulations.

Reviewed by:

Usha Trivedi
Product Acceptance Coordinator

Authorised by:

Gareth Evans
Professional Head of Track

PANDROL

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