Rail Stress Management

Procedure

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1. Purpose

The purpose of this procedure is to outline the approved processes for managing rail stress on the BHPBIO rail network.

2. Scope

This procedure details the theory behind rail stress and outlines the track work practices required to maintain a neutral rail stress network. Additionally the strategy and methods used to monitor and measure rail stress are covered along with BHPBIO approved rail stressing processes.

3. Policy / Procedure Statement

This procedure shall be adhered to unless otherwise specified in the following information.

Quality / Safety Message
Rail stress management is critical to preventing rail pull-aparts and track buckles. Preventing both these fault types is of the utmost importance to minimise the risk of train derailments on the BHPBIO network.

4. Disclaimer

It is acknowledged that in releasing this document there are a number of components, as listed below, that BHPBIO will not be able to be immediately compliant to. As such a 12 month grace period will be utilised to implement the necessary measures required for compliance.

During the 12 month grace period measures will be implemented for the following requirements to ensure full compliance is achieved by, as a minimum, the end of the grace period;

1. Installation of track monuments
2. Training and competency compliance
3. Procurement and use of appropriate plant and equipment to achieve compliance
4. Access to, and the use of correct forms

During this period, risk assessments will be conducted, were deemed necessary, on areas of non-compliance to ensure required preventative and mitigating controls are implemented. After the 12 month grace period full compliance to the procedure will be required.

5. INTRODUCTION TO RAIL STRESS

5.1. Temperature and Rail Stress

Steel rails naturally expand and contract when subjected to increases and decreases in temperature respectively. The amount of expansion or contraction is dependent on the original length of rail (L_0 (m)), the thermal expansion coefficient (α) (steel = 0.0000115 / ˚C) and the change in rail temperature (ΔT ˚C) as shown in Equation 1;

$$\Delta L = L_0 \times \alpha \times \Delta T \qquad \textbf{Eq 1}$$

For 68kg/m rail a 1˚C change in the temperature of a 200m length of rail will result in a 2.3mm change in length. Appendix 10.1 contains a table of calculated rail extensions for varying rail lengths based on variations from a Stress Free Temperature (SFT) of 37 ˚C.

When installed in track, the rail is fixed in place in a stress free state. The temperature at which this occurs is known as the Stress Free Temperature of the rail. During subsequent changes in temperature, as the rail is secured, it cannot expand or contract freely. This causes compressive (pushing) or tensile (pulling) longitudinal forces to build up within the rail. The amount of force created in the rail is dependent on the cross sectional area of the rail (A (m^2)), the Young's Modulus of steel (E (MPa)), the stress free temperature of the rail (T_N (˚C)), the current rail temperature (T_R (˚C)) and the coefficient of thermal expansion (α) as dictated in Equation 2;

$$P = EA\alpha \times (T_R - T_N) \qquad \textbf{Eq 2}$$

For 68kg/m rail a 1˚C variation from the rail SFT will result in a longitudinal force equal to 2.1 ton. Due to rail never being perfectly straight, when in compression, this longitudinal force has a lateral component which acts to push the track outwards. With further increases in temperature, the longitudinal force is proportionally increased, creating a greater lateral force and a greater risk of a track buckle. Appendix 10.2 contains a table of the forces (compression or tension) created in clipped in 68kg/m and 71kg/m rail due to variations in rail temperature compared to the SFT.

5.2. Design Stress Free Temperature

The Design Stress-Free Temperature (DSFT) is the temperature at which there are no temperature induced longitudinal forces, or stresses, within the rail. Rail temperatures vary throughout the day. Consequently, the temperature of correctly adjusted rails is seldom at DSFT.

Any variation in rail temperature from the DSFT results in compressive or tensile forces in the rail. The BHPBIO network experiences rail temperatures of between 0°C and +70°C, depending on location and season. Generally, the DSFT is approximately mid-way between the rail temperature extremes. For networks with greater track stability (greater resistance to buckling) or a more affinity for rail pull-aparts, the DSFT may be closer to the lower end of the temperature range, effectively reducing the maximum longitudinal tension force experienced. Conversely, to reduce buckling risk the DSFT can be set closer to the upper temperature limit to reduce the maximum compressive force experienced.

Figure 1 shows an example of the maximum and minimum rail temperatures experienced during a year and the DSFT selected to minimise the effect of thermal stresses on the track structure.

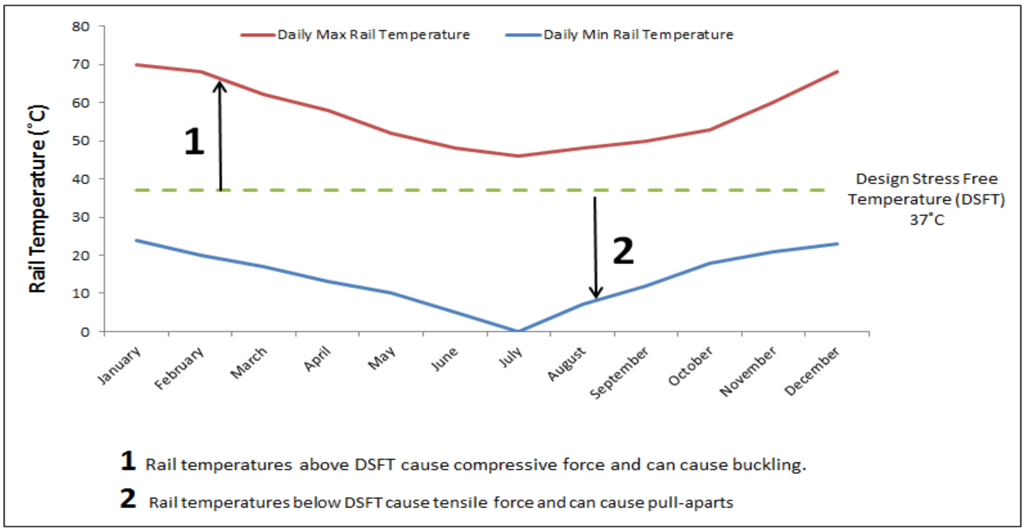


Figure 1 Comparison of DSFT and Annual Rail Temperature Ranges (Example)

Table 1 displays the current DSFT for each of BHPBIO rail network sections.

Table 1 DSFT for BHPBIO rail network sections

Rail Network Section	DSFT (˚C)
Hedland	37
Mooka	37
Redmont	37
Yandi	37
Newman	37

The SFT is the temperature of the rail at which it is actually stress-free, neither subject to tensile or compressive forces. It is different from the DSFT because it reflects what the track condition actually is, not its design condition. On correctly-stressed track, the SFT will be equal to the DSFT.

A high SFT means that the rail will be prone to pull-aparts during cold weather. In this case, there is “not enough rail”. As the rail temperature drops below the SFT tension forces are created, which, if large enough, will increase the risk of the rail pulling apart at weak spots such as rail welds (particularly aluminothermic welds) and internal rail defects.

A low SFT means that the rail will be prone to buckle during hot weather. In this case, there is “too much rail”. Track sections with poor track stability and a low SFT are at a greater risk of buckling when the rail temperature climbs above the SFT, creating greater compressive forces.

5.2.1. Factors Affecting the SFT

When rail is correctly installed or adjusted, the SFT will be the same as the DSFT. However, overtime it is possible for the SFT to drift away from the DSFT as a result of rail traffic or track disturbing work.

1. Rail creep due to rail traffic;
   - Train braking and/or acceleration, particularly on steep grades

2. Track-disturbing work due to maintenance and renewal activities;
   - Inserting mechanical fish-plated or insulated rail joints
   - Inserting closure rails (rail plugs) when removing rail defects or fixing broken rails
   - Re-railing & track relaying
   - Installing points and crossings
   - Repairing track buckles
   - Replacing a track panel longer than ten sleeper spacing’s that has been removed to enable underlying repairs to be carried out, e.g. bridge work, bog-holes
   - Repairing damaged track, e.g. from derailment or flood
   - Changing track alignment including slewing, lifting and lining
   - Track undercutting (ballast renewal) longer than ten sleeper spacing’s.

5.2.3. Visual Indicators of Drift from DSFT

Visual indications of drift from DSFT include;

- Track buckles or pull-aparts
- Lateral misalignments, including ‘kinks’ in straight track
- Curved track with sharp and/or flat curvature in the body of the curve
- Indications of curved track moving such as depressions in the ballast behind sleeper ends
- Broken or bent fishbolts
- Cracked or broken fishplates or insulated joints
- Creep marks on the rail indicating longitudinal movement (rail creep)
- Skewed sleepers (sleepers out of square or larger spacings)
- Heaped ballast in the cribs in front of the sleepers indicating longitudinal track creep
- Misalignment at turnouts including loss of detection or broken bolts

5.3. Track Stability

The standard track structure of formation, ballast, sleepers, fastenings and rail is designed to interact to provide a structure that resists the lateral forces generated by compressive or tensile forces in the rail. This is achieved by;

- Resilient fastenings, being properly installed, providing a ladder track structure
- Sound sleepers, firmly fastened to the rails and firmly bedded in the ballast
- A full profile of clean, free draining, and firmly compacted ballast.

The approximate contributions of each component to overall track stability are;

- Rails: 10%;
- Fastenings: 30%
- Sleepers and ballast: 60%.

The 60% of total resistance to lateral movement provided by the sleeper in the ballast is comprised of;

- Bottom of sleeper approximately 25% (reduces under traffic)
- Sides of the sleeper approximately 25% (full crib)
- Shoulder ballast approximately 10%.

Under traffic, the wave action of the track reduces the resistance of the ballast beneath the sleeper, increasing the importance and contribution of shoulder ballast.

5.4. Track Buckles

Railway track becomes unstable when forces acting on the track exceed the capacity of the track structure to resist those forces. Track buckling results when the track does not have enough resistance to the lateral, or sideways, component of the compressive forces which build up in the rail due to constrained thermal expansion and applied external loads.

Track buckling is a symptom of some deficiency in the track structure or in the track maintenance procedures. Mainline track buckling is usually lateral, however before lateral movement occurs the track lifts slightly vertical allowing the ballast friction on the bottom of the sleepers to be lost. The track then buckles sideways because of the reduced lateral restraining force. Buckles will occur at the weakest point. This may only be a short isolated piece of track in an otherwise stable section.

The forces acting on the track are;

- Residual forces from the rail manufacturing process;
- Longitudinal forces caused by the difference between actual rail temperature and SFT;
- Longitudinal force from rail movement (creep) over time; and
- Vertical, lateral and longitudinal forces from rail traffic.

Because track is never perfectly straight, longitudinal and vertical forces always have a lateral component which contributes to buckling.

The factors resisting the buckling forces are:

- Friction between the ballast and sleeper sides and base;
- Mass of the track structure, including the rail, sleepers and ballast above the level of the base of the sleepers;
- Stiffness of the rail; and
- Torsional resistance between the sleeper and rail created by the rail fastenings.

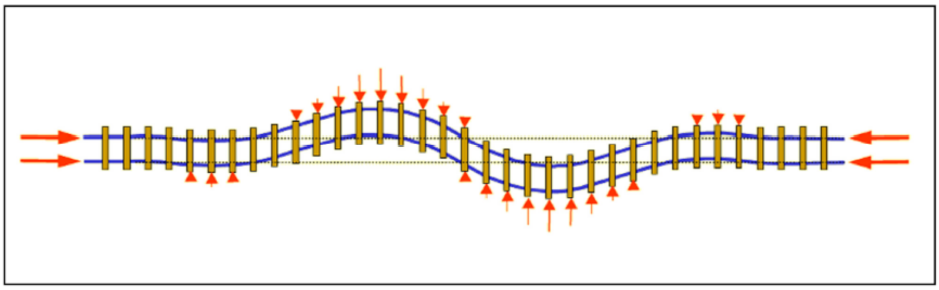


Figure 2 Forces acting on the track, contributing to and resisting, buckling

High temperature is not the direct cause of track buckles. Properly constructed and maintained track will not buckle during days of high temperature. For a buckle to occur the disturbing force must exceed the resisting force as a result of;

1. An increase in the disturbing force;
    - DSFT too low
    - Actual SFT too low through incorrect installation or drift from DSFT
    - Actual rail temperature too high
    - Normal traction (acceleration) and braking loads from traffic
    - Heavy braking forces on steep grades
    - Train emergency brake applications
    - Curves 'pulling in' during low temperature, effectively lowering SFT
    - Tamping and lining outside of location tolerances, effectively lowering SFT
    - Residual stresses in new rail normalising under traffic, effectively lowering SFT
    - Progressive rail creep
    - Horizontal geometry irregularity

2. A decrease in the resisting force;
    - Under-profile ballast (e.g. shoulder width / height not to standard)
    - Uncompacted (loose) ballast
    - Ineffective ballast particle locking caused by flooding or fouling,
    - Degraded or worn / rounded ballast
    - Reduced sleeper / ballast friction from abraded sleeper bottoms
    - Ineffective fastenings, such as clips with reduced toe load
    - 'Pumping' of sleepers due to local formation and drainage issues
    - Lateral track movement

5.4.1. Buckling Force and Resistance Management

To address the risk of buckling, an adequate track stability management plan (TSMP) should be formulated prior to hot weather periods to identify locations that are at risk of buckling during high rail temperatures. These locations are identified by reviewing;

- SFT measurements
- Welded Track Stability Analyses (WTSA)
- Creep measurements
- Track geometry defects
- Curve alignment data (particularly for sharp curves)
- Sleeper, fastening and ballast conditions

- Track maintenance activity data
- Buckle history
- Stressing records for stress welds undertaken since the last plan was prepared
- Bunching points.

The TSMP shall identify the higher buckling risk locations where the following action may be required;

- SFT measurements
- Planned inspections
  - Creep measurements (or rail movement determined by survey)
  - Curve alignment measurements
  - Track alignment (sleeper alignment etc)
- Extreme hot weather inspections
- Rail adjustment

Routine track stability maintenance should be completed to manage compressive rail stresses by;

- Checking that the construction, reconstruction or maintenance of concrete sleepered track must, where necessary, include measurement or re-establishment of SFT in the rails

- Conducting detailed inspections at locations where the SFT has been, or is suspected to have been, lowered for any reason.

Table 2 Track Buckles - Causes and Remedies

Contributory Factor	Preventative Remedy
Track disturbed by resurfacing, ballasting / cleaning	Check compliance with high temperature work restrictions and TSRs following track disturbing works
SFT out of tolerance- incorrect adjustment or creep	Adjust rail to DSFT
SFT out of tolerance - curve pull-in	Realign curve to survey and adjust rail to DSFT
Track has insufficient ballast	Apply more ballast. Apply TSR if required
Track has fouled ballast or bog holes	Recondition. Check drainage in vicinity. Consider TSR for stability.
Sleeper have resilient fastenings with weakened toe-load or deteriorated pads	Replace defective components
Sleepers and / or fastenings are defective	Renew where necessary to provide correct standards
Insufficient superelevation or sharp “kink” in curves	Adjust cross level to designed measurements and put curve on correct alignment
Sleepers not firmly packed	Manually pack, or tamp and consolidate

5.5. Adjusting Rail at Buckles and Pull-Aparts

Trouble spots or repeat buckle locations can be caused when repairing buckles or pull-aparts by not adjusting a sufficient length of rail beyond the fault, leaving parts of rail with a different SFT.

When a buckle occurs, the SFT is often affected for a much greater length than just the buckled track. If these affected sections are not restressed, they remain as a localised section of track where the potential for future buckles or broken rails is much greater. This can lead to the development of 'trouble spots' as shown in Figure 3.

Table 3 Minimum Rail Adjustment Lengths either side

Sleeper Type	Minimum Adjustment Length on Either Side	
	Buckles*	**Pull-Apart**
Timber	10 x buckle length	300m
Concrete	3 x buckle length	100m

*Note: Where a buckle or pull-apart occurs on a curve the entire curve should be adjusted

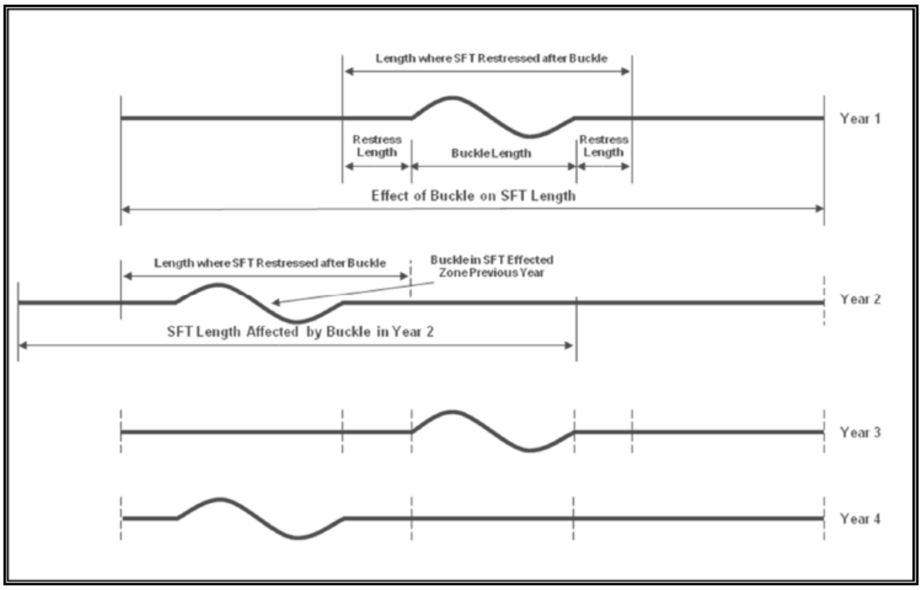


Figure 3 SFT affected either side of a buckle requiring restressing

6. RAIL STRESS MANAGEMENT

The management of longitudinal rail stress is important to ensure the risk of buckling, pull-aparts and other stress related defects is minimised. Stress management consists of two fundamental components;

1. Measuring and Monitoring;
    - Remote monitoring, planned inspections and SFT verification tests are conducted to monitor the rail stress across the BHPBIO network.

2. Track Maintenance Processes;
    - Track work is conducted to maintain, or return, the rail to a stress free state.

6.1. Measuring and Monitoring Rail Stress

Rail stress measuring and monitoring is undertaken to identify areas of risk in the BHPB rail network and plan rail adjustment work. The monitoring requirements, measurement methods and recording requirements are outlined in this section of the procedure.

Rail stress monitoring and measurement consists of the following components;

1. Remote Monitoring
    - Rail and ambient temperature is measured at individual locations along the network to provide a temperature profile.
    - SFT is monitored at select problematic locations to analyse drift from DSFT.

2. Inspections
    - Visual inspections are conducted to identify signs of rail stress issues.
    - Approved measurement methods are used to verify the SFT of track sections.

3. Track Maintenance Activity Data
    - Activity information such as weld data and rail clip up temperatures is captured for each item of track work and input into the TCMS to enable analysis of the rail stress.

The data from each of the sources is collected into the TCMS for use in mapping the SFT profile of the network, determining at risk areas and developing destressing work lists.

6.1.1. Remote Monitoring

6.1.1.1. Rail and Ambient Temperature

Rail and ambient temperature measurements should be recorded, using underfoot devices, at representative locations along the BHPBIO network. The temperature data is used to;

- Map the rail temperature profile of the network for each season to determine the appropriate DSFT for each track area.
- Assess the risk of buckling during periods of high rail temperature in areas where low track stability has been identified and take mitigating and preventative actions.
- Assess the risk of pull-aparts during periods of low rail temperature in areas where high SFT has been identified or is suspected and take mitigating and preventative actions.
- Determine if track maintenance activities (tamping, welding etc) can be safely conducted to maintain the track in a stress free state.
- Determine the optimum time to conduct rail stressing activities.

Figure 4 Proposed locations of Rail and Ambient Temperature Devices

6.1.1.2. Stress Free Temperature

Changes in the SFT of specific track sections should be monitored using strain gauging sensors attached to the web of the rail. The sensors measure the rail longitudinal stress and temperature to determine if changes in stress state are the result of temperature variations from the DSFT or if the actual SFT of the rail has drifted from the DSFT as a result of the factors outlined in Section 4.2.1.

The SFT sensors should be located in regions were rail stress issues have been identified such as;

- Repeated rail pull-aparts or buckles
- Rail creep
- Skewing sleepers

Prior to installation of the sensors, the track must be stressed to the DSFT. Any drift of the actual SFT from the DSFT is then detected by a change in the relationship between the strain in the rail and its temperature. Appropriate mitigating actions such as speed restrictions during high or low temperatures or rail destressing can then be used to mitigate the risk created by the SFT drift.

6.1.2. Inspections

Planned and unplanned inspections are used to identify track stability and rail stress issues that may increase the risk of buckling and pull-aparts.

6.1.2.1. Hot Weather Inspections

A planned general inspection of higher risk track is to be carried out prior to the end of October each year. The purpose of the inspection is to complete a welded track stability analysis (WTSA) on the predetermined higher risk locations to identify sections of low track stability that may be susceptible to track misalignment or buckling during hot weather periods. Prior to completing the inspection the list of higher risk track to be analysed shall be identified via the TSMP. The results from each WTSA are used in conjunction with other information to develop the actions in the TSMP for reducing the risk of rail stress issues at each location.

The template for completing a WTSA of a section of track is presented in Appendix 10.6. The WTSA focuses on the determining the track stability condition using the following metrics;

- Track alignment details (if possible)
- Rail creep (if possible)
- Ballast and Anchor conditions (condition of fasteners if resilient fasteners used)
- Train activity (braking, acceleration points)
- Track stability disturbance activities

Critical Rail Temperatures

Hot weather inspections must be performed on track sections with low track stability, when the current rail temperature is greater than 30˚C above the respective SFT. Additionally inspections should be carried out in addition on any other areas deemed at risk when the rail temperature is high such as;

- Recently disturbed track
- Track at the bottom of sags
- Locations where heavy braking occurs
- Fixed track structures, such as turnouts and bridges

Inspections will focus on signs of low track stability and high rail compression such as kinky or wavy rail or disturbances in the ballast shoulders.

If required a 60 kph TSR should be applied to the track section until the rail temperature has registered less than 30˚C above the SFT for 1 hr.

Unplanned inspections may be performed at any time of the year if there is reason to suspect track stability or rail stress issues that may increase the risk of buckling. The objectives of unscheduled inspections are to:

- Identify defects or conditions that indicate problems with track stability or rail stress.
- Detect signs of SFT drift from the DSFT
- Allow closer assessment of any condition that has been identified during Track Condition Monitoring Vehicle (TCMV) runs that may impact on lateral stability.

Unscheduled track lateral stability patrol inspections are to take into account;

- Track condition
- Known track performance in high temperature
- Forecast temperatures, hence likely associated rail temperatures and buckling forces
- Practicality (resources, distances involved, train density).

Unscheduled track lateral stability inspections should focus on, and give priority to, special locations and sites of recent disturbance.

Any rail stress or track stability defects shall be captured in the Track Condition Monitoring System (TCMS) and in the 1SAP work management system to enable remediation to be planned.

6.1.2.2. Cold Weather Inspections

Planned inspections of high tension stress risk locations should occur during the colder weather period May – August when the rail temperature is < 30˚C below the SFT. The aim of the inspections is to identify and control the risk of pull - aparts or track alignment faults. The planned inspections should utilise some or all of the following;

- Rail creep measurements
- Track alignment measurements (evidence of sleeper skewing, curve pull in)
- SFT measurements (VERSE testing)

Any identified rail tension stress issues shall be captured in the Track Condition Monitoring System (TCMS) and in the 1SAP work management system to enable remediation to be planned.

6.1.2.3. Rail Creep Inspections

Creep is the longitudinal movement, or migration, of rail over time as a result of:

- Track gradients
- Train operations, and/or
- Inherent stresses from manufacture or construction.

Track prone to rail creep includes:

- Track adjacent to 'fixed' structures such as turnouts and level crossings
- Bridge ends and highly-curved sections
- Areas with long or steep grades or where high traction or braking occurs
- Any other area where rail stressing or buckling / pull-apart problems have existed.

Rail creep changes the SFT of the rail as bunching of the rail can create compression and tension in separate sections of the track. The risk associated with this is an increased likelihood of rail breaks and buckles, with the risk of buckles compounded from disturbed ballast caused by potential sleeper movement. Measuring the rail creep into and out of a defined section of track allows us to estimate the change in the SFT of the section and hence if rail stress issues exist.

Creep is assessed by setting up a fixed point (monument) near the track and a marked point on the rail. Using a laser tool or string line the perpendicular distance between the fixed point and the mark on the rail is measured to assess movement. If rail movement has occurred, the laser or tape will touch the rail at a distance from the initial point. The distance between these two laser-projections has been considered as the amount of rail creep or rail longitudinal movement.

Monuments are permanent trackside fixtures. Examples of monuments include rail posts, or other steel sections concreted into the ground. Prior to setting a creep monitoring monument, the rail must be adjusted to the DSFT. Appendix 10.8 outlines how to establish a monument and measure rail creep.

Table 4 outlines where monuments are required for creep monitoring purposes.

Table 4 Monument requirements for creep monitoring

Track Feature	Required Monuments
Curves (<=1000m radius)*	1 every 100 m & transition points
Fixed Points**	60m before and after
Tangent***	1 every 500 m
High Gradients****	At bottom of and top gradient

** Curves with radius greater than 1000m are treated as tangent*
*** Fixed points include turnouts and bridges*
**** Applicable to sections of tangent > 500m in length, where creep issues are suspected*
*****Applicable to sections where gradient is > 1:1.3*

Table 5 outlines the minimum required frequency of creep measurements. More frequent inspections may be completed if mandated.

Table 5 Creep measurement frequency

Track Feature	Measurement Frequency
Curves (<=1000m radius)	3 months
Fixed Points	3 months
Tangent	6 months
Bottom of Gradients	3 months

Note: SFT measurements are preferable to rail creep measurements. Creep measurements are only valid if the reference point (monument) is established when the SFT of the rail is known.

30mm creep into or out of a 500m section of rail can change the SFT by 5.2˚C. Table 6 outlines the required response for different levels of rail creep.

Table 6 Responses to rail creep levels

Rail Creep* (mm)	Approximate ΔSFT (˚C)	Response	Time Frame (days)
30-60	5 – 10.4	Complete verse test to confirm SFT**	< 80
>60	>10.5	Complete verse test to confirm SFT and then plan in adjustment of rail to DSFT	< 60

**Creep over a 500m length of rail.*
***Complete SFT test within 100m - 300m of creep gaining monument or in the vicinity of the bunching point. Use SFT measurement response criteria (Table 9) to determine action based on SFT measurement.*

6.1.2.4. Curve Alignment

Lateral movements over the length of a curve can result in changes to the SFT. This effect is greater in tighter radius curves. The alignment of a curve is checked to ensure it has not pulled in under tension or is at risk of buckling at the transition point during high rail temperatures.
Curve alignment is to be measured where;

- The alignment is deemed faulty
- Alignment measurements are required for a WTSA
- The curve has a history of pulling in or misaligning.

Nominated curves which require measurement should be, as a minimum, re-measured annually. The annual schedule of curves to be measured is to be included in the TSMP. Curve alignment measurements may be completed at any other time if deemed required.

Measurements should be taken at 100m intervals or at established monuments If changes in the curve radius is measured, the results shall be recorded in the TSMP and realignment scheduled. If the required realignment is greater than that outlined in Section 5.2.2 then a SFT verification test is required.

6.1.3. Stress Free Temperature Measurements

Approved measurement methods can be used to verify the SFT of rail when required. Testing may be completed destructively, by cutting the rail or non-destructively using verse test equipment. SFT measurements shall be reported and recorded to maintain the network SFT profile.

Table 7 outlines the minimum requirements for verification of the SFT. In certain circumstances more urgent verification tests may be required to enable planning of potential rail adjustment prior to the winter or summer periods respectively.

Table 7 Requirements for SFT verification tests

Activity / Trigger	Time Frame
Re Rail outside of DSFT range*	< 42
Rail Replacement outside of DSFT range**	< 60
Tamping***	< 60
Rail creep	See Table 6
Ballast replacement (inc track undercutting)****	< 42
New track construction*****	< 42

* Rail lengths greater than 25m

**Rail Lengths less than or equal to 25m

*** See Section 5.2.2 for detailed criteria

**** Only if line and or level is altered or if SFT prior to work is unknown

***** SFT measurement to be completed after tamping and alignment activities

Additional requirements for SFT verification measurements may include;

- Where there have been indications of lateral instability
- Where there have been multiple repairs in the same vicinity
- Other locations or where compliant SFT is questionable
- As a requirement from a TSMP

Table 8 outlines the response required for different SFT test results. The stated time frames are minimum requirements. Stressing priority is also determined by other factors as outlined in Section 6.5.

Table 8 Responses for SFT test results

Measured SFT (˚C)	Response	Time Frame (Days)
<20	Adjust Rail to DSFT	Before September
20-<32	Manage via TSMP	Before October
32-42	-	-
>42-56	Adjust Rail to DSFT	Before June
>56	Adjust Rail to DSFT	Before May

6.1.3.1. Approved SFT Measurement Methods

The following SFT measurement methods are approved for the BHPBIO network.

1. VERSE Testing

VERSE is a non-destructive test which may only be conducted when the rail is in tension. This procedure is only to be used if the rail is in tension. Appendix 10.9 outlines the procedure for completing VERSE Testing.

2. Rail Gap Measurement

This technique involves measuring the growth or retraction of a rail after it is cut. The procedure is appropriate when the rail is either in tension or compression. Appendix 10.10 outlines the procedure for completing the SFT test.

3. Strain Gauge Measurement

This measurement can be conducted when the rail is in tension or compression and requires the rail to be cut to determine the change in strain. Appendix 10.11 outlines the procedure for conducting the test.

6.1.3.3. Data Recording Requirements

All SFT measurements are to be recorded using the form applicable to the testing method used.

The minimum information recorded shall include;

- Measurement method
- Reason for the test
- Location: kilometerage, track, rail
- Kilometre range the test is applicable over
- Date and time of test
- Rail temperature
- Measured SFT
- Required response based on Table 8
- Operator's name

Recorded data shall be provided to the Track Condition Monitoring Team via the appropriate channels for uploading into the TCMS. This ensures the network SFT register is maintained and updated.

A measured SFT will be deemed expired when;

- It has been superseded by a new measurement
- Any activity disturbing the SFT has been completed in the section (see Section 4.2.1)

6.1.4. Track Maintenance Activity Data

Activity data shall be recorded during track maintenance works and input into the TCMS to facilitate rail stress decision making processes. Table 9 outlines the information / data to be recorded for maintenance activities.

Table 9 Track maintenance activity data required for rail stress management

Activity	Required Information
Re Rail	Rail weld temperatures Rail clip up temperatures
Adjusting Rail	See Appendix 10.3
Tamping	Rail temperatures Lift/lower and slew distances
Rail Installation*	Rail weld temperatures

* Rail length <25m

6.3. Track Maintenance Processes

As outlined in Section 3.2.1 a large number of track maintenance activities can disturb the rail stress or track stability. Therefore it is a requirement that the rail SFT be returned to within the DSFT range.

6.3.1. Rail Installation

All rail across the BHPBIO network shall have a SFT that conforms to the DSFT range of 32-42˚C. If rail can be placed and fastened such that the clipped up SFT complies with the DSFT tolerances, the need to adjust rail stress is avoided. However if tamping is within the scope of the work, verification of the SFT after the tamping activity is required as per Table 7.

For track construction, ballasting and tamping following rail installation will smooth out irregularities in track line and level, which will tend to lower the SFT. The rail therefore can be placed and fastened within a temperature range somewhat higher than the intended final range, to assist in achieving DSFT range compliance after tamping is completed.

6.3.1.1. Re-Railing Plain Track CWR

Prior to plain track re-railing, it is desirable that the alignment of curves be checked and corrected as necessary to avoid altering of the SFT by alignment adjustment after re-railing. Curve alignment should be checked irrespective of whether or not the track is planned to be tamped as part of the re-railing.

For the re rail activities, to achieve a SFT within the DSFT range of 32-42˚C the;

1. Rail must be welded together or fastened down while its temperature is within 32-42˚C or
2. The rail must be stressed with tensors (possible only if the rail temperature is below the DSFT)

Rail that is laid within the DSFT and connected up (either through the use of anchors or via welding) such that further expansion or contraction is prevented may be fully fastened down at a later time. Under this situation it is acceptable if the remainder of the fastening occurs outside of the DSFT. Table 10 outlines the minimum anchors required for various rail lengths to ensure further expansion or contraction is prevented. Rail weld temperatures or anchor temperatures must be recorded to prove the rail was constrained within the DSFT range.

Table 10 Anchoring requirements for plain track laying to prevent rail movement

Module Length (m)	Required anchor at each end of module (Number of Sleepers Fastened)
<200	30
200-400	40

Rail that is laid below the DSFT range may be pulled using tensors to increase the SFT. The requirements for this are covered in Section 6.

If the rail is constrained outside of the DSFT range a follow up SFT verification test must be completed as per Table 8. SFT measurements for plain track re rail shall;

- Be carried out for every rail module. Depending on track alignment, a module length can be up to 800 metres.
- Be carried out at the centre of the module length (within 100m either side)

Refer to Table 8 for responses to SFT measurement results.

6.3.1.2. New Track Construction CWR

For track construction, where ballasting, lifting and lining are to be carried out the rail can be clipped up approximately 5°C above the DSFT to allow for a reduction in the SFT due to smoothing out during tamping and aligning. This methodology assists with achieving the required SFT and limits the potential rail adjustment required after tamping and alignment. However the SFT of the rail **must be** verified after tamping and aligning as per Table 7. SFT measurements for new track construction shall;

- Not be undertaken until track design levels have been achieved and DAR recording of the track has been completed and approved by the Company.

- Be carried out for every rail module. Depending on track alignment, module length can be up to 800 metres.

- Be carried out at the centre of the module length (within 100m either side)

Refer to Table 8 for responses to SFT measurement results.

6.3.1.3. Defect Removal

Smaller rail lengths (<25m) that are installed during the removal of defect rail or Insulated Rail Joints (IRJ) must be welded within the DSFT range of 32-42˚C. If welding is completed outside of this range, without appropriate means of rail adjustment (only when rail temperature is less than the DSFT 37 ˚C), verification of the SFT is required as per Table 8.

Rail in = Rail Out Method

It is preferable to check and correct rail adjustment whenever welding operations are undertaken in CWR track. However, when this is not practical it is essential that the rail SFT is not further altered. In its simplest terms this means ensuring during the repair work;

RAIL IN = RAIL OUT

This method of removing defects from CWR track does not check that the track is in correct adjustment. It only retains the previous adjustment of the track before the defect was removed. If the rail temperature is above 37°C and a rail defect is to be removed, rail tensors cannot be used to maintain adjustment. When such cases arise, and it is not practical to wait for the rail temperature to fall before removing the defective rail, then:

1. Mark the field side head of the rail, 200mm either side of the section to be removed
2. Measure and record the initial distance between the 2 marks.
3. Remove the fastenings from the section of rail that is to be removed.
4. Establish the length of defective rail to be removed. Mark, measure and record this distance.
   a. Extra anchoring around the defect may be used to reduce “jump back” of the rail.
5. Cut the rail and remove the defective section.
6. Once rail movement has stopped cut the closure rail to the required length
   a. AT Welding: Length = Gap minus 2 x AT welding gap
   b. FB Welding: Length = Gap + Welding Gap + Burn Off
7. Weld the free ends of the closure.
8. Replace all fastenings on the closure.
9. Measure and record the final distance between the two rail head marks
10. Record the difference between the measurements from Step 9 and Step 2 on the weld form
    a. Rail in / out = Final – Initial (i.e. positive = rail gained, negative = rail lost)

6.3.2. Track Realignment and Slewing

Track realignment and slewing changes the stress state of the track. Small lateral movements over a 100m length of curve, such as in Figure 5, can result in changes to the SFT, with the effect more severe in tighter radius curves. Realignments, while improving track geometry, can result in the rail becoming more likely to buckle or pull-apart due to the SFT moving from the DSFT.

The following alignment activities will cause a reduction in the SFT;

- Slewing inwards on a horizontal curve.
- Lifting in a concave vertical curve
- Lowering on a convex vertical curve

Slewing outward on a horizontal curve, lowering a concave vertical curve or lifting a convex curve will increase the SFT.

For a particular value of slew/lift/lower the effect on the SFT is more pronounced over small wavelengths on small radius curves and least pronounced over long wavelengths on large radius curves

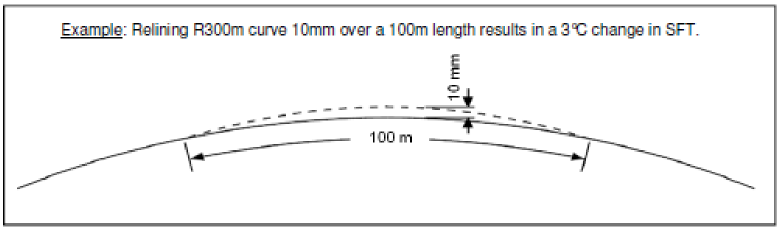


Figure 5 Impact of curve realignment on rail stress

As well as altering SFT, realigning or slewing track disturbs the track and reduces the forces resisting track buckling. Conducting these activates during periods of high rail temperature further reduces track stability and increases the risk of buckling. To reduce this risk;

- If not instructed otherwise, realignment shall not be completed if;
  - The rail temperature is in **excess than 55 ºC**
  - The worksite has sufficient ballast to provide a full profile when work is completed.

- Track realignment work should be ceased if at any stage the rail temperature exceeds 55 ºC or there are visible signs of track instability or movement.

To maintain track stability after track realignment works the following should be completed;

1. Consolidation of disturbed ballast using a Dynamic Track Stabiliser or;

2. Application of a 60 kph TSR if the rail temperature exceeds 55ºC during a minimum ballast consolidation period of 100,000 gross tonnes.

A SFT verification test of the track section after realignment or slewing shall be completed if;

- Rail temperature exceeded 55 ºC during the work and, or;

- **Alteration to Line:** Slewing inward on horizontal curves
  - Curve radius 750m or less: maximum slew is 30mm or more
  - Curve radius over 750m: maximum slew (mm) exceeds 0.04 times radius (m)

- **Alteration to Line:** Slewing outward on horizontal curves
  - Maximum slew (mm) exceeds 0.08 times curve radius (m)

- **Alteration to Level:** Lifting and/or increasing cant through concave vertical curves or lowering and/or reducing cant over convex vertical curves
  - Vertical curve radius 1875m or less: Maximum lift/lower/re-cant is 75mm or more
  - Vertical curve radius over 1875m: Maximum lift/lower/re-cant (mm) exceeds 0.04 times vertical curve radius (m)

- **Alteration to Level:** Lifting and/or increasing cant through convex vertical curves or lowering and/or reducing cant through concave vertical curves
  - Maximum lift/lower/re-cant (mm) exceeds 0.08 times vertical curve radius (m)

6.3.3. Replacing Fastenings after Track Work

‘Toe load’ is the positive pressure, or clamping force, which a rail clip exerts on the rail foot. The force may be transmitted either directly or with an insulator. The purpose of the toe load is to;

1. Help prevent (but not eliminate) rail creep; and
2. Provide torsional resistance, making it more difficult for the rail to rotate in the rail seat

Loss of toe load can occur with repeated removal and application of fastenings particularly with Pandrol e-clips. As a result the fastenings provide less resistance to rail creep and rail rotation. In turn, this means changes in SFT are more likely and the track has less resistance to buckling.

Loss of toe load is compounded in sections of the track where the fastenings are repeatedly subjected to high lateral forces from train wheels. Over time, these repeated load cycles affect the properties of the clip and reduce the toe load. This is particularly an issue in curve transitions. Changes in SFT occur as the track moves out of alignment, and again when relined.

Before performing rail adjustment the condition of fasteners must be inspected (including an additional 50m either side of the track section to be adjusted / renewed) for signs of wear or loss of strength.

During adjustment / renewal replace all fastenings (clips, insulators and pads) identified as weakened.

7. RAIL STRESS ADJUSTMENT

Rail stressing is the process by which the rail is manually adjusted to bring the SFT of the track in line with the accepted DSFT range. This chapter outlines the criteria, requirements and approved methodology to conduct rail stressing on the BHPBIO network.

7.1. General Requirements

This section details the general requirements that are applicable to both below neutral temperature and natural stressing of CWR on the BHPBIO network.

7.1.1. Requirement for Adjustment

Adjustment of rail may be required whenever representative SFT measurements indicate the SFT of the track section is not within ±5°C of the DSFT (37°C) as outlined in Table 8. Because of this requirement destressing is commonly required;

- After plain track re railing or new track construction
- Following significant track disturbance works
- In regions of excessive rail creep

To confirm the destressing requirements as minimum SFT measures shall have or be;

- Carried out at the centre (within 100m either side) for every destressing module

The approved methods of measuring the SFT are outlined in Section 5.1.3

7.1.2. Competencies

Prior to commencing any destressing task the job supervisor or coordinator shall have current, qualifications in, as a minimum;

- TLI 32511, Certificate III in Rail Infrastructure
- TLIB 3102A, Adjust Rail

7.1.3. Preparation

Before stressing rail, ensure track structure and condition complies with the CoP, including;

- Ballast at the correct profile and track has correct top and line
- Sleepers are square to the rails and ineffective sleepers within allowable limits
- Fastenings and rail anchors are in good condition

Where the track structure is non-standard seek advice from the Track Engineer on the course of action.

7.1.4. Methods of Adjustment

Stressing of rail may occur;

- At DSFT (natural stressing),
- Below the DSFT (applied force)

Rail cannot be stressed when the rail temperature exceeds the DSFT.

Stressing at DSFT involves unclipping a rail module, making a cut and allowing expansion or contraction to occur naturally. The module is then constrained once the rail temperature reaches the DSFT.

Stressing below the DSFT involves applying a tensile force to the rail to simulate the expansion that would occur under the influence of a temperature increase. The force is applied using rail tensors, which are either incorporated into the flashbutt welding head, or stand-alone. This method of destressing is the preferred over natural destressing as it is not reliant on rail temperatures being inside the DSFT range.

7.1.5. Adjustment Temperatures

Rail shall not be adjusted with rail tensors at rail temperatures below 10˚C for the following reasons;

- To ensure rail tensors are not over stressed. Adjusting below 10˚C requires in excess of 60 tonnes of force, which poses safety risks and may overstress the tensor units.

- Longer modules may not be evenly stressed

Above the DSFT of 37˚C, correctly adjusted CWR should be in compression. As compression cannot be simulated by pushing the rails apart the maximum rail temperature for which adjustment can be commenced is 37˚C.

If rail temperature rises after adjustment has commenced, the adjustment can be carried out up to a maximum of 40˚C.

If rail is cut and the temperature rises above 40˚C, adjustment must be stopped, the rail welded together and the details of the gap and temperature recorded. The affected section must be scheduled for re-adjusted when the rail temperature drops below 37˚C.

7.1.5.1. Measuring Rail Temperatures

Temperature readings shall be taken;

- Using only approved magnetic thermometers.
  - Non contact types such as laser or infrared guns shall not be used
  - Thermometers should be recalibrated every 6 months and a register maintained (See Appendix 10.11)

- On the shaded side of the web of the rail.
  - If shaded side is not obvious, take a measurement from the web of the rail on each side and use the lower of these two measurements

- At least every 500 metres; and

- With a minimum of three readings over the total length of rail being adjusted, of which:
  - One reading must be near the Cut Point; and
  - One reading must be near the ITT of each length to be pulled

The temperature readings shall be averaged to obtain the rail temperature to be used in the rail adjustment calculations.

Note: The rail temperature measured on a north-facing rail web can read 2°C higher than the average rail temperature. Rail adjusted using the higher temperature as a reference will result in the track having an actual SFT approximately 2°C lower than the target.

7.1.6. Adjustment Length

The maximum lengths of CWR that can be adjusted in one direction are outlined in Table 11.

Table 11 Maximum stressing lengths and (pulling length in one direction)

Curve Radius R (m)	Maximum Stressing Length (m) (pull in one direction) Without under head rollers	Maximum Stressing Length (m) (For stressing at DSFT) With under head rollers
R ≥ 2000 and tangent	800 (400)	TBD
2000 > R ≥ 1600	500 (250)	TBD
1600 > R ≥ 400	300 (150)	TBD
R < 400	150 (75)	TBD

NOTE: Actual adjustment lengths will depend on equipment and practices to ensure an even distribution over the adjustment length. Module length is to be no more than twice the maximum length of adjustment and subject to approval by the Principal Track Engineer or their delegate.

The maximum stressing length is achieved when the pulling point is at the middle (i.e. both pulling lengths are the maximum permitted pull in one direction length). The pulling point may be located anywhere in the stressing length, provided the maximum pulling length limits are not exceeded.

Factors to be considered in establishing the stressing length and pulling point include;

- The stressing length must not exceed that permitted by Table 11
- Where the radius changes through the module length, the maximum pull length shall be determined by the minimum radius.
- The cut point shall be at least 6m from welds or joints, and midway between two sleepers
- Rail must be free to move unimpeded along the sleepers, but with sufficient fastenings remaining to maintain alignment of the curve
- Tensor capacity (load and extension) must be adequate.
- Stressing length must not contain any mechanical joints

Curve stressing shall span the total length of the curve including the transition areas between the outer curve tangent points.

7.1.7. Stressing Rollers

If used, stressing rollers must be spaced in accordance with Table 12.

Table 12 Stressing Roller Spacings

Curve Radius R (m)	Maximum Roller Spacing
Tangent to R ≥ 800	Every 12 Sleepers
800 > R ≥ 500	Every 5 Sleepers
500 > R ≥ 400	Every 3 Sleepers
R < 400	Every 2 Sleepers

7.1.8. Anchor Lengths, Tell Tales and Reference Points

7.1.8.1. Anchor Length

The minimum anchor lengths for rail stressing shall be 40 metres and confirmed by zero movement at the Outer Tell Tale (OTT). The anchor section shall have all the ballast shoulders pulled up and cribs sufficiently full of ballast to ensure track stability. Anchors shall be established a minimum 90m from turnouts, bridges and level crossings.

The position of the OTT shall be monitored for the duration of the stressing work. If at any stage there is movement at the OTT, the anchor length must be increased by 10 meters until no further movement is detected. Some movement at the ITT is expected and acceptable.

Note: The anchor length must not contain any mechanical or insulated rail joints.

7.1.8.2. Tell Tales

The purpose of the tell tales is to monitor the effectiveness of the anchor length during stressing.

A tell-tale is normally formed by using a sleeper as a monument, painting the rail foot, and accurately scribing the tell-tale on the foot of the rail and top of bearer. A sleeper used as a tell-tale monument must be unclipped prior to cutting the rail at the pulling point to prevent any rail movement causing the tell-tale monument sleeper to move through the ballast.

There are two tell-tales located at either end of each anchor length;

- Inner tell-tale (ITT): the ITT is the first bearer inside the stressing length, immediately adjacent to the anchor length. This bearer must be unclipped and rail foot painted and accurately scribed before cutting rail at the pulling point. The next two (2) bearers inside the stressing length should also be unclipped before cutting rail.

- Outside Tell-tale (OTT): The OTT bearer is the first outside the anchor length. This must be unclipped and the foot painted and accurately scribed before rail is cut.

Alternative methods of establishing tell-tale monuments are;

- Two (2) star pickets driven into formation either side of track and a string line between them to mark the tell-tale on the rail head

- Survey pegs driven into ballast adjacent to the rail and the rail marked

Caution – these two methods require a penetration permit prior to use.

Rail Movement at the ITT and OTT

Rail movement at the OTT shall not be greater than 2mm. If greater than 2mm of movement occurs the anchor length is deemed not effective and;

- The anchor length must be increased; or
- The fastenings replaced

Some rail movement at the ITT is to be expected during stressing. Movement may be towards or away from the midpoint, depending upon the SFT of the anchor. Movement towards the midpoint should be ignored. Movement away shall be added to the gap extension calculations.

Any movement of the rail at the tell tales, when the fastenings are released shall be noted on the CWR Stressing Work Form (see Appendix 10.3)

7.1.8.3. Stressing Adjacent Lengths

When stressing on a face, the anchor lengths are to be reversed so that the previous anchor length is now included within the next stressing length. Overlapping stressing lengths are permitted provided the new anchor is installed before the old anchor is released.

Anchors

As shown in Figure 6 the anchor length for the next stressing length shall be located within the completed stressing length. One sleeper at the common point may be used in both anchor lengths.

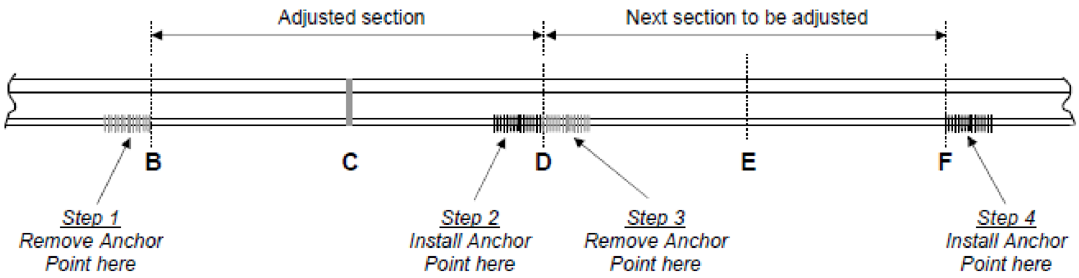


Figure 6 Changing the anchor for the adjacent stressing module

Tell Tales

The ITT is within the stressing length as close as practical to the anchor point. When the rail is scribed using a sleeper as the monument it must be the first one inside the stressing length.

When using a common anchor point sleeper the ITT sleeper for the next stressing length becomes the sleeper the other side of the anchor point than the previous ITT.

7.1.8.4. Reference Marks

Reference marks are established as monitoring points along the stressing length, to enable checking and confirmation of correct rail movement during stressing.

Reference marks must be established at the quarter points; ¼, ½, ¾ locations along each pulling length as shown in Figure 7. The marks are formed in the same way as tell-tales, including unfastening the rail, but they are not scribed until when the rail is fully relaxed. The points are to be marked by painting the foot of the rail and the sleeper and accurately scribing the mark on the painted sections.

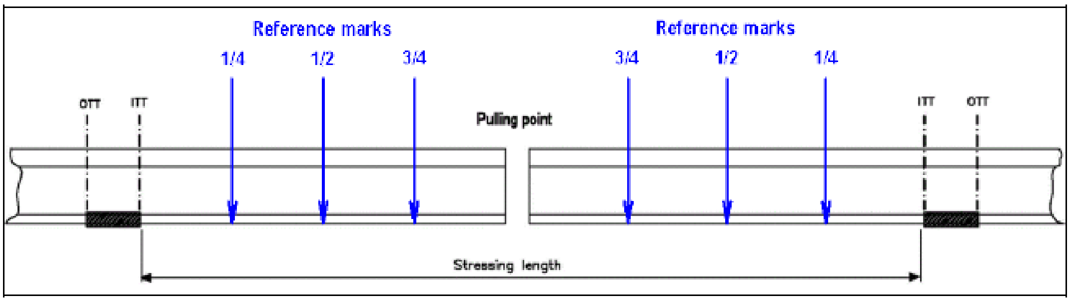


Figure 7 Location of reference marks

Reference marks shall be established on the field side head of the rail 200mm on each side of the pulling point, prior to cutting. The marks are used to measure the amount of rail removed or added.

After completing stressing, accurately re-measure and record the distance between the two rail marks on the CWR Stressing Work Form.

7.1.9. Relaxing Rails

Rail is relaxed from anchor point to anchor point to relieve the stresses and to make the rails stress free, ready to be adjusted. To relax the rail prior to stressing;

- Pre pull the rails and release a minimum of three (3) times. When the rail is relaxed the reference points at the quarter point shall be accurately scribed

- Recorded the force applied by the tensors in the stressing work form

Whilst relaxing, check to see that the rail is not locking up, to ensure a stress free state. To prevent locking up, make sure:

- All anchors and resilient fastenings are OFF,
- Sleepers and sleeper plates are square to the rail and not allowed to twist,
- Welds are not jamming against sleeper plates, and
- There is no binding of the rail to sleeper plates in curves.

If the joint or oxy cut gaps close during the vibrating, open them further by cutting rail out, to allow destressing to continue.

7.1.10. SFT Tolerances

Table 13 outlines the allowable SFT tolerances for different methods of stressing. Verification measurements shall be conducted on, as a minimum, 10% of the stressed locations.

Table 13 Allowable tolerances on SFT when adjusting rails

Stressing Method	Tolerance on DSFT (˚C)
Rail Tensors	± 3
Natural Stressing	± 5

The SFT of each rail stressing module shall be confirmed within 21 days if;

- During stressing with tensors or at neutral temperature the quarter point intermediate extension measurements were not within 5mm of the correct figure. This indicates the rail may be obstructed and should be investigated and corrected prior to welding.

- At any point during stressing the actual pull force was significantly higher than calculated. This indicates the rail may be obstructed and should be investigated and corrected prior to welding.

- Welding is carried out above 43°C

The module shall be re-stressed if the SFT test results following destress are outside of the DSFT range of 37 °C ±5°C.

7.1.11. Reporting Requirements

The person in charge of the rail adjustment is required to complete the CWR Stressing Work Form found in Appendix 10.3

The following parameters shall be recorded as a minimum in the CWR Stressing Work Form for each destress module (East & West rail);

- Location
- Destress rail cut – time, rail temp and gap
- Rail Type (to check record embossed and indented markings)

- Length of Pull
- Calculated extension
- Movement at quarter points, ITT and OTT
- Closure length (if required)
- Actual extension
- Rail temp (during rail cutting, tensing rail, and prior to welding)
- Calculated and actual pull force
- Destressing Register

7.1.12. Additional Requirements

- No destress welds shall occur on or within 90 metres of bridges, fixed structures and level crossings.

- Destress welds shall be flash butt welds. The use of ATW shall be approved by the Principal Track Engineer or approved delegate.

- Closure rails shall be prepared and NDT tested prior to use.

Where stressing is required, but not completed prior to returning the track the work group shall:

- Highlight the high risk areas to the Track and Signals A&I Engineers in the hand back documentation and monitor rail stress until destressing can be completed.

7.2. Rail Stressing below DSFT

Rail Stressing below the DSFT requires a tensile force to be applied to extend the rail. This shall be achieved using flash butt welder rail tensors, or were approved rail pullers.

In addition to the general requirements outlined in Section 6.1, this section outlines the fundamental requirements and process for adjusting below the DSFT with rail tensors.

7.2.1. Equipment

In addition to normal track equipment the following items are required for below neutral temperature destressing works;

- Mobile Flash butt Welder with a tensor head, capable of stressing 800 metres combined length without the use of rollers. Rail super pullers may be used for AT welding if approved by the Principal Track Engineer.

- Rail extension and tensor pulling force tables, and CWR Stressing Work Form (Appendix 10.1 - 10.3)

- Calibrated rail thermometers (approved type)

7.2.1.1. Rail Tensor Planning

Prior to using a rail tensor the following inspections shall be undertaken;

- Visually inspect the rail jaws, tie rods for faults and the tensor hydraulic hoses and cylinders for damage and leaks.

- Confirm availability of tonnage or pressure gauge for use as a reference only tool and check that the tensor has been tested with a current fit for use certification.

- Ensure that the tensor arms have an available secondary safety device such as safety chains or restraining straps to be securely fitted during use.

7.2.2. Calculating Required Rail Extension

The rail extension required, to adjust rail to the DSFT (37˚C), is calculated using Equation 3;

$$e = L_0 \times 0.0115 \times (37 - T_R) \qquad \textbf{Eq 3}$$

Were;

e = Extension in (mm)
L_0 = Length of free rail (m)
T_R = Actual average rail temperature (°C)

The rail extension shall be based on the average actual rail temperature of the rail to be stressed. A CWR Rail Adjustment Table is presented in Appendix 10.1 and an example of how to calculate the required gap for stressing with a flashbutt closure weld is presented in Appendix 10.3.

7.2.3. Calculation of Pull Force

The pull force to achieve the required rail extension shall be calculated using Equation 4;

$$F = M_R \times 0.03111 \times (37 - T_R) \qquad \textbf{Eq 4}$$

Where:

F = Pulling force (ton-force)
M_R = Rail weight per meter (kg)

T_R = Actual average rail temperature (°C)

The pull force shall be based on the average actual rail temperature of the rail to be de-stressed. A CWR Rail Tensor Pull Force table is presented in Appendix 10.2.

7.2.4. Welding with Tensors

When tensors are used to maintain rail adjustment while a weld is being installed at rail temperatures between 10°C and 40°C, DO NOT release the tensors until at least 20 minutes after the excess head metal has been removed from any new welds.

Welds on opposing rail legs shall be adjacent to each other (i.e. square) as per Track CoP.

7.2.5. Method

1. Complete the preparation checks in accordance with Section 6.3.1

2. Check that the rail temperature is more than 10°C and below 35°C (and not increasing by greater than 1˚C per 15 minutes) for work to commence.

3. Mark out rail adjustment block and record the details in *CWR Stressing Work Form*
   I. Establish adjustment length & pulling point (see Table 11 for required stressing lengths)
   II. Establish the ITTs and OTT by marking the sleeper and the rail foot and remove the fastenings

4. Establish cut / pulling point. Mark, measure and record two reference marks approximately 200mm either side of the cut point and record the distance in the *CWR Stressing Work Form.*

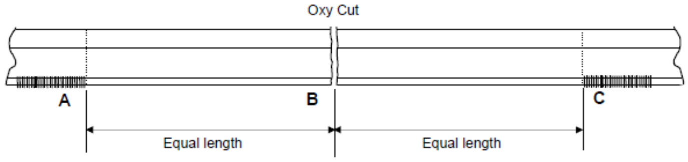


Figure 8 Anchor points for rail adjustment

5. Cut the rail using oxy/acetylene equipment. Do not make initial cut with a rail saw as the blade can jam if the rail is under compression.

6. Place calibrated thermometers on the shaded rail web, near the pulling point, and at the ITT of each anchor block.

7. Remove anchors or resilient fastenings between anchor points.

8. Relax rail along the adjustment length, cycle the tensors at least 3 times and record the position of the punch marks to ensure rail movement has stopped. Place people at the OTT to ensure no movement during relaxation cycles. If movement occurs, increase the anchor length by 10m and reset the OTT as per Section 6.1.8

9. Establish ¼. ½ , ¾ points either side of pulling point- *Record in the CWR Stressing Work Form*

10. Measure movement at the ITT points- *Record in the CWR Stressing Work Form*

    I. Movement into the stressing length = Ignore
    II. Movement out of the stressing length = Add to extension requirements

11. Measure the required gap to achieve a SFT of 37˚C;

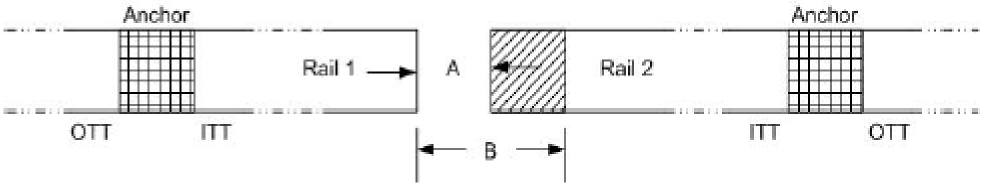


Table 14 Measuring the required gap

Step	Action Required
1	Determine the required rail extension (RE) (mm) using the CWR Extension Table
2	Measure the current gap (A)
3	Determine the required gap (B); ATW Gap (mm) = RE + ITT (Rail 1) + ITT (Rail 2) + 25mm FBW Gap (mm) = RE + ITT (Rail 1) + ITT (Rail 2) - Weld Gap - Burn off
4	Calculate the difference between the actual gap and required gap; $R_A = B - A$ R_A = Positive: Cut R_A (mm) from one of the rail legs R_A = Negative: R_A (mm) must be added using an additional rail length

12. Trim the gap between the rails to the required amount

13. Set up welder or tensor in stressing point; ensure they are fully extended and central to pull point

14. Tense the rail to the required weld gap

15. Measure any net rail movement into the stressing length at the ITTs

16. Further trim from the pulling point the additional rail movement into the stressing length measured at the ITTs and then re tense the rail to the required weld gap.

I. Note: ITT movement of less than 3mm for stressing lengths 300m, or 5mm or less for lengths over 300m need not be trimmed
II. Confirm no movement at the OTTs. If movement occurs, release rail and increase anchor length by 10 meters.

17. Measure rail movement at the quarter reference points- *Record on CWR Stressing Work Form*
    I. Note: The intermediate extension at the reference marks should be within 5mm of the correct figure (half the total extension). Where this is not achieved, the cause should be investigated and any identified problems corrected.

18. Measure and record the maximum pressure gauge reading on the tensor and compare to the calculated pressure reading from Appendix 10.2. Record details on the *CWR Stressing Work Form.* Excessive pressure may mean that rail has jammed on an obstruction.

19. Whilst the rail is tensioned complete the weld. The tension shall be held for at least 20 minutes after shearing.

    I. Note: Clip up of the rail can begin during weld setup, starting at the quarter reference points. Clip up temperature must be recorded on the *CWR Stressing Work Form*

20. Whilst weld is cooling, clip up the remaining sections.

21. Complete final walk through to confirm all fasteners in place and tooling removed

Site Records

1. Complete the CWR Stressing Work Form containing the following information:
    - Name of Person in Charge of Stressing;
    - Location of stressing length and Pulling lengths;
    - Rail temperature during stressing;
    - Calculated extension;
    - Movement of rail at ITT away from the pulling point when rail is relaxed;
    - Required and achieved extension at each reference point;
    - Pulling tonnage (gauge pressure) measured on the tensor immediately prior to welding;
    - Movement at each ITT when rail is extended immediately prior to welding;
    - Measurements before and after stressing at the rail reference marks;
    - Additionally also complete the weld records information.

2. Complete all additional quality management site records including:
    - Weld testing – refer CoP for requirements
    - SFT quality check measurements

7.3. Rail Stressing at DSFT (In Development)

Rail adjustment at the neutral temperature involves unclipping specific rails and allowing expansion or contraction to occur naturally. When the rail temperature falls within the DSFT range, the rail module is constrained in place ensuring the SFT of the track is within the required range.

In addition to the general requirements outlined in Section 6.1, this section outlines the fundamental requirements and process for natural destressing.

7.3.1. Equipment

In addition to normal track equipment the following items are required for rail stressing at DSFT;

- Vortok underhead rail stressing rollers
- Rail extension table and CWR Stressing Work Form (Appendix 10.1 & 10.3)
- Calibrated rail thermometers (approved type)

7.3.2. Method

1. Mark out rail adjustment block and record the details in *CWR Stressing Work Form*
   I. Establish adjustment length & cut point
   II. Establish the ITT and OTT by marking the sleeper and the rail foot and remove the fastenings

2. Establish cut point. Mark, measure and record two reference marks approximately 200mm apart either side of the cut point and record the distance in the *CWR Stressing Work Form*

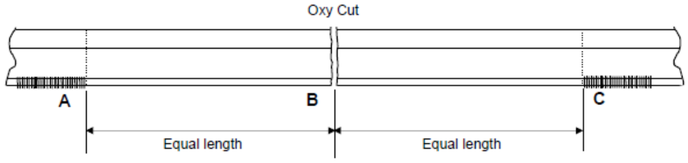


Figure 9 Anchor points for rail adjustment

3. Cut the rail using oxy/acetylene equipment. Do not make initial cut with a rail saw as the blade can jam if the rail is under compression.

4. Place calibrated thermometers on the shaded rail web, near the pulling point, and at the ITT of each anchor block.

5. Remove anchors or resilient fastenings between anchor points.

6. Mark out the ¼, ½, ¾ reference points

7. Place the unclipped rails on the under head stressing rollers. Splay the rail ends to ensure they can pass each other if rail extension occurs

8. Check for movement at the ITT and OTT. If greater than 2mm movement occurs at the OTT, the anchor length must be increased by 10m

9. Measure and monitor the rail temperature. When the rail temperature reaches the lower end of the DSFT range (32˚C) being removal of rollers and commence installation of anchors at the quarter reference points. See Table 15 for required anchor lengths.

Table 15 Require anchor lengths to constrain rail modules

Length (m)	Required anchor at each end of rail length (Number of Sleepers Fastened)
<200	30
200-400	40

10. Monitor rail temperature and continue clipping up from the ¼ marks towards the cut point

11. Cut the rails to produce the required weld gap

    I. Note: Installation of closure rail may be required to achieve the necessary weld gap depending on the original SFT of the rail.

12. Completing the required welds

13. Remove welding debris, fill cribs with required ballast and pack all sleepers

14. Complete the CWR Stressing Work Form to verify the SFT of the rail.

7.5. Turnouts (In Development)

Turnouts in continuously welded rail (CWR) shall be clipped up within the DSFT range of 37°C ± 5^0C,

If the above requirement is not met the following method shall be used to adjust the SFT to within the DSFT range……

7.6. Removal of Rail Defects

At all sites that require the removal of rail / weld defects or require short rail installation, it is recommended to establish the SFT status of the track either from historical records, from any indication that the SFT of the rail may be incorrect or established using the approved SFT measurement methods.

Generally, short rail installation will comprise activities associated with the removal of rail or weld defects, repair of broken rails, insulated joint replacement or short rail replacement not exceeding 25 metres. The installation of short rail is an acceptable alternative for the preservation of the existing rail SFT, where the SFT status is known to be within the range (37°C +/- 5°C). In the case of broken rails / pull-aparts or buckles the track section should be either stressed immediately as per the requirements of Section 4.5. If the following process is used to repair such a fault, the larger area must be flagged for follow rail stressing as per Table 3.

Section 5.2.1.3 outlines the “RAIL IN = RAIL OUT” method used to maintain the SFT of the rail section when the rail temperature is above the DSFT of 37°C.

Where the stress history of the rail is known or where there is no indication that the SFT of the rail may be incorrect, the following short rail installation method can be used to **maintain the existing SFT** when the current rail temperature is below or at the DSFT. For areas of unknown SFT the regular stressing method outline in Section 6.2 shall be used;

1. Mark the location of the intended cutting points for the closure rail.

2. Establish reference marks 200mm either side of the cutting points on the field side of the rail head clear of where tensors or welds will be located.

3. Measure the distance between the rail head marks:

    - For rail or weld defect removal measure the distance between the marks and record.

    - For broken rail, measure the distance between each mark and nearest end of the broken rail. Add these two measurements to give the total amount of rail in track between the marks; this excludes the gap at the break. Record the sum of these measurements.

4. The recorded amount of rail between the marks should also be marked on the rail.

5. Establish secondary tell-tale reference marks;

- For rail/ weld defect removal at least 6 metres from each end of the proposed closure rail (or weld location) to monitor for rail movement.
- For broken rails or buckles adhere to the requirements of Table 3.

6. Cut and remove the defective rail. Use the strain gauging or gap method to determine the actual SFT of the section;

7. Weld in the closure rail at one end.

8. After the weld has cooled for the required period, using rail tensors, re-establish the original distance between the rail head reference marks.

9. Record the pull force tonnage/pressure gauge reading.

10. Complete final weld, leaving the tensors for a minimum 20 minutes after shearing.

11. Measure and record the final distance between the rail head marks, which should equal the original distance. A tolerance of +/- 5 mm is acceptable.

Note: At step 5, after cutting the rail and if the rail gap closes up (and the distance between the head marks reduces), then the existing SFT is too low (and there is too much rail), this method must be discontinued with the repair completed using the standard method for stressing below the DSFT (refer to Section 6.2)

7.7. Prioritising Rail Stressing (In Development)

The basic requirements for rail stressing are outlined in Table 8. To facilitate a risk based approach to rail stress, the following metrics are used, in addition to SFT measurements, for the prioritisation of work;

- Track gradients
- Rail creep measurements
- Broken rail and track buckling history
- Track alignment faults (e.g. skewing and movement of sleepers, curve pull ins)
- Rail weld temperatures
- Monthly maximum and minimum mean rail temperatures

The process for prioritising rail stressing works is as follows…….

8. Responsibilities

Position	Role	Description of Task
Works Supervisor	Job supervisor	Ensuring procedures are followed, quality achieved, paperwork completed
	Project Engineer	
Rail Worker	Any worker undertaking rail adjustment	Obtain and maintain required competencies (Section 6.1.2)
Engineering Manager	Rail Engineering Manager	Ensure standards / procedures are up to date
Track Manager	Track & Signals Manager	Ensure compliance to standards and procedures
	Track Renewals Manager	
Principal Track Engineer	Principal Track Engineer	Approve alternative method of rail adjustment
		Provide advice on rail adjustment works
Asset Integrity	Data management specialist	Ensure rail stress databases are maintained and updated accordingly.

9. Definitions and Abbreviations

Term	Description
AREMA	American Railway Engineering and Maintenance-of-Way Association
AS	Australian Standard
BHP Billiton	BHP Billiton Iron Ore Pty Ltd.
BHPBIO Responsible Manager / Engineer	BHPBIO persons authorised to approve the document on behalf of the Company.
Ballast	Ballast is a free draining coarse aggregate of a specified grading used to support railway tracks
Buckle	A buckle occurs when the compression generated in the rails exceeds the ability of the structure to hold itself in place and the track is displaced laterally. Lateral displacement of rail in high temperature should be treated as a buckle.
Bunching Point	A section of track where SFT may reduce due to an accumulation of rail resulting from creep, including on the approaches to fixed points, bottoms of gradients, signals where trains regularly stop, train braking zones, or where there is a change in track type (e.g. non-resilient to resilient fastenings).
Company	BHPBIO
Compression	The compressive (squeezing) force generated in constrained rail when rail temperature increases above the SFT
Creep	Longitudinal movement of rail (or rail plus sleepers) over time, resulting in changes to stress free temperature.
COP	Track Maintenance Code of Practice No. 0002664
Crossover/Turnout	A mechanical installation enabling trains to be guided from one track to another
CWR	Continuous Welded Rails
DAR	Data Acquisition Recorder
Destressing	The process of returning rail to the stress free temperature (SFT) by way of unclipping sections of rail, cutting the rail, adding or removing a section of rail and re-welding the rail.
DSFT	Design Stress Free Temperature
VERSE	Non-destructive method of measuring the stress free temperature (SFT) of continuous welded rail (CWR).
Fixed Point	A section of track, which offers greater resistance to longitudinal rail movement than plain track.
IRJ	Insulated Rail Joints
ITP	Inspection Test Plan
ITT	Inner Tell Tale
LPA	Local Possession Authority
MDR	Manufacturers Data Report
NCR	Non Conformance Report
OEM	Original Equipment Manufacturer
OTT	Outer Tell Tale
Pull-apart	A rail break and contraction of rail ends, when in tension during cold weather.
“Rail out = rail in” process	A method of repairing rail defects or breaks in CWR by ensuring that there is no net change to the amount of rail.

Rail temperature	The average of temperatures recorded on the web of the rail, on the shaded side, as measured by several thermometers
Resilient fastenings	Fastenings which exert a toe load on the rail foot
SEP	Standard Engineering Practices
SFT	Stress Free Temperature
Shall	An action that must be completed
Should	An action that is recommended
SPEC	Specification
Stress free	Rail that it is neither in compression nor in tension.
TSR	Temporary Speed Restriction
VERSE	Vertical Rail Stiffness Equipment
VOC	Verification of Competency
Tension	The tensile (pulling) force generated in CWR when rail temperature decreases below the SFT, and the rail cannot contract.
TSMP	Track Stability Management Plan
WSTA	Welded Track Stability Analysis

10. References

Reference	Title
0128091	Verse Testing to Determine Rail SFT
0002664	Track Maintenance Code of Practice
AS 4292	Railway Safety Management
AS 1085	Railway Track Material
AS 7643	Infrastructure – Track Stability

11. Appendices

11.1. CWR EXTENSION TABLE

CWR EXTENSION CALCULATION (mm) FOR DSFT 37^0

Note: Extension should be calculated as per equation - E = [37 - Rail Temp in C^0] x 0.0115 x Rail Length in Metres

	Length of Free Rail in Metres (Single Leg)										
Rail Temperature (C^0)	50	100	110	150	165	200	220	250	300	350	400
0	21	43	47	64	70	85	94	106	128	149	170
1	21	41	46	62	68	83	91	104	124	145	166
2	20	40	44	60	66	81	89	101	121	141	161
3	20	39	43	59	65	78	86	98	117	137	156
4	19	38	42	57	63	76	83	95	114	133	152
5	18	37	40	55	61	74	81	92	110	129	147
6	18	36	39	53	59	71	78	89	107	125	143
7	17	35	38	52	57	69	76	86	104	121	138
8	17	33	37	50	55	67	73	83	100	117	133
9	16	32	35	48	53	64	71	81	97	113	129
10	16	31	34	47	51	62	68	78	93	109	124
11	15	30	33	45	49	60	66	75	90	105	120
12	14	29	32	43	47	58	63	72	86	101	115
13	14	28	30	41	46	55	61	69	83	97	110
14	13	26	29	40	44	53	58	66	79	93	106
15	13	25	28	38	42	51	56	63	76	89	101
16	12	24	27	36	40	48	53	60	72	85	97
17	10	23	25	35	38	46	51	58	69	81	92
18	11	22	24	33	36	44	48	55	66	76	87
19	10	21	23	31	34	41	46	52	62	72	83
20	10	20	22	29	32	39	43	49	59	68	78
21	9	18	20	28	30	37	40	46	55	64	74
22	9	17	19	26	28	35	38	43	52	60	69
23	8	16	18	24	27	32	35	40	48	56	64
24	7	15	16	22	25	30	33	37	45	52	60
25	7	14	15	21	23	28	30	35	41	48	55
26	6	13	14	19	21	25	28	32	38	44	51
27	6	12	13	17	19	23	25	29	35	40	46
28	5	10	11	16	17	21	23	26	31	36	41
29	5	9	10	14	15	18	20	23	28	32	37
30	4	8	9	12	13	16	18	20	24	28	32
31	3	7	8	10	11	14	15	17	21	24	28
32	3	6	6	9	9	12	13	14	17	20	23
33	2	5	5	7	8	9	10	12	14	16	18
34	2	3	4	5	6	7	8	9	10	12	14
35	1	2	3	3	4	5	5	6	7	8	9
36	1	1	1	2	2	2	3	3	3	4	5
37	0	0	0	0	0	0	0	0	0	0	0

11.2. RAIL TENSOR PULL FORCE TABLE

Relationship between rail temperature difference, rail weight, pull force and tensor pressure gauge readings

Tensor pull force (tonnes) = rail weight per metre(kg) x (37 – T) x 0.03111
Pressure reading (lbs/sq.in) = 110 x tensor pull force (tonnes)*

***For a 70 tonne Permaquip tensor**

Rail Size kg/m (nominal)	68 kg		71kg	
Rail Temp (x^{0}C)	Pull forces (tonnes)	Pressure (lbs/sq.in)	Pull forces (tonnes)	Pressure (lbs/sq.in)
0	**78**	**8610**	**82**	**8990**
1	**76**	**8377**	**80**	**8747**
2	**74**	**8145**	**77**	**8504**
3	**72**	**7912**	**75**	**8261**
4	**70**	**7679**	**73**	**8018**
5	**68**	**7446**	**71**	**7775**
6	**66**	**7214**	**68**	**7532**
7	**63**	**6981**	**66**	**7289**
8	**61**	**6748**	**64**	**7046**
9	**59**	**6516**	**62**	**6803**
10	**57**	**6283**	**60**	**6560**
11	**55**	**6050**	**57**	**6317**
12	**53**	**5818**	**55**	**6074**
13	**51**	**5585**	**53**	**5831**
14	**49**	**5352**	**51**	**5588**
15	**47**	**5119**	**49**	**5345**
16	**44**	**4887**	**46**	**5102**
17	**42**	**4654**	**44**	**4859**
18	**40**	**4421**	**42**	**4616**
19	**38**	**4189**	**40**	**4373**
20	**36**	**3956**	**38**	**4130**
21	**34**	**3723**	**35**	**3888**
22	**32**	**3491**	**33**	**3645**
23	**30**	**3258**	**31**	**3402**
24	**28**	**3025**	**29**	**3159**
25	**25**	**2792**	**27**	**2916**
26	**23**	**2560**	**24**	**2673**
27	**21**	**2327**	**22**	**2430**
28	**19**	**2094**	**20**	**2187**
29	**17**	**1862**	**18**	**1944**
30	**15**	**1629**	**15**	**1701**
31	**13**	**1396**	**13**	**1458**
32	**11**	**1164**	**11**	**1215**
33	**8**	**931**	**9**	**972**
34	**6**	**698**	**7**	**729**
35	**4**	**465**	**4**	**486**
36	**2**	**233**	**2**	**243**
37	**0**	**0**	**0**	**0**

Note: **Maximum pulling force is dependent on welder head capacity.**
Caution: Pressure is within 20% of maximum system capability, working at these pressures should be avoided.

11.3. CWR STRESSING WORK FORM

Line: ______ Track: MainL / MainR / Loop Leg: East/West From: To:

Rail Size: ______ Section: ______________ To ______________ Anchor Length ______________

Grade: ______________

Rail Temperature:(Average) ______ °C Curve Radius: ______________

Proceed to carry out further steps only if the temperature is less than 38°C

Unclipped Length (ITT to ITT) ______ m

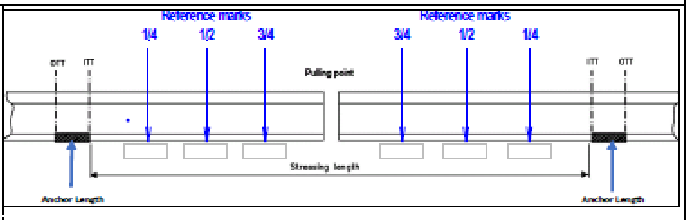
Pulling Point (e.g. 159.132km) ______ km

Length of Pulls (metres) End 1 ______ m End 2 ______ m

Extension: (from Chart/Calculation)

Extension = (38° - Rail Temperature °C) x 0.0115 x Unclipped Length in metres

(A) ______ mm (B) ______ mm



Pop Marked Monitoring Points

Distance Between Marks BEFORE Cut ______ mm (C)

Calculated Rail extension ______ mm (A+B)

After Cut & Relax Rail

Weld Gap ______ mm (D)

ITT move out stressing length End 1 ______ mm (E)

ITT move out stressing length End 2 ______ mm (F)

(Ignore ITT movement into stressing length)

Cut Gap equal to ______ mm (A+B+D+E+F)

Final Trim before weld ______ mm

Final trim only if ITT moves into stressing length after pulling

After Weld

Distance between pop marks ______ mm (G)

Actual Rail Cut Out: (H)= (C- G) ______ mm (H)

Check Displacemnt at

Check Displacemnt at	End 1 Calc	End 1 Actual		End 2 Calc	End 2 Actual
(A)		-	(B)		-
3/4 Point					
1/2 Point					
1/4 Point					
ITT	-			-	

Pull Tonnage / Pressure Gauge reading (at Maximum load) ______ tonne / psi

Calculated Neutral Temperature = (H) ÷ Unclipped Length ÷ 0.0115 + Temperature

= ______ °C

Site Monumented: Y / N

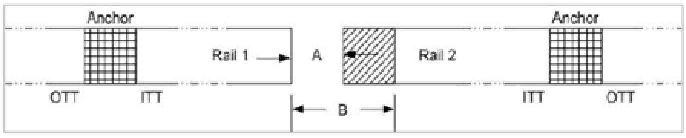
Notes:

Signature: Date

Note: Take the rail temp reading at the same time as measuring the distance between the pop marks after pull and release. Use this temp also to calculate the amount of rail to cut out. If the rail temp increases during the pull (up to 38°C) don't recalculate. Record any movement of the OTT if anchor length has to be adjusted

11.4. RAIL STRESSING EXAMPLE

Summary of Stressing Calculation



To determine required gap for Flashbutt Weld:

Step 1: A = gap as first cut or placed

Step 2: B = required total gap = extension length (from calculations) + ITT(Rail 1) + ITT (Rail 2) - Weld Gap - Burn Off

Step 3: Cut rail B mm from the end of Rail 1

Step 4: Pull up rail and recheck both ITT's. Any rail pulled into the stressing length past the ITT to be measured at each anchor.
The total amount ITT is to be further trimmed from the rail at the weld location.

Step 5: Further tense to close up weld gap and then weld up.

Notes:

1. The design SFT is 37°C.
2. For rail stressing lengths use equation: **Extension [in mm] = [37 - Rail Temperature in °C] x 0.0115 x Rail Length in metres**.

Example Calculation

Stressing Module Length: 500 metres
Average Rail Temperature: 22°C, SFT = 37°C
Actual Gap when rail was first cut (A) = 16 mm
Assume ITT (Rail 1) moves 2 mm and ITT (Rail 2) moves 3 mm

Extension required (E) [mm] = (37- Rail Temperature [°C]) x 0.0115 x stressing Length [m] + movement at ITTs
= 86.25 mm + 3 mm + 2 mm = 91.25 mm

Required Gap (B) = E - Weld Gap - Burn Off = 91.25 - 5 - 50 = 36.25

Cut Rail 2 at 36.25 mm from the end of Rail 1
Pull up, check ITT (Rail 1) and ITT (Rail 2). If either ITT pulls in again, trim gap accordingly. Complete weld and clip up starting from the quarter points

11.5. TRACK STABILITY MANAGEMENT PLAN OUTLINE

General

- Track section covered by plan.
- Responsibilities for implementation.
- Dates of last review and last revision.

Buckling Force Management

- Schedule of SFT measurements to be undertaken.
- Schedule of creep measurements to be undertaken (or rail movement determined by survey).
- Curve alignment measurements to be undertaken.

Buckling Resistance Management

- List activities that need to be undertaken prior to the onset of high temperature (e.g. WSTA)
- Ballast profile inspection and assessment
- High temperature work restrictions applicable to the area (tailored local restrictions or standard restrictions). These restrictions will be for work that reduces ballast compaction.

High Temperature Risk Mitigation

- The trigger temperature(s) at which unscheduled track lateral stability patrol inspections are to be undertaken; and the section of track to be patrolled.
- For some track sections there may be a requirement for two levels of trigger temperatures for high temperature inspections. For example, at the lower temperature, only the track with stability issues may be listed for inspection, but at a higher trigger temperature, additional tracks may be listed for inspection.
- Tracks with a proven history of good track stability, inspections may not be required.
- The locations where speed restrictions are to be applied on days of high temperature and the trigger temperatures for application
- Staff responsible for obtaining weather forecasts, reviewing the need for speed restrictions, and applying such restrictions on days of high temperature.

Special Locations Register

- Location.
- Reason for inclusion (e.g. track disturbance, bunching point).
- Special requirements (if applicable).
- Localised initiators – WMS generated report.

11.6. STRESSING PRIORITY FOR LOCATIONS OF UNKNOWN SFT (Draft)

This appendix describes how to conduct an assessment of track having no record of SFT, i.e. where there is neither a stressing record nor a direct measurement. It takes account of the three contributions to total risk, i.e. rail stress (***A***), lateral resistance (**B**) and consequences of buckle (***C***).

A stressing priority assessment shall be made for each length of track without stressing records. The maximum continuous length of track in one assessment shall be one mile, this being shortened if conditions along the length vary significantly.

Scores shall be attributed against the assessment parameters in the table.

Section A: rail stress

A1, Years since installation SFT tends to fall with time, particularly where there are other contributory factors. One point is awarded for each year (maximum ten) since installation.

A2, Curvature SFT is lost through pulling-in of curves in winter, particularly where smooth lining is carried out without reference to datum pegs. A zero score may be awarded if the track position is known to be as at installation.

A3, Discontinuities not protected by expansion switches These include significant changes of sleeper type (timber to concrete) or significant change of rail section (e.g. FB98 to FB113A). A higher score applies to semi-fixed points such as direct-fastened bridges, level crossings or S&C.

A4, Rail creep Rail creep is a significant contributor to changes in SFT. Points shall be awarded additively for

- poor fastenings or pads (where lack of toe load is suspected);
- situations at the bottom of an incline where traction or braking may cause bunching;
- locations where repeated braking or acceleration occurs (stations, signals, junctions etc.).

A5, Maintenance history Points shall be awarded if rail defects have been repaired without restoration of stress.

A6, Track subsidence This can significantly alter the SFT and such sites are normally specially monitored. Unstable formation where large settlements occur, generally or locally, shall also be taken into consideration.

The rail stress scores are summed to obtain the rail stress total ***A***.

Section B: lateral resistance

B1, Ballast shoulders) Assessment shall be based
) on the worst portion
B2, Ballast cribs) of the section being assessed.

B3, Ballast condition A general assessment shall be made, to determine lateral resistance to sleeper movement. Clogged ballast need not necessarily be considered poor from this point of view.

B4, Track alignment This shall be based on the worst eighth mile of track geometry recording data, excluding S&C.

B5, Sleeper type Points shall be awarded where timber sleepers exist in significant consecutive numbers, excluding S&C.

B6, Exposure Assessment shall be made of the degree of exposure to the sun. Shaded or windy sites shall score low. Sheltered sites in cuttings exposed to afternoon sun, and other such hot spots, will score high.

The lateral resistance scores are summed to obtain the lateral resistance total ***B***.

Section C: consequence of buckle

C1, Linespeed Linespeed will determine the derailment probability if a buckle occurs, and the potential for injury. This is disproportionately higher at higher linespeeds.

C2, Traffic The derailment risk may be considered to be proportional to the total traffic.

C3, Cutting/embankment The consequences of a derailment will be greater, hence attracting a higher score, if the track is mainly on embankment or if there is a significant number of structures (bridges, stations, tunnels).

C4, Number of tracks The consequences of a derailment will be related to the number of adjacent tracks, which will determine the collision risk.

The consequence scores are multiplied to obtain the consequence total ***C***.

Assessment of final score

Track buckling probability is governed by the sum of the partial totals ***A*** and ***B***. Consequence of buckling is given by the consequence total ***C***. Buckling risk is therefore expressed as (***A*** + ***B***) x ***C***. The resulting score can be used to prioritise sites for stressing. A high score will indicate a high risk.

Assessment of the lateral resistance total ***B*** may be used also to indicate where other action may be needed, e.g. the placing of extra ballast.

Table : Priority rating for stressing					
Section A: rail stress		**Section B: lateral resistance**		**Section C: consequence of buckle**	
Condition	**Score**	**Condition**	**Score**	**Condition**	**Score**
A1, Years since install'n		**B1, Ballast shoulders**		**C1, Linespeed**	
Number of years award one point/year (Limit = 10 points)		In accordance with this spec. 0 50% of this spec. 25 No shoulder above sleeper 50		< 50 mph 1 50 - 85 mph 2 ≥ 90 mph 3	
A2, Curvature		**B2, Ballast cribs**		**C2, Traffic**	
>2000 m 0 2000 - 500 m 10 <500 m 20		Full 0 50% 10 Empty 20		< 5 MGT 1 5 - 15 MGT 2 > 15 MGT 3	
A3, Discontinuities not protected by exp switches		**B3, Ballast condition**		**C3, Cutting or embankment**	
Change of track type 10 Bridges, LCs, S&C 20		Good 0 Poor 10		At grade/in cutt'g 1 Embankment or structures 2	
A4, Rail creep (add scores)		**B4, Track alignment**		**C4, No. of tracks**	
Poor fastenings 10 Bottom of incline 5 Repeated braking/accel 5		Max SD > 3 mm 30 Max SD 2.5 - 3 mm 15 Max SD < 2.5 mm 0		1 1 2 2 > 2 3	
A5, Maintenance history		**B5, Sleeper type**			
Defects removed and stress restored 0 >2 defects/mile removed and stress not restored 20		Concrete or spade-end steel 0 Timber 20			
A6, Track subsidence		**B6, Exposure**			
Settlements >100 mm 20 Severe subsidence 50		Majority shaded 0 Normal exposure 10 High exposure, sheltered from wind 20			
Sum of values *A*		**Sum of values *B***		**Product of values *C***	
				Risk factor (*A* + *B*) x *C*	

11.7. WELDED TRACK STABILITY ANALYSIS FORM (Draft)

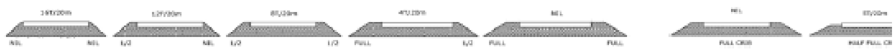
WELDED TRACK STABILITY ANALYSIS - Data Collection (CWR & LWR)

TEAM: ____________________ RECORDED BY: ____________________ SIGNED: ____________________ DATE:

BASECODE: ____________________ TEAM MANAGER: ____________________ SIGNED: ____________________ DATE:

KM	PEG LOCATION	ALIGNMENT DETAILS			CREEP		ANCHORS	BALLAST		FB, PJ, PF, BC, RC YES/NO	ELBOWS OR SHARP ALIGNMENT	BRAKING H=HEAVY S=STEADY N=NONE	DISTURBANCE	
		DESIGN	ACTUAL	ERROR +/-	UP RAIL	DOWN RAIL	OK YES/NO	SHOULDER YES/NO T/20m	CRIB YES/NO T/20m				TYPE	DATE

CODES: FB=Foul Ballast; PJ=Pumping Joints; PF=Poor Formation; BC=Ballast Contition; RC=Rail Corrugation



11.8. CREEP MEASUREMENT METHOD

11.8.1. Monitoring Points

Installing creep pegs

Pegs are to be installed on either side of the track. Locate the post clear or access roads, ballast regulator operating areas and drains, etc.

To install creep pegs, place the post at least 500mm into the ground at sufficient height above ground to allow the check string to be stretched without touching the rail.

Installing Rail Marks

Single marks are placed on the field side of the head of each rail, in line with the end of each creep peg. To install punch marks:

- Stretch a stringline between the two opposing creep pegs and accurately mark the rail with a fine marker.

- Place a small mark on the field side of the head of each rail. Use a centre punch for creep punch marks, NOT a cold chisel. This single mark is the measurement point for the end of one section of track and the start of another.

11.8.2. Creep Measurement

The following method shall be used to evaluate SFT change due to rail creep;

1. Locate the track side monuments for the rail section length
2. Locate the punch marks on the field side of the rail head
3. Run a reference line (string line or laser points) across the rail, between the monuments.
4. Record perpendicular distance (see Figure 10) between the reference line and the rail punch marks (sign convention: positive towards port)
5. Measure the actual change in creep length (Lc) using the creep measurements at each measurement point (see Figure 11)
6. Determine the estimated change in SFT using the following Equation;

$$\Delta SFT = \frac{L_c}{0.0115 \times L_0} \qquad \textbf{Eq 5}$$

Were;

ΔSFT = Change in Stress Free Temperature (°C)
L_0 = Length of rail section that creep is measured over (m)
L_c = Actual change in rail section length due to creep (mm)

Recording Tangent Creep (Double Punch Marks)

Sheet shows prior to re-adjustment

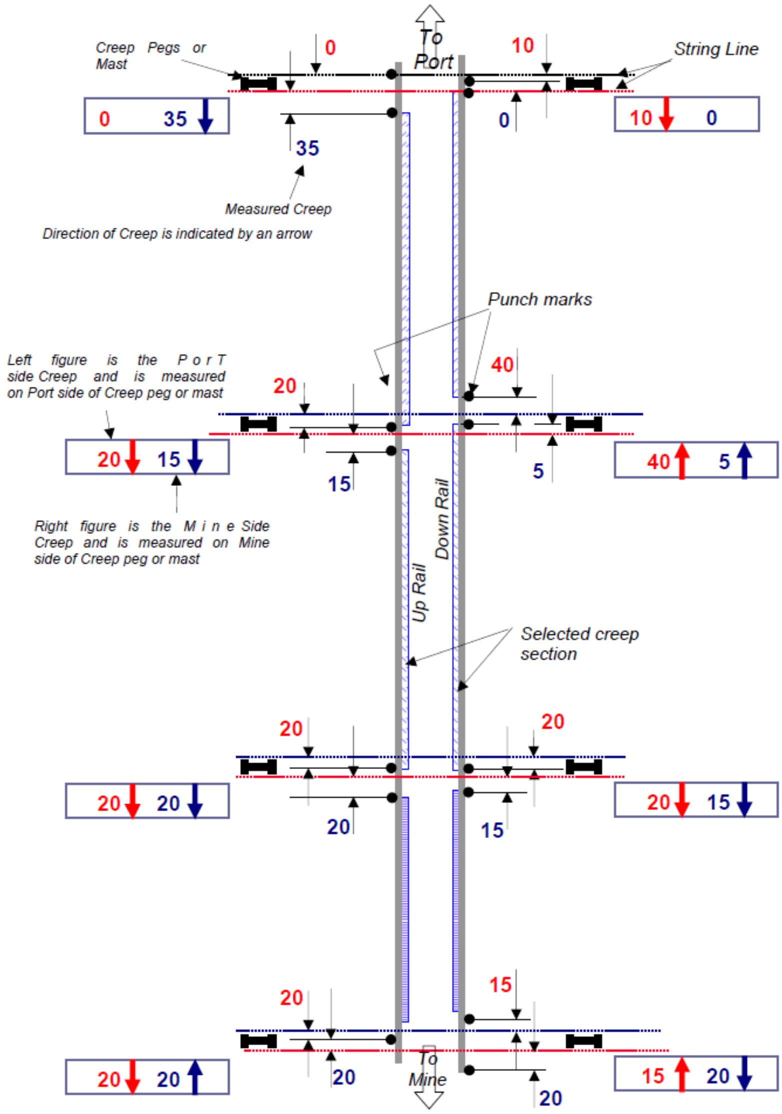


Figure 10 Recording tangent creep

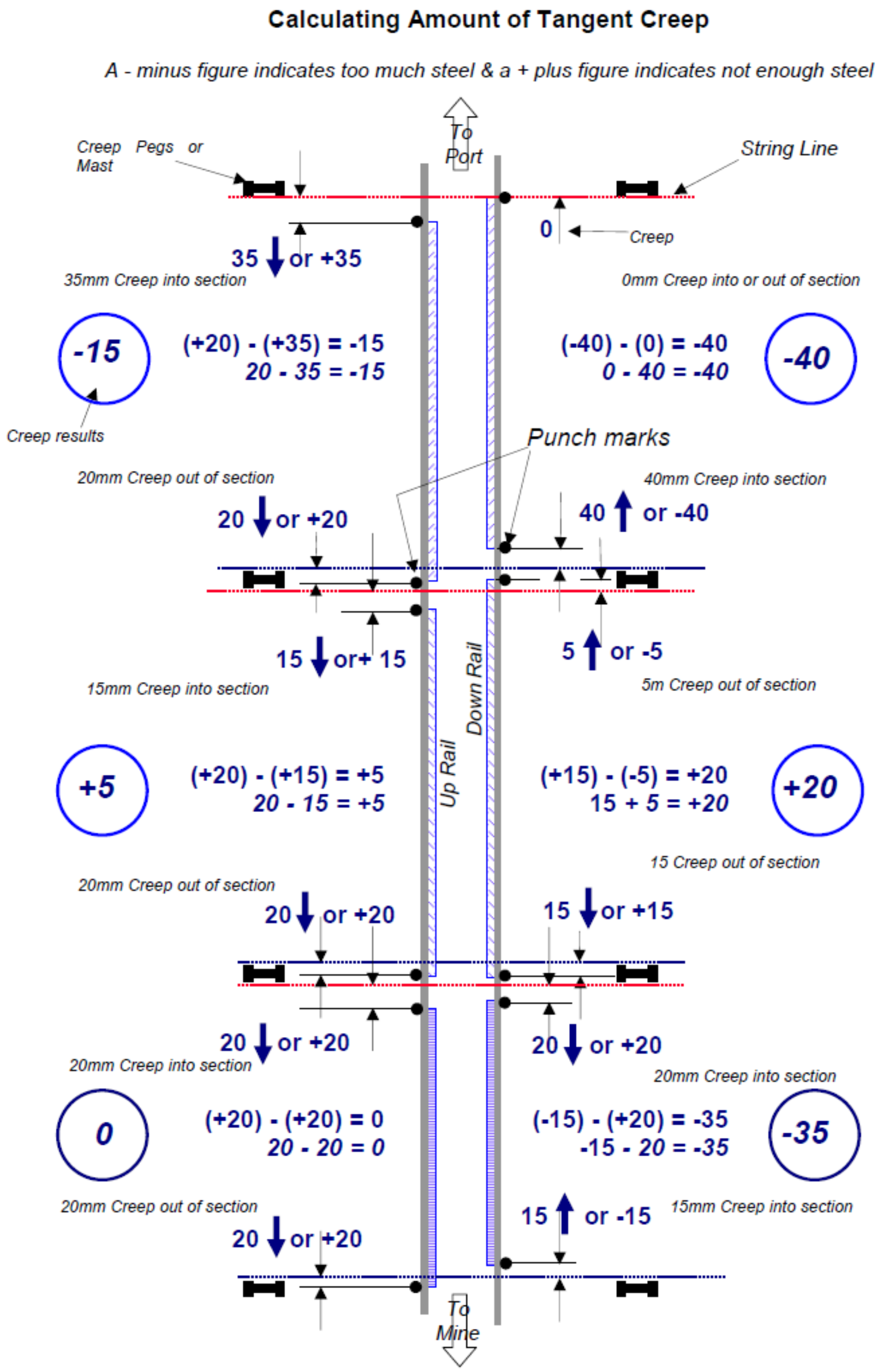


Figure 11 Calculating the amount of tangent creep

11.9. SFT MEASUREMENT: VERSE TESTING

Competency Requirements

Personnel completing VERSE testing must have as a minimum;

- Verification of competency from Pandrol or;
- Completion of BHPBIO internal LMS VERSE Training course: RALVERSETRG

Location Selection

The test location should be chosen to reflect the area where the concentration of steel is likely to be greatest. The location must not be on track with curvature sharper than 500m radius.

If the track stress is expected to be homogeneous, i.e. no bunching points; no major changes in grade; it can be treated as a single unit provided it does not contain any curves less than 500m radius. In this case the test location should be roughly in the middle of the section. Track which is not able to be treated as homogeneous shall be to assessed by reviewing each area of localised steel concentration.

The test sites;

- MUST NOT be closer than 30m from any turnout

- MUST be uniform and free of aluminothermic welds, mechanical joints or IRJs

Tests;

- MUST NOT be undertaken if rail temperature is changing by more than 1°C in 15 minutes.

- MUST only be undertaken if the rail is in tension (SFT higher than rail temperature)
  - As a guideline tests shall not be undertaken if the rail temperature is above 27˚C.

- MUST NOT be undertaken if the rail temperature is lower than 5˚C.

Process

1. Prior to accessing the site, verify that the VERSE® recording equipment operates and is properly calibrated and the batteries in the apparatus are fully charged and of the correct type.

2. At the work site, identify flash and/or alumino-thermic welds within the selected 30m test site. Finalise the lift point based on this information, ensuring that any welds are greater than 20m from the lift point. Record exact location of the lift.

3. Place calibrated thermometers on the shaded rail web or foot as appropriate, near the lift point, and at each of the spacer points. Leave for a minimum of 15 minutes before taking a temperature reading. Record thermometer calibration numbers and temperatures.

4. Measure and record the rail height and record the rail type / section.

5. Mark out and record (to nearest mm) the positions shown in Figure 12;

    a. Spacer positions ~10m either side of lift point;
    b. Anchor points ~6m from spacers

6. Ensure excess ballast is removed from around the rail, sleepers and clips in the 30m section so the equipment can be set up, does not impede the results and does not obstruct re-clipping.

7. Unclip the 30m length of rail.

8. Jack the rail up and insert the 'T-piece spacer blocks' at the marked positions.

9. Remove all insulators from the rail in the unclipped section.

10. Install the VERSE® equipment at the lift point and perform 3 lifts. The average of the three measurements is taken as the SFT of the rail section

11. Verify 'T-pieces' are removed upon completion of VERSE®.

12. Verify all insulators have been re-installed correctly.

13. Verify that the 30m of track is properly clipped before leaving the site.

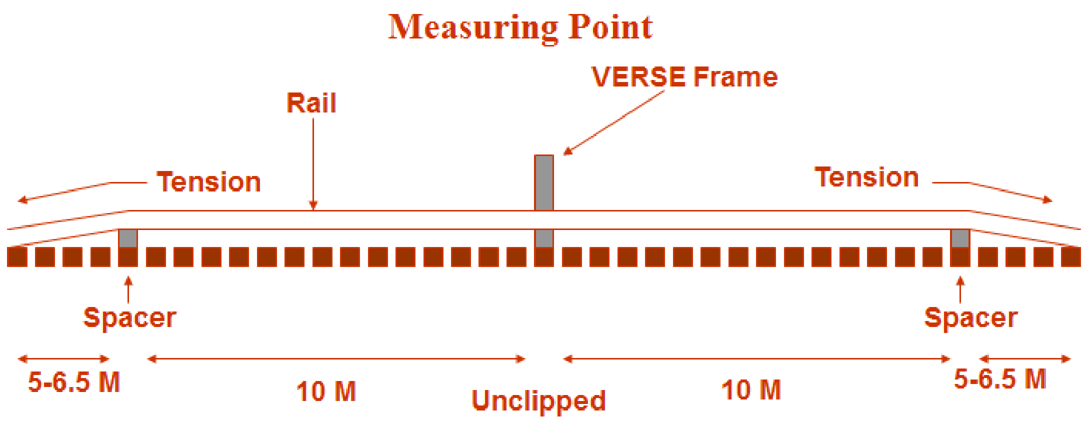


Figure 12 VERSE testing setup

VERSE TESTING CHECKLIST & LOG

Date:	Time:	Location (km, track, rail):	Ambient Temperature:	Rail Temperature:

Verse test should only be conducted below SFT. If SFT unknown only complete test if rail temperature is below 30 degrees

Location	Rail (West /East)	Span1 (Inner)	Inner Span 1 (12)	Span 1 (Total)	Inner Span 2 (12)	Span 2 (Total)	Versine 1 (Clipped)	Versine 2 (Unclipped)	Rail Height	Track Temp (Start)	Track Temp (End)	SFT	File name	Comment

Tester	Name	Signature	Date
Reviewer	Name	Signature	Date

11.10. SFT MEASUREMENT: RAIL GAP METHOD

The procedure for conducting SFT measurements using the rail gap method is as follows;

1. Mark the foot of the rail and the sleeper 1 meter either side of the cut location. Record the distance between the two marks.
2. Place calibrated thermometers on the shaded rail web side 3 meters from the cut point, and at the start of each anchor block.
3. Make cut with oxy, remove enough material to allow expansion.
4. Remove clips on 50m of track either side of the cut and if required place rail on rollers.
5. Allow rail to grow or retract.
6. Measure the distance between the two marked points and record the rail temperature (average of the three measurements).
7. Using the equation below calculate the SFT of the rail section prior to the cut;

$$SFT = \frac{\Delta L_G}{0.0115 \times L_0} + T_R \qquad \textbf{Eq 6}$$

Were;

SFT = Stress Free Temperature before cut (°C)
ΔL_G = Change in gap between rail marks either side of cut points (mm)
L_0 = Unclipped rail length (m)
T_R = Rail temperature (°C)

11.11. SFT MEASUREMENT: STRAIN GAUGE METHOD

The procedure for conducting SFT measurements using the rail gap method is as follows;

1. Prepare the strain gauge and connecting wires
2. Clean the rail section and attach the strain gauge to the web of the rail approximately 2m from applied to the rail.
3. Place a calibrated thermometer on the shaded rail web side close to the strain gauge.
4. Connect the strain gauge to the measurement device and set stress reading to zero.
5. Input the rail temperature
6. Cut rail with oxy torch
7. Unclip sleepers from rail cut to strain gauge ensuring rail is free to move.
8. Read the SFT off device. This is the SFT of the section prior to cutting.

11.12. RAIL THERMOMETER CALIBRATION REGISTER

RAIL THERMOMETER CALIBRATION REGISTER			
Workgroup:		Team Leader:	
Location / Station:		Phone Number:	
Thermometer Storage Location (Secured):			

Equipment ID	Calibrated by	Date Calibrated	Date of next Calibration	Comments

11.13. RAIL CLIP UP TEMPERATURE FIELD LOG

RAIL CLIP UP TEMPERATURE LOG

bhpbilliton

The rail temperature of each 400m long string must be measured at 100m intervals by calibrated magentic rail thermometers on the shaded side of the rail.
Rail should be clipped up in the stress free temperature range outlined in the Track Maintenance Code of Practice.

Date	Track	Kilometerage		Rail Laying									Temperature Conditions			Comments
		From (km)	To (km)	Time (24hr)	Rail Temperature T1 (°C)		Rail Temperature T2 (°C)		Rail Temperature T3 (°C)		Average Rail Temperature (°C)		Rising	Steady	Falling	
					WR	ER	WR	ER	WR	ER	WR	ER				
6/01/2017	NML-WT	15.485	15.858	10:20	42		44		41		42.3			Y		

Supervisor:	Work Order	Remarks

For entry into the TCMS the completed log sheet is to be sent in .xslx format to DL-IOR-HED-TrkandSignals-ConditionMonitoring-Team@bhpbilliton.com

Email subject is to be titled - *Rail Installation Temperature Log_KM-Track_Date (eg Rail Installation Temperature Log_236.700- 238.700km-NML-WT_050117)*