

Track Handbook 6

G3206

Prevention of buckling



**Please read the Written Notices
attached to this standard**

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1 Purpose

The purpose of this handbook is to give guidance on the track installation and maintenance practices, and the precautions to be taken in hot weather, in order to prevent track buckling. It is intended to assist staff in complying with standard S1177.

2 Scope

This handbook covers activities relating to both welded and jointed track, and conductor rails.

3 Introduction

This handbook is one of a series intended to help those responsible for managing the track asset achieve standards and meet LU corporate objectives.

This handbook offers:

- ◆ practical advice on track activities
- ◆ guidance on choices and alternatives
- ◆ 'do's and don'ts' for use on site
- ◆ technical data and illustrations
- ◆ material to use in staff training.

Before you first use this handbook, you should familiarise yourself with its contents. The subject headings are set out in the Contents list.

The first three sections in this handbook discuss why buckling occurs, the effects of weather and rail temperature, and the preventative track maintenance necessary to reduce the risk of track buckling. The next three sections deal with the precautions necessary to prevent track buckling in conductor rails, short rails and welded rails, and the last section guides you through the corrective actions which need to be taken if a track buckle occurs.

You will find in this handbook notes and comments based on the day-to-day experience of staff, outlining methods they have found successful in particular conditions as well as points not to be overlooked in carrying out the work.

In the time following the first issue of this handbook some practices have dropped out of favour, for example “sunlocking” of long welded rail (especially under traffic), and resleepering of welded track under traffic. Content regarding such activities has been removed or reduced in this issue of the handbook.

At the end of some sections there is a list of sources of further information. **In the event of any conflict between this handbook and LU standards, the latter shall prevail.**

4 Why buckling occurs



Buckling occurs when longitudinal compressive forces in the rails overcome the lateral stabilising forces which can be generated within the track structure. Buckling is localised, often related to a local weakness, and poses a derailment risk. Instead of local buckling another result can be a “pushing out” of the alignment on curves: this may compromise clearances. In both cases the rails are seeking to relieve themselves of the compressive forces.

The compressive forces arise from heating of the rails in hot weather: for every degree C rise in rail temperature an extra compressive force of approximately 1.7 tonnes is generated in flat-bottom rail and 1.4 tonnes in bullhead. Modern flat-bottom CWR is deemed to resist forces of some 55 tonnes in each rail (equivalent to 32C rail temperature effect) before hot weather precautions are necessary. In order to avoid greater forces, LU requires rails in open sections to be free of force at a rail temperature somewhere between 21C and 27C. This then allows for the rail temperature to rise to at least 50C without precautions having to be taken, which is well above normal levels.

Short-rail track is also affected by hot weather, especially once rail gaps become closed.

In both welded and short-rail track, rail creep will lead to extra compressive force if the rails are being driven towards a fixed object such as occurs when fishplates come into contact with a chair.

Resistance to buckling comes from well compacted ballast, especially on the shoulders, and friction on the sides and undersides of the sleepers.

Whatever the type of track - whether short rail or welded rail - you need to make sure that it is maintained in a condition to withstand the stresses arising as a result of temperature changes. Maintenance practices must be focused on keeping the stress-free temperature of CWR at the correct level and keeping the track in good condition. The latter is particularly concerned with ballast and, in the case of short-rail track, the regulation of joint gaps and the control of rail creep.

The safety risks associated with track buckling underline how essential it is to maintain every component of the track – rails, fastenings and supports, sleepers, ballast beds and shoulders, expansion gaps and joints – in a sound condition which meets the requirements defined in track standards.

5 Weather and rail temperature



On summer days with hot strong sunshine, rails may become substantially warmer than the surrounding air. Rail temperatures are likely to climb throughout the morning and afternoon, though significant compressive stresses in the rail do not usually occur before 14.00 hours. If sunshine extends into the late afternoon and evening, and there is no cloud cover to reduce its intensity, the temperature of the rails will continue to rise with the risk of excessively high compressive forces developing within the rails.

It is important to bear in mind that the relationship between weather conditions and rail temperatures is a complex one, and highly dependent on the circumstances of each site. Assumptions cannot be made about the effects of hot weather and there is no substitute for close and systematic monitoring of rail temperatures.

5.1 Weather information and rail temperature readings

The Met Office is the principal source of general weather information providing twenty four hour and five day ahead forecasts.

Information on rail temperatures is obtained each day during the 'hot weather period' at automated recording locations around the network. The information received from these locations will indicate whether it is necessary for Track Managers to take any site-specific safety precautions. Requirements during spells of exceptionally hot weather are discussed in the next section.

5.2 Recording rail temperature manually

5.2.1 Rail thermometers



One type of contact thermometer is used by LU. It is a dial type and is shown in plate 1.

To ensure accuracy, dial thermometers, by nature of their operation, require checking against one another and a master thermometer each time they are used.

During the 'hot weather period', taken as 1 March to 31 October, when undertaking local work, staff need to carry rail thermometers and monitor the rail temperature taking the appropriate precautions if it rises to or exceeds 29C.



Plate 1 Rail thermometer in use (dial type)

The thermometer is applied to the shaded side of the rail to avoid exposure to direct sunlight

5.2.2 Method of recording

To record rail temperatures, apply the following procedure:

- ◆ use as many thermometers as are necessary to obtain accurate data for the specific site and check that they have been calibrated (each should have a tag stating the date of calibration) and compare each with the others to ensure consistency of reading: have at least three thermometers available when assessing welded rail sites
- ◆ select recording locations no more than 200m apart
- ◆ at each recording location, place a thermometer on the rail foot or web of flat bottom rail, or on the web of bullhead rail, in both cases on the shaded side to prevent the effect of direct sunlight
- ◆ leave the thermometers in place for at least ten minutes to allow them to 'settle' before taking the initial reading
- ◆ when the readings of all thermometers are reasonably stable, record the individual readings and calculate their average.

5.2.3 Calculating average rail temperature

In calculating the average rail temperature it is important to take into consideration any variations due to the site (e.g. cutting or embankment) and weather condition (e.g. sun, cloud cover or wind). Taking the rail temperature at several locations will ensure that the average is not influenced unduly by the conditions at a specific recording location. If any reading is obviously inconsistent with the rest, a new reading should be taken with a different thermometer.

5.3 Temperature factors



The key values used in managing rail temperatures are the stress-free temperature and the critical rail temperature. Every length of welded track has both a stress-free temperature and a critical rail temperature.

The **stress free temperature (SFT)** is the rail temperature at which the rail is under no thermal force, i.e. the rail is in neither tension nor compression arising from the effects of temperature.

The **critical rail temperature (CRT)** is the temperature to which the rail may be allowed to rise before measures to protect traffic are to be taken. The amount by which the CRT exceeds the SFT depends on the configuration and condition of the track.

There are two CRTs: **CRT(W)** and **CRT(25)**. They are, respectively, the rail temperatures at which a Watchman or some other form of monitoring is deployed, and at which a speed restriction of 25mph is to be applied.

S1177 gives values of CRT(W) and CRT(25) for a range of track conditions and configurations, in terms of increments above the SFT value. They are copied below, in table 1:

- ◆ the upper part gives the values of CRT(W) and CRT(25) for “baseline” track, i.e. 56E1 rail, 26 concrete sleepers per 18.3m/60ft and track radius above 1500m;
- ◆ the lower part gives adjustments to the CRT(W) values for variations in track curvature, sleeper spacing and sleeper type. Adjusted values are then fed back into the upper part of the table to derive an appropriate CRT(25) value.

Table 1: Critical rail temperatures			
Track condition	CRT for “baseline” track		Period for which CRT shall apply
	CRT(W) C	CRT(25) C	
Undisturbed, fully ballasted and consolidated	SFT + 32	CRT(W) + 10	Permanently
Re-railed only (no other disturbance or deficiency)	SFT + 32	CRT(W) + 10	Permanently
No heaping of ballast shoulder: level with sleeper top (no other disturbance or deficiency)	SFT + 27	CRT(W) + 8	Until shoulder is restored
Tamped/lined with slues/lifts up to 25mm; Kango packing	SFT + 22	CRT(W) + 7	3 days
Tamped/lined with slues/lifts > 25mm	SFT + 20	CRT(W) + 6	5 days
Mechanised stoneblown	SFT + 20	CRT(W) + 6	5 days
Measured shovel packed/hand-held stoneblown	SFT + 17	CRT(W) + 5	3 days
3 consecutive sleepers voided at 15mm or more	SFT + 17	CRT(W) + 5	Until packed and stable
Unconsolidated line-side drainage works	SFT + 17	CRT(W) + 5	Until packed and stable
Active subsidence or earthworks failure	SFT + 17	CRT(W) + 5	Until the subsidence or earthworks has been repaired or removed
Misalignments, particularly at welded or insulated joints not complying with 1-159	SFT + 17	CRT(W) + 5	Until misalignment has been corrected
Rail creep, particularly of plain line towards unprotected junction works	SFT + 17	CRT(W) + 5	Until protection provided
Ballast generally full between sleepers and on shoulders, but not consolidated (8 beds or more)	SFT + 15	CRT(W) + 5	Until consolidated (see table 5)
Ballast generally full between sleepers and on shoulders, but not consolidated (less than 8 beds)	SFT + 15	CRT(W) + 5	5 days
3 or more consecutive slurried beds, where ballast is not compacted against the sleeper ends	SFT + 10	CRT(W) + 5	Until packed and stable
Severe shortage of ballast between sleepers and/or part sleeper ends exposed, extending 8 beds or more *	SFT + 10	CRT(W) + 3	Until fully ballasted and consolidated
Severe shortage of ballast between sleepers and/or part sleeper ends exposed, extending less than 8 beds *	SFT + 10	CRT(W) + 3	Until fully ballasted, then 5 days
* Note that exposure of sleeper ends and the consequent loss or absence of lateral resistance may arise from inadequate ballast retaining walls at underbridges, or from work being carried out on an adjacent track or adjacent supporting infrastructure			

Table 1: Critical rail temperatures (cont)	
Change to baseline track configuration	Change to CRT(W) shown above
Track curvature radius between 1500m and 800m radius between 800m and 400m radius below 400m	subtract 4 subtract 7 subtract 9 (but 7 if lateral resistance plates are fitted or if ballast is glued)
Sleeper/bearer spacing (no. per 60ft (18.3m) length) 24 28 30	subtract 2 add 2 add 4
Sleeper type Wood (FB) Wood (BH); fully compliant track Wood (BH); no heaping of ballast shoulder but no other deficiency Wood (BH) except as above	subtract 9 subtract 6 subtract 7 subtract 9

As examples, Table 2 indicates the values for different types of welded track that is fully ballasted and consolidated by traffic and has a radius above 1500m. **These values assume the SFT is 21C.**

Table 2: Example CRTs (C) for fully ballasted and consolidated track, radius above 1500m						
Rail	Sleeper		Sleepers per 18.3m (60ft)			
			24	26	28	30
56E1	concrete	CRT(W)	51	53	55	57
		CRT(25)	61	65	65	67
56E1	wood	CRT(W)	42	44	46	48
		CRT(25)	52	54	56	58
95RBH	wood	CRT(W)	45	47	49	51
		CRT(25)	55	57	59	61

5.4 Maintenance activities unaffected by hot weather

The following maintenance activities do not adversely affect the stability of the track, and can be undertaken at any time of year without affecting track stability:

- ◆ tightening down chair or baseplate fastenings
- ◆ renewing chair fastenings or baseplate fastenings, one at a time
- ◆ tightening fishbolts to the torque setting appropriate to the bolt size and type of joint
- ◆ shimming fishplates.

5.5 Postscript on cold weather



Tensile forces occur in rails below the stress free temperature. These forces may become intense during extremely cold weather and cause the failure of blockjoints and welds, particularly aluminothermic welds. High tensile forces will tend to 'flatten' the alignment of sharp curves, and this disturbance to the design alignment may create a potentially dangerous situation at structures where already minimum clearance exists. It is essential that ballast conditions are adequate to counteract this movement, particularly in the six foot and ten foot ways.

As in extremely hot conditions, the ballast consolidation is not to be disturbed. Where the ballast is full but not consolidated, even correctly stressed welded rail can move inward on curves, overcoming ballast resistance when rail temperature is at or below 0C.

No tamping or lining is to be carried out if:

- ◆ the rail temperature is at or below - 7C or if the ballast is frozen
- ◆ the rail temperature is at or below 0C and:
 - ◆ within 90m of adjustment switches, or
 - ◆ on stressed welded track with a curve canted greater than 90mm, or
 - ◆ on stressed welded track with a curve radius of less than 500m.

Ensure that during cold weather, when the rail temperature falls below 0°C, track alignment is checked to fixed references at least once a week if:

- ◆ newly ballasted welded rail is laid on curves below 600m radius, or
- ◆ the cant is 100mm or more, irrespective of ballast consolidation and rail temperature.

5.6 Summary

- ❑ Daily weather forecasts and weekly long-range projections are provided by the Met Office.
- ❑ During the 'hot weather period', staff need to carry rail thermometers and, when undertaking site work, check the rail temperature taking appropriate precautions if it reaches the CRT(W) or CRT(25).
- ❑ Rail temperatures are taken at designated sites throughout the Underground between 11.00 and 13.00 hours every day during the 'hot weather period'.
- ❑ Have dial thermometers checked and adjusted as required every time before use.
- ❑ When measuring rail temperatures, local conditions need to be considered and it is prudent to take the temperature at several locations to establish a 'reasonable average'.
- ❑ The key values in managing track stability against buckling are the stress free temperature and the critical rail temperature.
- ❑ Cold weather can produce tensile forces in the rail which can cause misalignment on tight curves.
- ❑ It is necessary to restrict maintenance work, which disturbs sleepers or ballast when rail temperatures are between -7C and 29C.
- ❑ Section Track Managers need to retain copies of their rail thermometer calibration records for at least five years.

6 Preventative track maintenance

6.1 Introduction

This section discusses the general precautionary measures which have to be taken to reduce the risk of track buckling, regardless of rail configuration. A special track inspection at the start of the year will indicate locations where maintenance work is required to keep the track in an acceptable condition.

The condition of the ballast and its impact on track stability are key factors in the maintenance process. Work which involves disturbance of the track, such as on-track mechanised tamping and lining, needs to be undertaken with particular care between the beginning of March and the end of October (the hot weather period) to ensure that track stability is not impaired.



Rail temperatures should be read as a routine maintenance activity. During spells of exceptionally hot weather, when the air temperature rises above 30C, additional temperature readings and safety patrolling will be necessary. Rail temperatures can reach 1.5 times the air temperature, depending on the degree of exposure.

6.2 Inspecting the track

Well before the start of the 'hot weather period' you need to identify locations where track maintenance will be needed to ensure that rails exposed to summer temperatures are given adequate support. An inspection needs to be undertaken before the end of January each year and the check list in table 3 is provided for guidance.

Table 3: Track inspection check list		
Component	Questions you need to answer	Action required if answer is "yes"
Ballast profile	☐ Are the ballast shoulders not to the correct width and height for the type of track with sleeper ends bare of ballast? ☐ Are the beds poorly filled with ballast?	Restore ballast shoulders Fill beds with ballast
Wet spots	☐ Are there any wet spots pumping? ☐ Are there any drainage problems?	Dig out, drain site, replace ballast, fettle
Sleeper condition	☐ Are the sleepers in poor condition with split ends? ☐ Are any fastenings working under traffic? ☐ Are sleepers off square to the rails?	Replace sleepers Tighten/replace, fettle Square sleepers
Fastenings	☐ Are fastenings loose and working? ☐ Are any fastenings broken or missing? ☐ Are ferrules damaged or loose?	Tighten/replace, fettle Tighten/replace, fettle Tighten/replace, fettle
Expansion joint condition	☐ Are joints unable to expand and contract freely? ☐ Are rail ends lipped? ☐ Are fishing surfaces dry and not greased? ☐ Are joints not properly packed and floating?	Regulate rails Remove lipping Grease fishing surfaces Pack joints
Tight joints in short rails	☐ Are there more than six consecutive rail joints that have closed up tight?	Regulate expansion gaps as required
Adjustment switches	☐ Are adjustment switches wrongly set? ☐ Are sliding surfaces dry and lack free movement?	Set correctly Lubricate surfaces
Expansion and adjustment switches	☐ Are expansion switches wrongly set? ☐ Are sliding surfaces dry and lack free movement?	Set correctly Lubricate surfaces
Pointer / datum mark distance	☐ Does measurement of pointer to datum mark distance, rail joint gaps and rail temperature indicate that de-stressing is necessary?	Destress site
Rail creep	☐ Are fishplates bearing up tight against sleeper fastenings? ☐ Are sleepers out of square to the track? ☐ Are the expansion gaps closed up when the rail temperature is low?	Re-space, re-align and compact ballast beds Cut 114mm out of BH rail & adjust gaps or cut in new rail
Rail pad position	☐ Are rail pads located off centre on the sleeper? ☐ Are rail pads missing?	Adjust rail pads Replace rail pads
Vertical & horizontal alignment	☐ Are there any 'dipped joints' or other dips in the top? ☐ Are there any signs of 'dog legs' developing in the alignment?	Joint straighten and pack Fettle top & line
Conductor rails	☐ Are conductor rails snagging on insulator lugs? ☐ Are fiddle cuts fouling point mechanism?	Adjust insulators Adjust fiddle cuts

6.3 Checking the ballast



Well-maintained ballast beds and shoulders, with no visible sleeper ends, provide the track stability necessary to resist the tendency for it to buckle during hot weather. Properly-filled beds give the necessary longitudinal and lateral resistance, while the ballast shoulder provides additional lateral resistance. Track defects such as wet spots and 'working' sleepers make the ballast less effective in fulfilling this function. Poor track alignment causes weak spots which are vulnerable to the compressive forces that produce track buckles.

6.3.1 Ballast dimensions

Figure 1 shows the required ballast cross-section. Table 4 sets out the minimum dimensions for ballast shoulders consistent with safety (see S1157).

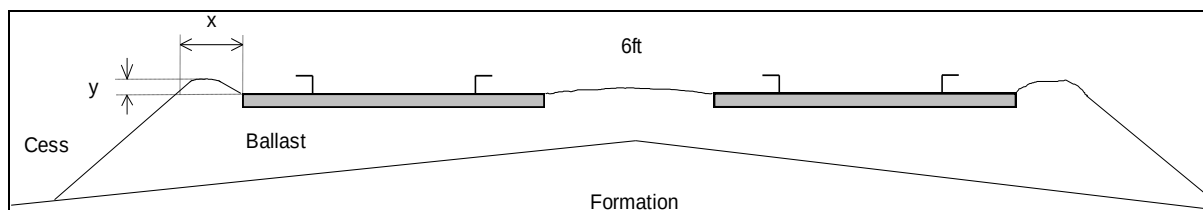


Fig.1 Cross section of track ballast, showing shoulder dimensions

Table 4: Ballast shoulder dimensions by track type			
Track type	Location	Minimum shoulder width X(mm)*	Minimum shoulder height Y(mm)*
Short rails	All situations	250	level
Welded rails	Straight	300	100
	Curves >600 m radius	350	100
	Curves <600 m radius	450	100
	Tunnel sections	250	level
Junctionwork	Welded, in Open locations	250	100
	All other situations	250	level
All	Depots & sidings	250	level

* Measurements X and Y relate to Fig 1 and need to be taken level with the top of the sleeper

Before the end of January each year, track fettling work needs to focus on packing all working sleepers, drying out wet spots, rectifying alignment faults and correcting ballast deficiencies. The fouled ballast in wet spots needs to be removed to provide a cross-fall to the cess or drain, and the cess lowered 300mm below the bottom of the sleeper to ensure free drainage from the wet spot. The treated section needs to be back filled with clean ballast and any loose sleepers packed.

In locations of potential weakness, such as expansion switches, the minimum width of ballast shoulder needs to be increased to 450mm.

6.3.2 Track consolidation

Once the track has been disturbed by renewal or maintenance work, it will need to regain its strength and compaction. Empirical evidence indicates that loosened or new track ballast becomes consolidated after the passage of two million gross tonnes of traffic, or 100,000 tonnes if the work was tamping only.. The time that this process of consolidation takes depends on the volume of traffic carried by the track, as shown in table 5.

Table 5: Time required to achieve track consolidation, by volume of traffi		
	Two million tonnes	100,000 tonnes
Number of trains per day (Monday to Friday)	Number of weeks	Number of days
35 to 45	67	20
45 to 65	50	15
65 to 85	34	10
85 to 95	27	8
95 to 110	24	7
110 to 135	20	6
135 to 165	17	5
165 to 220	14	4
220 or more	10	3

6.3.3 Opening out beds

It is important to ensure that other departments do not schedule for the 'hot weather period' work which could reduce the lateral resistance of the track support. If the work is essential and cannot be reprogrammed, a temporary speed restriction needs to be imposed on the section and the site monitored accordingly.



Track excavations reduce further the resistance to buckling and during the 'hot weather period', excavations in or around the cess and ballast shoulder need to be strictly controlled.

Any excavation work undertaken within 2.5m of the nearest running rail during the 'hot weather period', which affects the stability of the track, needs to be completed before normal traffic commences or the following precautions need to be taken:

- ◆ impose a temporary speed restriction if the excavation is closer than 2.5m from the running edge of the nearest running rail
- ◆ ensure that the track alignment is good, with no sleepers 'working'
- ◆ ensure that not more than 30m of ballast shoulder is removed at any one time and the track is struted (where possible) at least every third sleeper
- ◆ if any portion of a manhole is less than 600mm from the sleeper ends, build up the manhole to the top of the sleeper level or higher, so as to retain the ballast shoulder
- ◆ on welded rail sites if the shoulder is removed and cannot be replaced and adequate strutting is not provided, use a CRT described in table 1.

When opening out half-beds, alternate between the cess and six foot sides. As soon as the work on the sleepers or timbers is completed, replace the ballast. All beds must be back-filled before the end of any shift. During traffic, no more beds than the number indicated in table 6 may be opened out at the same time. Table 1 provides the CRTs for opening out beds.

Table 6: Opening out beds		
Type of track	Maximum number of beds which may be opened out at one time	
	Number of alternate half beds	Number of consecutive full beds
Short rails	16	8
BH welded rails	10	5
FB welded rails	6	2



Before undertaking work on welded rail during the hot weather period, you need to complete form TB5 (see attachment 5) and obtain authorisation.

6.4 Precautions during hot weather

6.4.1 Inspections

On work sites, staff need to record the rail temperature regularly between 10.00 and 15.00 hours when the average rail temperature is approaching 29C, and special precautions need to be taken.



If the average rail temperature rises to 29C:

- ◆ stop all local trackwork immediately
- ◆ refill any beds that have been opened out
- ◆ restore the full ballast shoulder
- ◆ refasten chairs or baseplates.

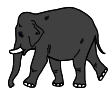


If the average rail temperature goes above 29C:

- ◆ do not open out any ballast beds or disturb the shoulder ballast
- ◆ do not jack up sleepers
- ◆ do not re-align track
- ◆ do not do any work that requires the removal of all fastenings of any chair or baseplate.



If trackwork is being undertaken under an Engineer's possession, the above precautions do not apply within the section of track covered by the possession.

**REMEMBER!****Additional safety inspections (patrolling)**

During the 'hot weather period' it is essential that the track is closely monitored. In the case of welded track sufficient rail temperature readings should be taken to give warning if the temperature approaches the CRT. In the case of short-rail track additional patrolling is necessary when:

- ◆ the rail temperature reaches 35C by 11.00 hours and continues to rise
- ◆ the rail temperature reaches 37C at any time.

Additional safety inspections (cab-riding)

In the case of welded track the Section Track Manager needs to arrange the visual inspection of the track (on foot or from the cab of a train) when the rail temperature reaches the CRT(W). In the case of short-rail track this should apply when the rail temperature reaches 44C .

6.4.2 Watchmen (track grade)

When you need to monitor a sub-standard section of track it may be necessary to post one or more watchmen to patrol the length of affected track. Make sure the watchmen are qualified and certificated as competent in hand signalling duties, and able to provide an immediate response for train protection in an emergency.

Watchmen need to undertake the following duties:

- ◆ constantly patrol the affected length of track and be alert for any unsafe or potentially unsafe conditions which may arise
- ◆ take the rail temperature every hour and continue to do so until the rail temperature falls to 5C, or more, below the CRT(W) described in tables 1 and 7
- ◆ be prepared to slow or stop trains as necessary in accordance with the Rule Book.

Table 7 gives examples (drawn from table 1) of CRT values for a number of conditions which may result from maintenance or renewal activities. All these CRT values assume that SFT is 21C..

Table 7: CRTs for unsatisfactory or weakened track						
	56E1 on concrete sleepers		56E1 on wood sleepers		95BH on wood sleepers	
	CRT(W)	CRT(25)	CRT(W)	CRT(25)	CRT(W)	CRT(25)
A length of rail with a misalignment exceeding 25mm over a 6m length, particularly at welded or blockjoints	38	43	29	34	32	37
A length with inadequate ballast on shoulders	48	56	39	47	41	49
A length with severe shortage of ballast, 8 beds or more	31	34	22	25	22	25
Renewal site: ballast full but unconsolidated, 28 sleepers/18m	36	41	N/A	N/A	N/A	N/A
A length where local knowledge or experience indicates that extra inspections are necessary, e.g. areas liable to subsidence, catchpoints, longitudinal bridge timbers, bridges with inadequate ballast retaining walls	38	43	29	34	29	34



Watchmen need to be posted when the rail temperature reaches CRT(W). If the track shows any signs of stress or significant misalignment, the watchman needs to impose a temporary speed restriction or stop traffic.

6.4.3 Monitoring alignment

On welded rail sites during cold weather, there is a risk of loss of stress due to 'pulling in', particularly on sharp curves with heavy cant. This condition has to be monitored closely, since it may result in poor alignment. The alignment needs to be restored and, if necessary, the track restressed before the onset of hot weather. If structural and/or passing clearances become unacceptable, immediate action needs to be taken to restore and hold the original alignment.



Where to find more information about preventative track maintenance

S1158 Track – Inspection and maintenance
S1159 Track – Dimensions and tolerances
S1177 Track – Prevention of buckling

6.5 Summary

- ☐ The effectiveness of ballast resistance is reduced by maintenance which disturbs the ballast, 'working' sleepers and 'wet spots'.
- ☐ Poor alignment reduces the track's resistance to compressive forces, and increases the chances of a buckle occurring.
- ☐ Additional track patrols need to be undertaken on short-rail track if the rail temperature reaches 35C by 11.00 hours and is still rising, or if the rail temperature reaches 37C at any time, and on welded track if the rail temperature reaches the CRT(W).
- ☐ During the 'hot weather period', rail temperatures need to be measured at regular intervals between 11.00 and 13.00 hours at the nominated locations throughout the system and reported to the Line Service Centres.
- ☐ Full consolidation can require the passage of up to two million gross tonnes of traffic, equivalent to more than 52 weeks' traffic depending on the line and location.
- ☐ During hot weather one or more watchmen need to be posted at sites where track has not been consolidated with 100,000 gross tonnes of traffic.
- ☐ The track alignment needs to be monitored until the ballast has been consolidated with the passage of two million gross tonnes of traffic.
- ☐ The Track Manager and the Section Track Manager need to agree which sites require watchmen to be posted.

7 Preventing buckling in welded rail



Because the scope of this section is so comprehensive, the following list of the subjects covered is provided for guidance.

- 7.1 General
- 7.2 Design considerations
- 7.3 Stressing welded rail
- 7.4 Stressing FB continuous welded rail
- 7.5 Stressing BH and FB long welded rail
- 7.6 Maintenance of welded rail
- 7.7 Major work on welded rail sites
- 7.8 Specific precautions during hot weather

7.1 General



On well designed and maintained track, welded rail offers a high degree of resistance to the distorting forces produced by extreme fluctuations in rail temperature. Its use also provides the benefit of improved customer comfort by minimising the necessity for fishplated rail joints, which are recognised areas of weakness in the track. However, owing to some tight curvature and the need for blockjoints to facilitate signalling it is not possible to eliminate fishplated rail joints entirely.

Two configurations of welded rail are employed by LU: continuous welded rail (CWR) and long welded rail (LWR). CWR is the standard configuration for new work and is mainly 56E1 rail. The long welded rail sites are made up mainly of 95-lb bullhead rail. References in this handbook to LWR should be read in the context of maintenance and component replacement rather than complete track renewal, as the latter will normally be in CWR.

S1622 (Glossary of terms) defines these terms as follows:

Continuous welded rail (CWR)

"rail continuously welded together to form a single rail length over 200m with no maximum length. Continuous welded rail may incorporate blockjoints"

It should be noted that this definition of CWR is a little out of date. CWR is now any length of rail more than 36.6m with expansion switches at both ends. S1157 allows lengths of up to 140m (but less with high-toe-load clips or on curves) to remain unstressed. Also, shorter lengths of CWR need not contain any welds, as rail is now rolled in lengths of 108m or even more.



Continuous welded rail can be used for bi-directional running.

Long welded rail (LWR)

"continuous lengths of welded rail (which may include tight joints) between 200m and 730m in length with adjustment switches at each end. Long welded rail may incorporate blockjoints"

It should be noted that this definition of LWR is also a little out of date. The 730m length limit was based on the assumption that stressing of the rail would be managed under traffic in a single shift, with 730m being a practical limit for a day's work. This methodology no longer applies and the limit is now withdrawn.



Long welded rail cannot be used for bi-directional running.



Managing welded rail involves, essentially, keeping the stress-free temperature (SFT) at an appropriate level, and maintaining the lateral stability of the track so that the critical rail temperature (CRT) is unlikely to be reached.

The correct SFT (27C in Open sections) is achieved by stressing the rails. When the actual rail temperature is below 27C the rails should be in tension. The amount of tension can be calculated and is applied to the rails by stretching them, so that the rails become stress-free when the temperature reaches 27C. At temperatures above SFT the rail goes into compression, so it is important that the lateral stability of the track is sufficient to prevent buckling.

Stressing should also be carried out to reinstate the SFT when it is known to have dropped below 21C.



This handbook does not cover the installation of CWR and LWR: see Track Handbook 2 *Renewing the track*.

7.2 Design considerations



Good design is the first essential element in minimising the risks of track buckling and the volume of maintenance needed on welded rail sites.

Before installing a length of welded rail, you need to consider the line and level of the track and examine the condition of the formation and drainage. It is also necessary to look at the condition of the ballast and assess its ability to provide track stability. Track curvature needs to be examined to ensure that the minimum design conditions are not compromised. The types of rails and sleepers used on each site require consideration as do the criteria for expansion switches and adjustment switches. The effect of stressing or restressing welded rails in tunnels may also need to be taken into account.

7.2.1 Line and level

Welded rail sites need to have the existing track alignment surveyed and the welded rails installed to a suitable design. A levelling survey needs to be undertaken to provide a basis for designing the top, cross levels and vertical curves.

The design needs to be set out and 'proved' on site, temporary dimensions provided for use during renewal work and, whenever possible, permanent markers installed for both line and level to identify the track position and provide design references when undertaking future track maintenance.

7.2.2 Formation and drainage

Check the condition of the formation and track drainage by excavating trial holes in the cess, four-foot and six-foot every 100m or less, depending on site conditions. Any remedial work that may be found necessary, such as blanketing, renewing old drains, or providing catch pits, needs to be undertaken. When ballast cleaning, ensure that the crossfall of the formation is continuous to the drain and that the drainage system is adequate and in good working order. Where drains are deeper than normal and it would not be practical or economical to excavate to the drains, cess lowering from the sleeper ends to the drains can provide suitable free drainage of the formation.

7.2.3 Ballast

At the same time as checking formation and drainage, use the same trial holes to check the condition and depth of ballast. If the ballast condition is inadequate, undertake remedial work (e.g. ballast cleaning, ballast replacement and track lifting). The ballast needs to be clean and have a minimum depth of 230mm, measured from the underside of the sleeper to the top of the formation or blanketing layer. Where an existing underbridge is involved, you need to consult The Track Engineer and the Senior Engineer (Structures) to establish the minimum and maximum ballast depth permissible. The ballast profile has to be maintained to dimensions that provide sufficient lateral stability for the track (see table 4).

7.2.4 Different track levels

To maintain resistance to lateral movement on curves, it is necessary to limit the variation in track level between inner and outer tracks, ensuring that the six foot sleeper ends of the outer track are not more than 75mm below the six foot sleeper ends of the inner track over a six foot of 1970mm.

Where the six foot is wider than 1970mm, an increase in height of 12mm per 100mm increase in six foot is permitted and to ensure stability, the ballast must be heaped up at the end of the higher sleepers (see S1157).

7.2.5 Curvature

At temperatures below the stress free temperature, the tensile forces within welded rails act to reduce the length of the rail, which tends to straighten out curves. This 'pulling in' effect is particularly strong on tight curves and so there is a restriction on the minimum radius of curvature to which they may be installed (see S1157 and table 8). In open sections, CWR may be installed where the radius is above 300m. In other sections, and in open sections where it is short enough not to require stressing, CWR may be installed down to 200m radius. LWR has a 300m radius limit but should no longer be installed as new track.

Table 8: Curvature and sleeper requirements				
Sleeper type	Radius (m)	Rail type	Number of sleepers per 18.3m (60ft) of track	Sleeper spacing (mm)
concrete	300 to 600	flat bottom	28	650
concrete	straight to 600	flat bottom	26	700
hardwood	All	flat bottom	28	650
softwood	All	bullhead	24	750

7.2.6 Rails

Only 56E1 rail is normally used for CWR. If an LWR site requires rerailing, the existing rail type (normally 95-lb bullhead) will be used. Both types of rail will usually be delivered in pre-welded lengths for subsequent welding on site.

7.2.7 Sleepers

Concrete sleepers are to be used on flat bottom continuous welded rail sites and wood sleepers on bullhead long welded rail sites. Table 8 gives the type and recommended sleeper spacing for all sites. On concrete sleeper sites, it is acceptable to install hardwood sleepers at locations where concrete sleepers cannot fit, such as adjacent to manholes. However, short-ended concrete sleepers are available for this purpose.



S1157 requires that where a concrete sleeper site abuts a softwood sleeper site, a minimum of two hardwood sleepers be installed between the concrete and the softwood. In addition, any change between concrete and wood sleepers is not to be within two sleepers of an alumino-thermic welded or fishplated joint.

At locations where weight restrictions exist due to the condition of a structure, viaduct or ash embankment, hardwood sleepers may be used instead of concrete but the sites with poor ground conditions require monitoring for any signs of settlement. Hardwood sleepers may also be used on bridges with limited ballast depth, provided adequate resistance to lateral movement is ensured and on viaducts, weak embankments and other locations where the additional weight of concrete sleepers would be undesirable.

In certain areas, to provide greater lateral resistance, it may be preferable to use 300mm wide hardwood sleepers instead of standard 250mm wide due to their greater weight and cross-section.

7.2.8 Expansion switches (Network Rail scarf type)



Expansion switches (see plate 2) are installed and site-welded between CWR and jointed track, and between CWR and unstressed junctionwork, in order to prevent rail forces being transmitted from the CWR into the jointed track or junctionwork.



Plate 2 FB rail expansion switches

Note the single strengthening strap in the four foot. The second strap is still to be installed. The power cable through the centre of the expansion switch increases maintenance problems and needs to be repositioned at least three beds clear of the expansion switches

7.2.8.1 Expansion switch settings

Where possible, expansion switches should be sited on straight track and laid with the inside tongues trailing in the direction of normal traffic (see figure 2). Table 9 gives the dimensions for overlap and gap opening you need to use when setting expansion switches. If the gap openings are inconsistent with the overlap, the correct setting is the overlap measurement. Ensure that the end of the expansion switch rail is within the clamp plate by at least 60mm measured from the edge of the clamp plate, and that the full width of the rail foot is on the baseplates by at least 30mm: see plate 3 for a non-compliant situation. Do not overtighten holding down bolts, take up slack on thread until the spring washers start to compress.

Table 9: Expansion switch settings		
Average rail temperature (C)	Expansion switch overlap (mm)	Gap opening (mm)
-4 to 2	631 - 639	129 - 121
2 to 7	637 - 645	123 - 115
7 to 13	644 - 652	116 - 108
13 to 18	650 - 658	110 - 102
18 to 27	656 - 674	104 - 96

When permanently installed, the length of rail from the tip of the expansion switch to the nearest tight joint or welded joint must be no less than 4.5m and when inspecting expansion switches, any expansion switch gap opening found to be less than 60mm needs to be reported to the Track Manager, together with the rail temperature.

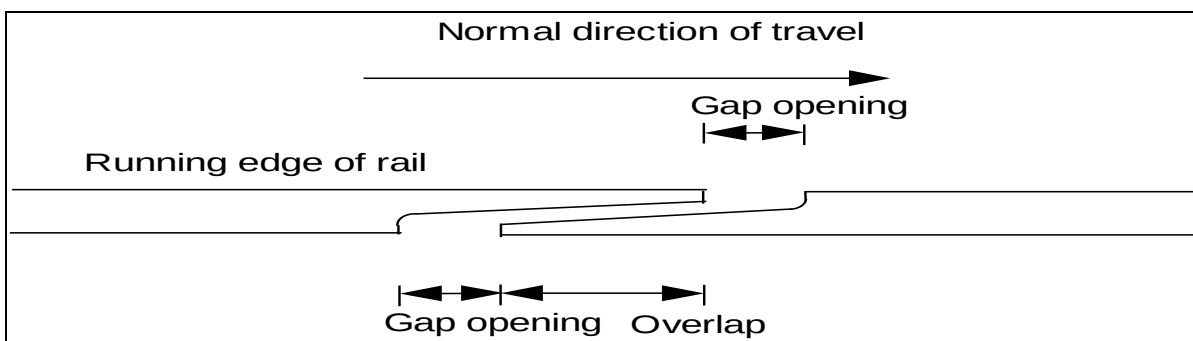


Fig. 2 Expansion switch settings



Plate 3 Non compliant expansion switch

This shows a non-compliant expansion switch where the full width of the rail is not supported at all. The full width of the rail needs to be at least 30mm within the baseplate. The rail/sleepers need adjustment to meet this requirement.

7.2.8.2 Expansion switches at bridges

Expansion switches are not to be sited on the span of underbridges. However, exceptions exist. e.g. where a viaduct has a long steel bridge within the structure or where continuous welded rail adjoins short rails on a viaduct or vice versa.

Unless a "slip membrane" is provided under the ballast, expansion switches need to be installed on continuous welded rail sites at underbridges where the deck length exceeds 27m.



Guidance needs to be sought from the LU Head of Track Engineering on the suitability of including expansion switches within continuous welded rail sites, on bridges with:

- ◆ multiple spans
- ◆ direct fastening track
- ◆ track fastened to longitudinal timbers
- ◆ other non-standard arrangements.

On ballasted track, expansion switches need to be located at the end(s) of the underbridge where longitudinal movement is expected and not less than 4.5m clear of the deck end, measured from the weld between the expansion switch and rail. In the case of skew span bridges, measure from the end of the sleeper closest to the bridge deck.

7.2.8.3 Expansion switches during relaying works

During relaying work, it may be necessary to cut into existing long welded rail. If the long welded rail is less than 200m in length, cut into 36.6m sections and treat as short rails. When the long welded rail is greater than 200m in length, prepare the site according to figures 3 and 4, depending on whether you are relaying with or against traffic.

- ◆ When relaying with traffic, either cut the long welded rail into 36.6m maximum lengths and treat as short rails or before cutting any rails, make sure you install a 50m anchor using rail anchors on existing bullhead long welded rail (see figure 3) to anchor the long welded rail.

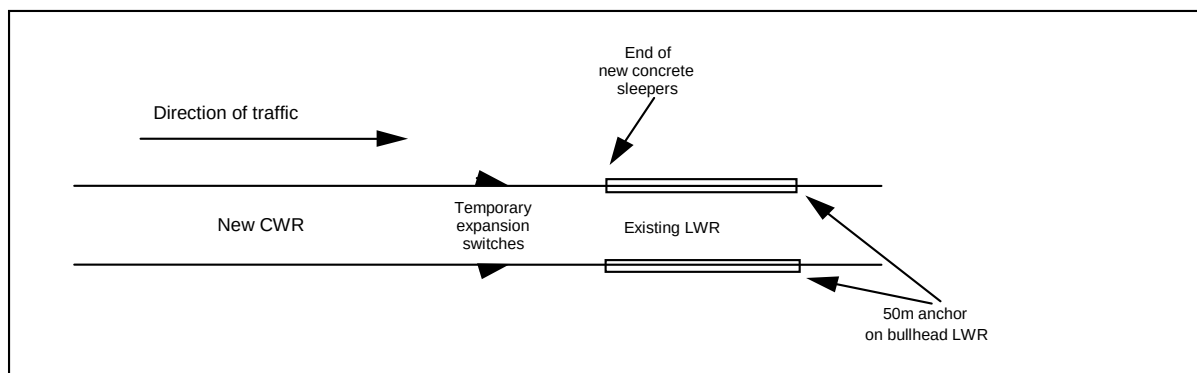


Fig. 3 Position of expansion switches when relaying with the traffic

- ◆ When relaying against traffic, make sure the long welded rail is cut into 36.6m maximum lengths, set expansion gaps (see table 27), fishplate the joints and treat as short rails (see figure 4).

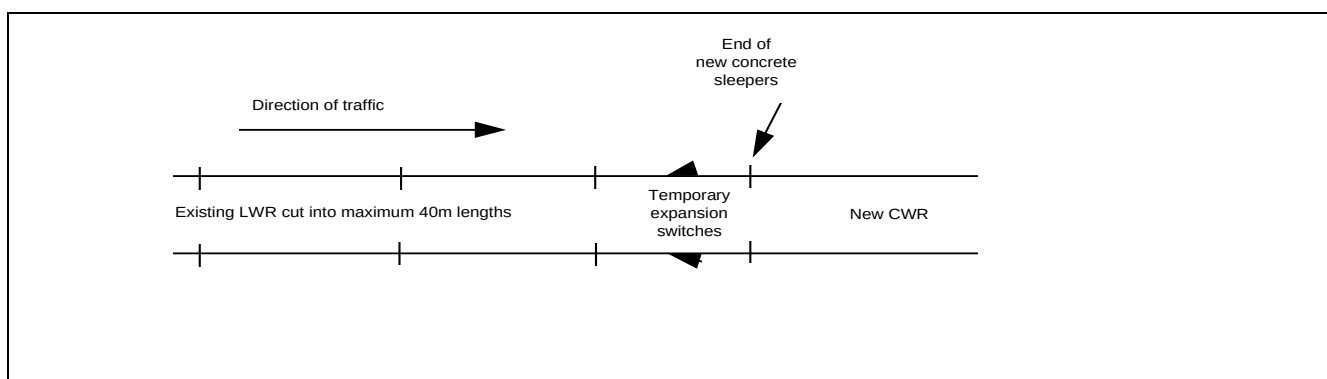


Fig. 4 Position of expansion switches when relaying against traffic

Expansion switches may be fishplated where relaying is continuing for several weeks, but the fishplates need to be removed as soon as practicable and the expansion switches welded in their final position.

7.2.9 Adjustment switches



Adjustment switches allow the ends of rails in LWR to move longitudinally, enabling stresses induced in the rail by temperature variations to be relieved. They also provide the opportunity for adjusting the rails after relaying abutting sites. Adjustment switches are used in both bullhead and flat bottom LWR sites and are required at both 'running on' and 'running off' ends with the switch rails in the trailing direction to normal traffic.

Adjustment switches are installed opposite and square to each other at intervals up to 730m on straight track and on sites which have reverse curves with less than 100m straight track between the curves. They are not required on reverse curve sites where there is a section of straight track longer than 100m. The overall length of an adjustment switch is 11.810m for BH rail and 11.958m for FB rail (see drawings Pm2626 and P60992).

Adjustment switches need to be set as described in table 10 and you need to ensure that the slide chairs or slide baseplates are greased and clamps correctly adjusted.

Table 10: Adjustment switch settings	
Average rail temperature (C)	Dimension (X) from switch toe to edge of slide chair or slide baseplate (mm)
-4 to 2	25
2 to 7	19
7 to 13	12
13 to 18	6
18 to 27	0

During inspections, you need to ensure that the switch toe is fully supported by the slide chair or slide baseplate (see figure 5) at all times.

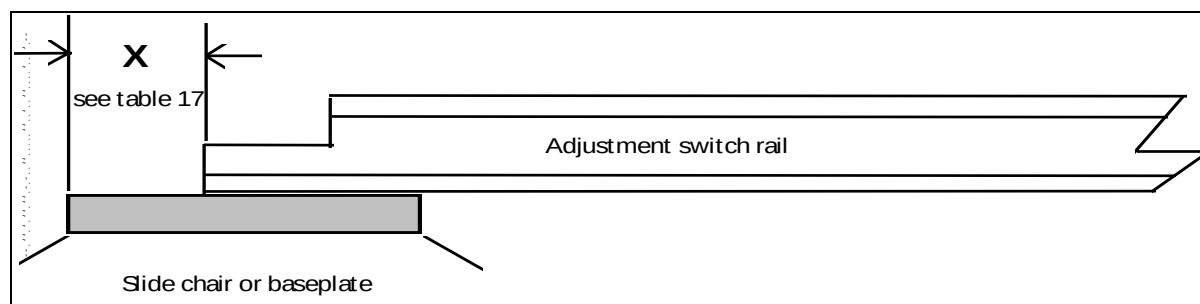


Fig. 5 Adjustment switch settings

7.2.10 Adjoining continuous welded rail and long welded rail sites

On sites where continuous welded rail and long welded rail adjoin, adjustment and expansion switches are required as shown in table 11 (copied from S1157).

Table 11: Switches at sites where LWR and CWR adjoin

Track preceding	Joining configuration, in direction of running	Track following
BH LWR	Either: - BH adjustment switch, BH-to-FB transition rail, FB expansion switch, or - Composite BH/FB expansion switch (see Note 1)	FB CWR
FB CWR	Either: - FB-to-BH transition rail, BH adjustment switch, or - FB adjustment switch, FB-to-BH transition rail, or - FB expansion switch with FB to-BH transition at running-off end, BH adjustment switch	BH LWR
FB LWR	FB expansion switch	FB CWR
FB CWR	FB adjustment switch	FB LWR (Note 2)
BH CWR	BH adjustment switch	BH LWR
BH LWR	BH adjustment switch, BH expansion switch (see Note 1)	BH CWR
Notes:		
1. Expansion switches accommodate less rail-end movement than adjustment switches and should not be used at the running-off end of BH LWR unless it is considered that the movement can be accommodated.		
2. Or use an FB expansion switch, thereby converting the LWR to CWR.		

7.2.11 Expansion and adjustment switches at tunnel portals

At one time expansion or adjustment switches were installed at tunnel portals to allow for the difference in rail temperatures outside and inside the tunnel environment. Where they still exist they need to be maintained with the correct overlaps and gaps. However, current practice is to dispense with them and stress the welded rail outside the tunnel, with the stressing anchor length set up just inside the tunnel. The rail inside the tunnel, more than 40m from the portal, is assumed not to experience significant thermal effects and can be expected to remain free of thermal force.

7.2.12 Insulated joints

Insulated joints classed as CWR-compatible (glued and Tenconi types) do not require expansion or adjustment switches to protect them.

Six-hole insulated joints require careful sleeper spacing to ensure that the rail clips can be correctly fitted.

7.2.13 Junctionwork

Unstressed junctionwork abutting CWR or LWR sites needs to be protected by expansion switches or adjustment switches respectively. The switches need to be installed not more than 40m from the junctionwork element they are protecting.



Where to find more information about welded rail design

S1157 Track – Performance, design and configuration

7.2.13 Summary

- ☐ Install permanent markers for both line and level.
- ☐ Ensure drainage systems are adequate and in good working order.
- ☐ Ensure the design provides a minimum ballast depth of 230mm.
- ☐ Ensure that the designed difference in sleeper level over a 1970mm six foot does not exceed 75mm between adjacent tracks.
- ☐ Do not install CWR in Open sections where the track radius is less than 300m.
- ☐ Ensure adjustment and expansion switches are properly sited.