Technical Authority

RailEI Technical Seminar

Making a Point: Developments in S&C Design, Installation and Maintenance

S&C Stressing

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Together, we're delivering a simpler, better, greener railway.

Simpler. Better. Greener.

Why do we stress track and in particular S&C

If a rail was unrestrained, a 60°C rail temperatures would cause each 1000m of rail to expand by approximately 380 mm.

When constrained this builds up compressive forces in the rail which can exceed 60 tonnes on an exceptionally hot day (assuming a stress free temperature of 27°C). Similarly, the rail sees similar magnitude tensile forces in winter.

Increased buckle risk in summer and risk of broken rails in winter. Typically, 2/3 of our broken rails occur in 1/3 of the year from November to February.

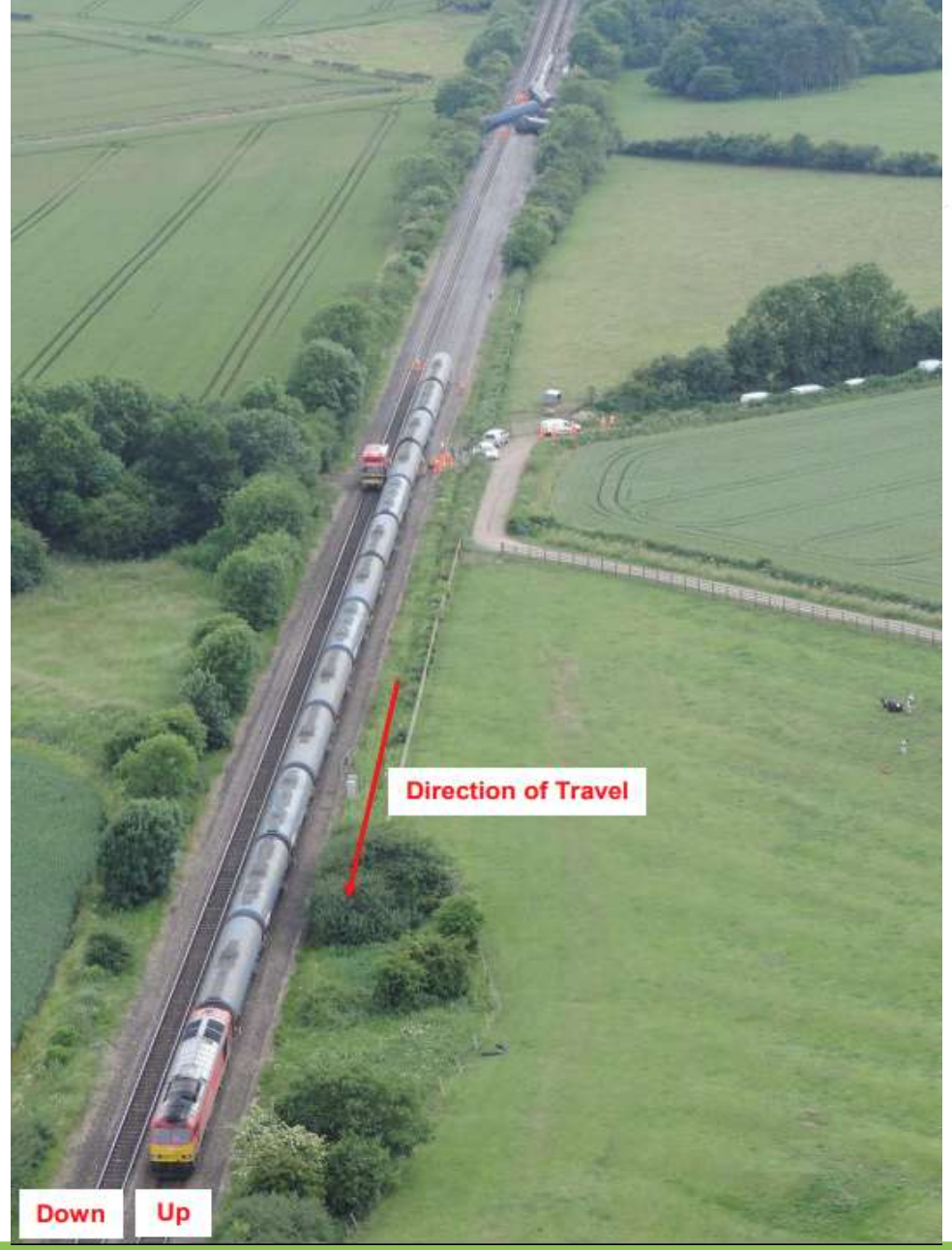
Significant increases in service affecting failures, particularly point failures are also experienced during periods of hot and cold weather.

A large majority of our buckles occur on sites which are not on the CRT register but with hindsight, should have been.

Buckle risk and hot weather mitigation relies on knowing an accurate stress free temperature of a section of track, the temperature of the rail and the lateral strength of the track. The latter is derived from any prior ballast disturbance, the ballast conditions, and other factors such as an existing misalignment, voiding, fastening and pad condition.

The Risk - Track Buckles and Broken Rails

Langworth Derailment 30th June 2015



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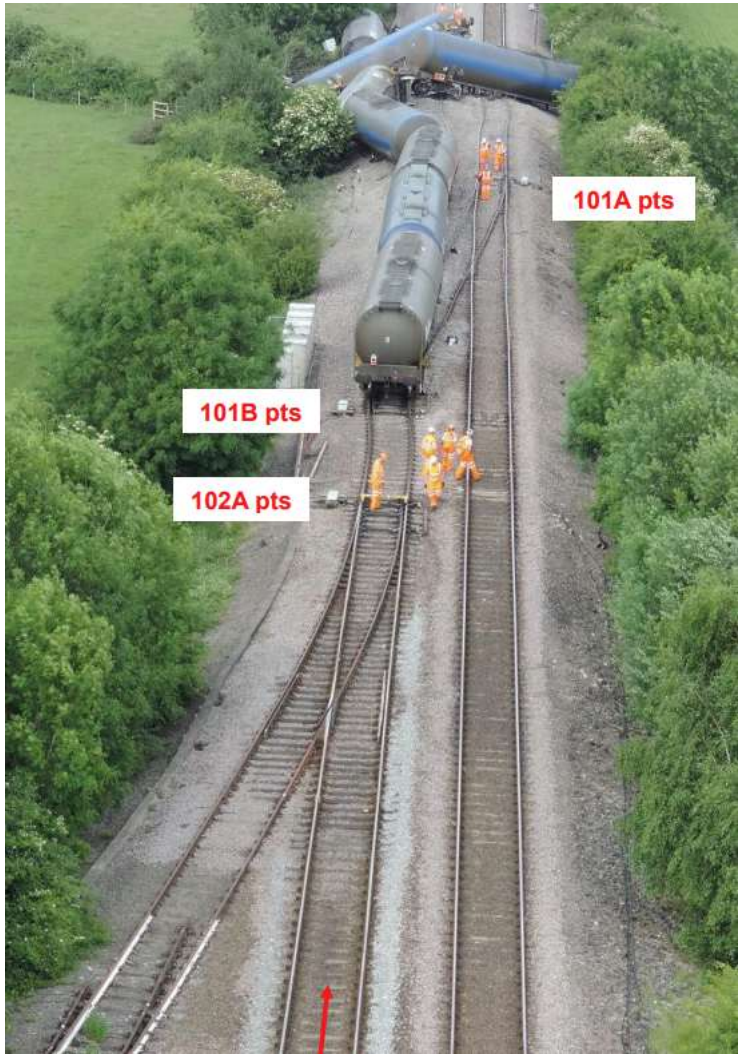
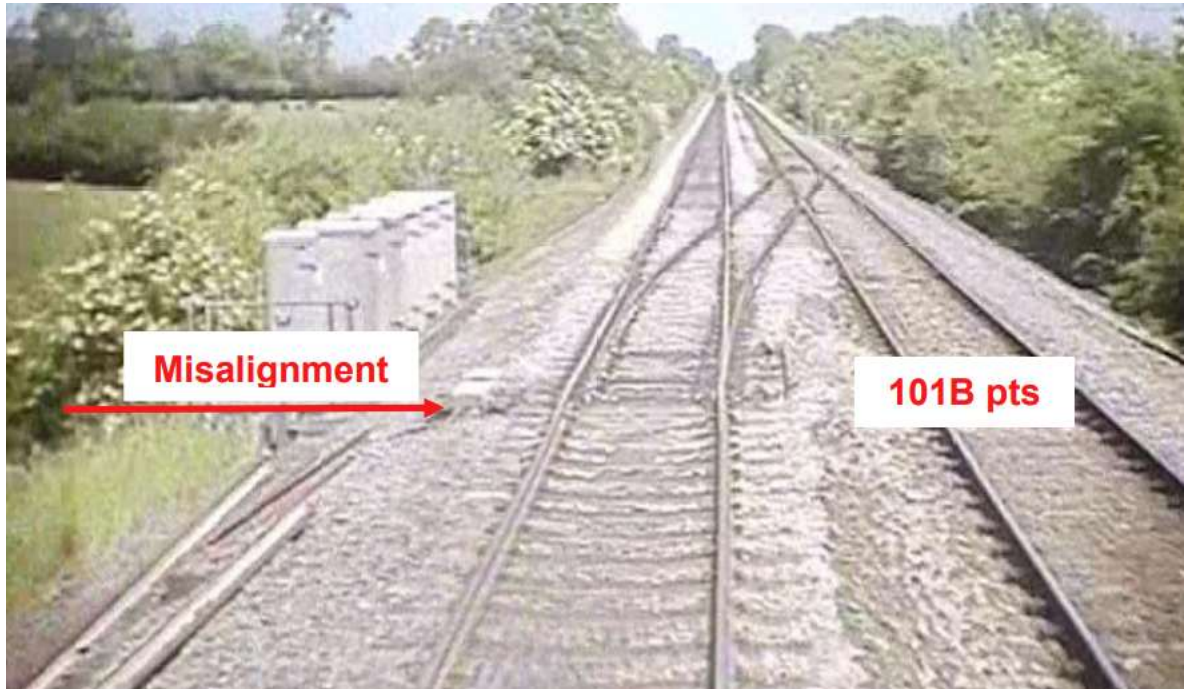




2 hours before the derailment East Mids FFV

Stressing:

Latest stressing cert from when the S&C was originally stressed in 1990 (25 years old)

101B Points had a cast crossing with a casting date of 2004 and is welded into a strengthened layout. There are no stressing records for the replacement of this crossing.

There were records of a defect removal (from a GEOGIS Update Form) on the Up line in 2008 but no Level One stressing record (or higher) to cover the site. No entry was been made in Rail Stress for this defect.

Track Buckle Prevalence and Identification Analysis

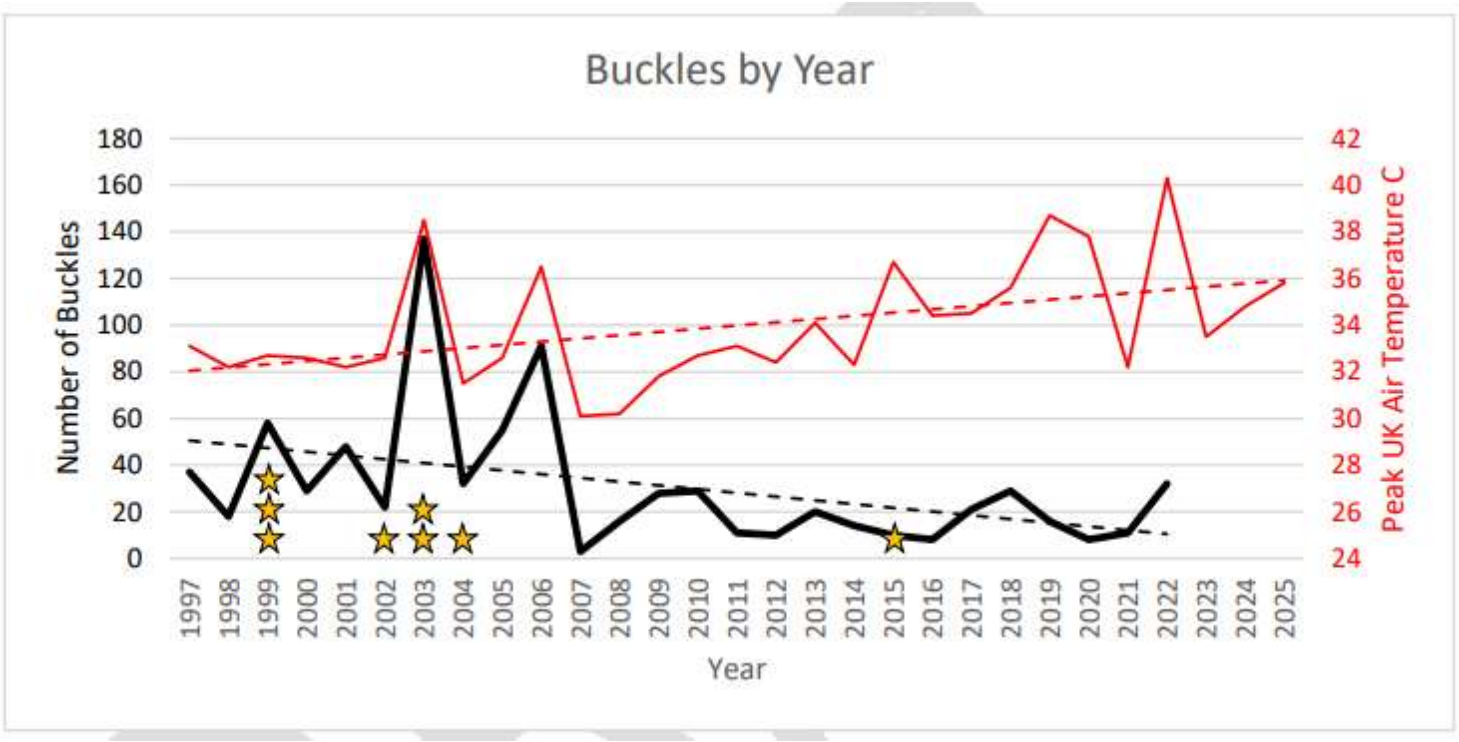
Analysis was undertaken on the track buckle dataset which covered the years 1997 to 2025, (809 buckles) and has been enhanced by cross-referencing to other Network Rail data such as INM.

The trend in the number of buckles each year is reducing while the temperature trend is increasing, suggesting that the management of track buckling risk is improving. Whilst the recent hot summer of 2022 caused a spike in buckles, the hot summers of 2003 and 2006 had a much greater effect.

The majority of buckles are identified by the drivers of trains passing over them, highlighting the importance of assessing the derailment risk of trains passing over buckles, and understanding the way that buckles may grow slowly or rapidly as trains pass over them.

Where a buckle has been identified by a train driver, then in most cases the measurement of the buckle (to provide geometry data) will occur after the passage of the train which could grow rapidly if subject to further traffic.

Buckles and Derailments

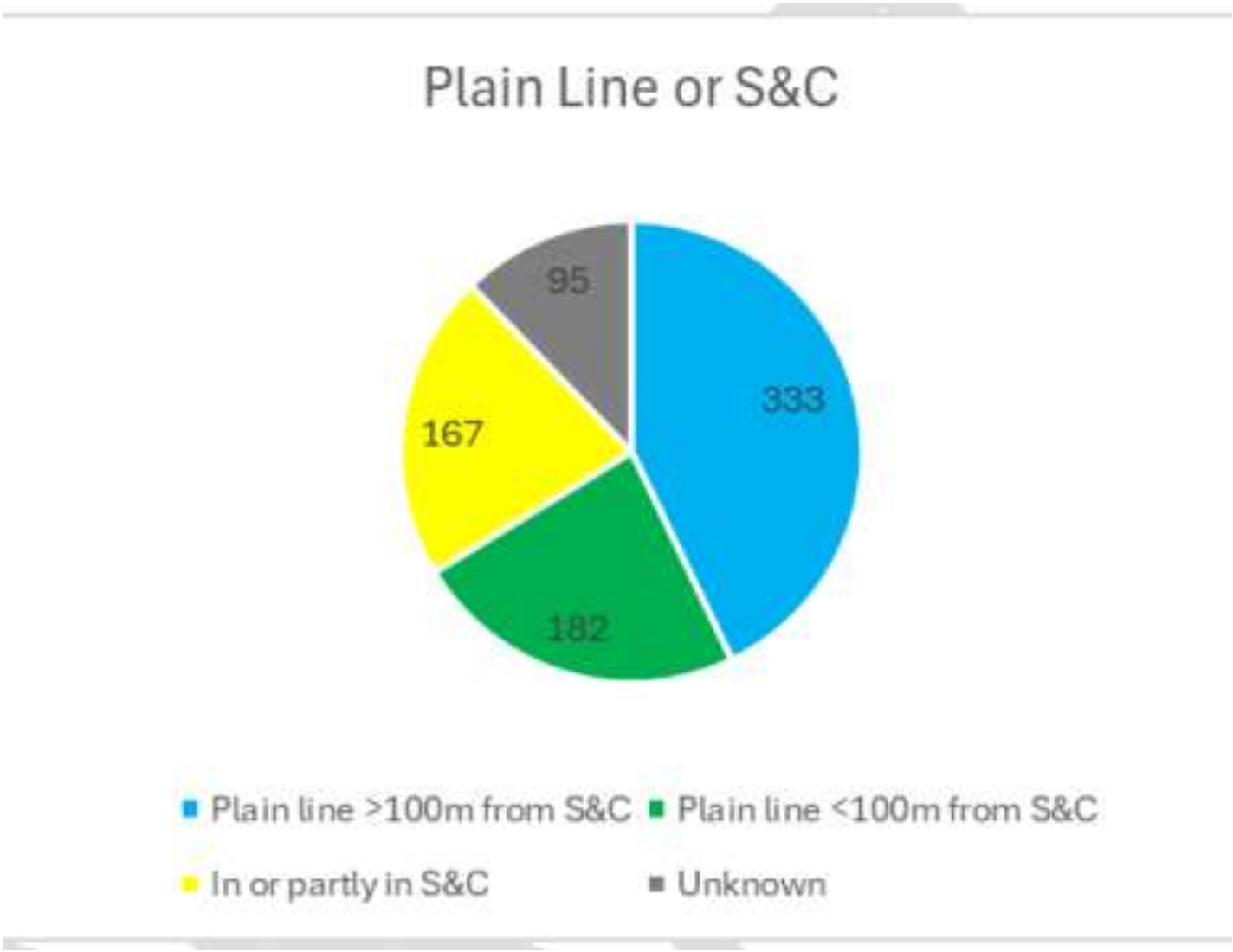


The years when derailments on buckles occurred (are marked with stars) superimposed on the wider trends in temperature and number of buckles each year. It is notable that in the past 20 years only one derailment on a buckle has been identified, against a background trend of increasing peak temperatures. This may indicate a more effective, or more cautious, approach to management of the buckle risk.

The trends identified within the dataset could provide the foundations of a risk assessment into the formation of track buckles and the likelihood and consequences of a train derailment on the buckle.

Consider the use of a buckle register to accurately record key buckle parameters extracted from TEF3032 forms

Plain Line vs S&C



About half of track buckles occur in plain line more than 100m from S&C. The remainder occur within S&C layouts, or in the plain line adjoining the S&C.

Considering that S&C comprises a small percentage of the total track mileage, it is associated with a disproportionate number of buckles. This is an important finding, because most studies of track buckles focus on the simpler plain line case.

Buckles in S&C are also the most prevalent on busy high-speed lines in categories 1A and 1, potentially the highest-risk scenarios..

Cumulative Effects of Trains Passing over Buckles

Small buckles do not cause any significant reduction in longitudinal rail stress – this is only achieved when the buckle has grown catastrophically to a size that is clearly unsafe for train operation.

In some circumstances, the track is unstable, poised to buckle catastrophically when disturbed by a passing train. This behaviour is influenced by temperature, trackform strength and buckle geometry. Vehicle speed and type are less significant.

In other circumstances the track is almost stable but the influence of wheel/rail forces causes the buckle to grow. Initially it may grow so slowly that many trains can pass over it before it becomes unsafe. This behaviour is speed-dependent: the growth rate will be slower at low train speeds and with vehicles that exert lower track forces. As the buckle grows, the track becomes less stable, and the buckle grows at an increasing rate under the passage of trains – the almost stable scenario eventually becomes unstable and the buckle will then grow catastrophically.

Buckle Risk? Barton South Junction 20th June 2022

Buckle reported by a train driver

DBP1 1100, Track Category 1A 125mph

Buckle in the moveable length of S&C (toe to toe junction).

44mm amplitude with a 20m wavelength (10m, ½ sine wave).

Not on the CRT Register, no disturbance or deficiency identified.

Stressing records indicate 27C from 2015

Rail Temperature measured at 39°C (measured at 18:54)

Verse test to be carried out to identify accurate stress condition.

Ballast shortage on shoulder.

Voiding of 8mm in switch area following S&C tamp on 30.04.22.

Whole Junction manually ballast regulated.

Junction to be restressed if Verse results indicate a low or non-uniform rail stress within the junction.

Buckle Growth and Derailment Risk
Simplified Severity Index - SSI

What is a buckle and what is the risk?

Research and analysis undertaken to determine practical parameters to estimate buckle severity from existing available measurements.

The SSI parameter has a good correlation with lateral track forces and derailment risk on both buckles and kinks, while being simple to calculate based on the available data. It has been defined using the units specified on the Network Rail buckle report forms for each input parameter:

For buckles: **SSI = speed (mph) × amplitude (mm) ÷ wavelength (m)**

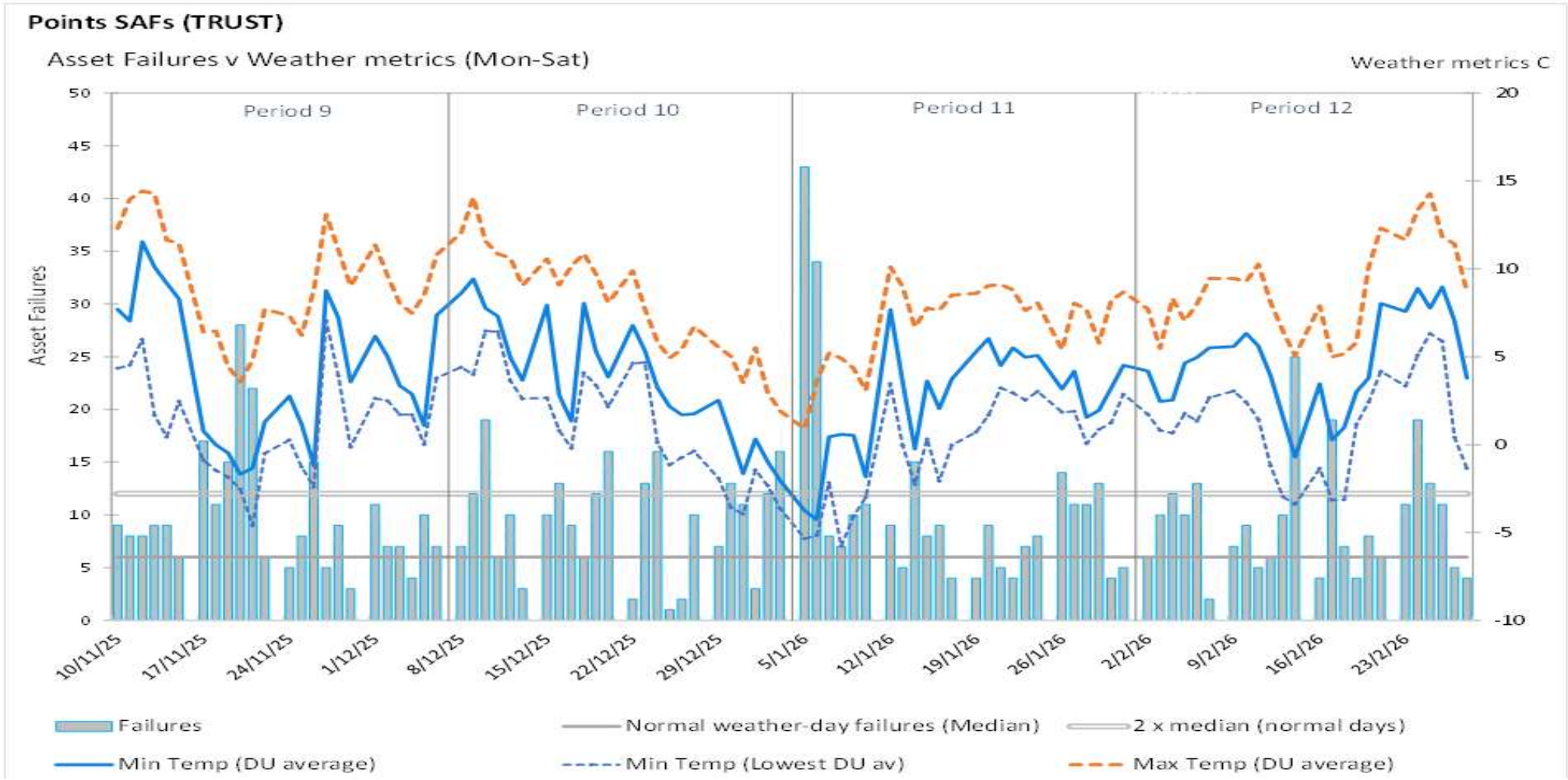
For kinks: **SSI = speed (mph) × kink angle (mrad) ÷ 4**

Typically, an SSI less than 200 is considered benign and indicates a low derailment risk and acceptable track forces. In contrast, an SSI over 400 represents a high risk of derailment or significant track shifting.

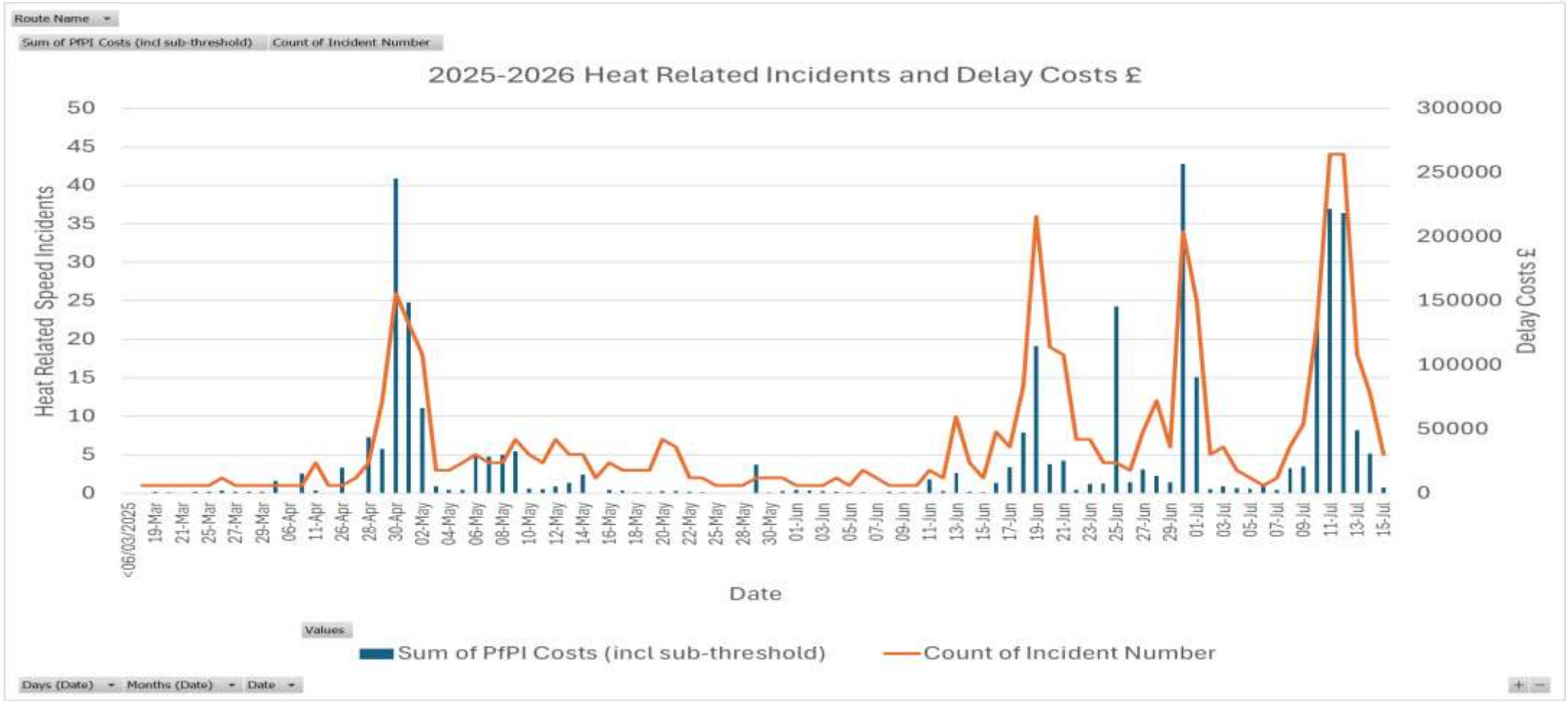
Between 200 and 400 the risk becomes vehicle-dependent.

Using the simplified severity index, about half the buckles have a severity below 300 and represent a lower risk. However, there are over 100 high-risk examples with an index ≥ 600. These high-risk buckles are distributed across the track categories, particularly category 1A and 1 representing busy main lines. The less severe buckles (index < 300) are mostly on track categories 4, 5, 6 representing lower-speed, lower-traffic lines. Although buckles are less common on busy routes, when they do occur, they often have a high severity index.

Cold Weather 2025 – 26 vs Points Service Affecting Failures

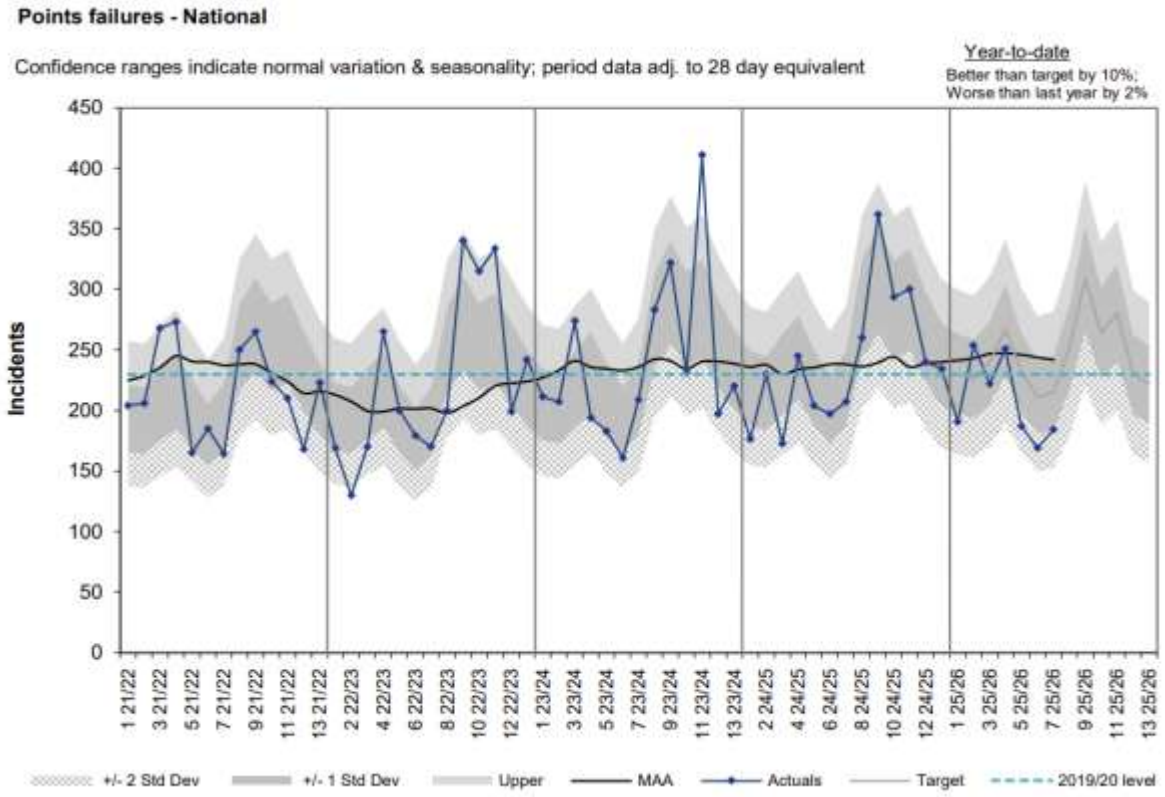


Hot Weather 2025 - National Heat Related Incidents and Schedule 8 Costs £

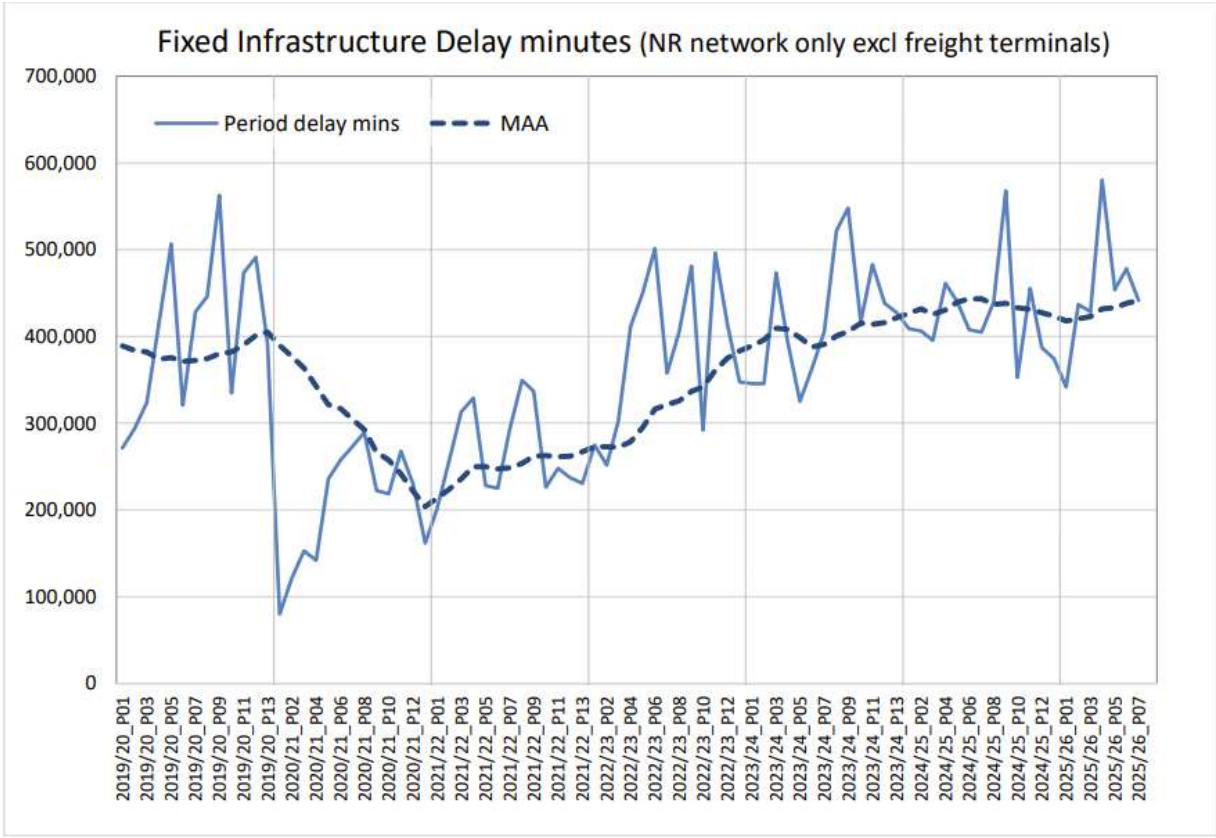


Asset failures account for 60% of NR caused train delays and 37% of overall rail industry delay. Failure rates are influenced by asset age and condition, weather, and the effectiveness of maintenance

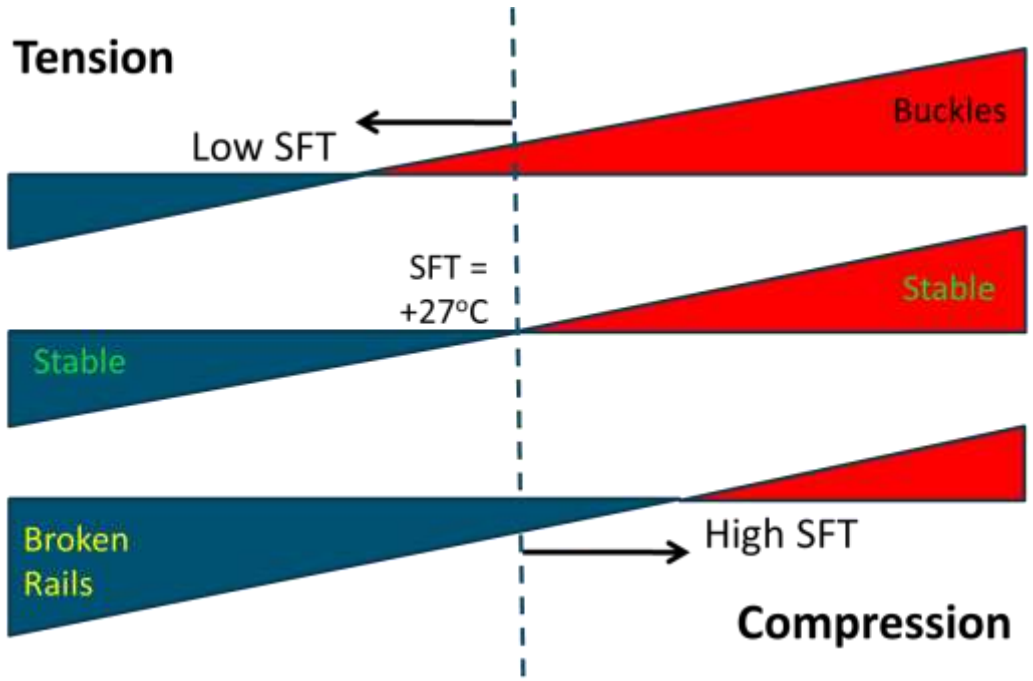
Points Failures Strongly Influenced by Weather and in particular Temperature.



SAFs relatively constant but delay minutes steadily Increasing



Stress Free Temperature – Climate Change



Still set at 27°C as a balance between expected low and high rail temperatures (-10 to +60°C) and the ability to hold stress in tighter curves and older designs of track. Accept 27 to 30 °C for natural stressing.

Reviewing whether 21°C is still an acceptable minimum for certain infrastructure with a higher risk of buckling. Confidence in stressing historic records.

Continued research to develop a less intrusive and quicker way of assessing SFT in track.

Why 30°C for new rail?

Historical research using Verse test results through a series of curves over time indicated that new rail could lose 3°C SFT after a period of time under traffic.

This potentially leaves new rail stressed sites with a SFT of 24°C.

Further work to be planned to confirm or disprove “roll out” in new rail and SFT reduction under initial traffic.

The new 3011 Issue 8

Draft completed yesterday

3.1 Table 1 – List of Modules

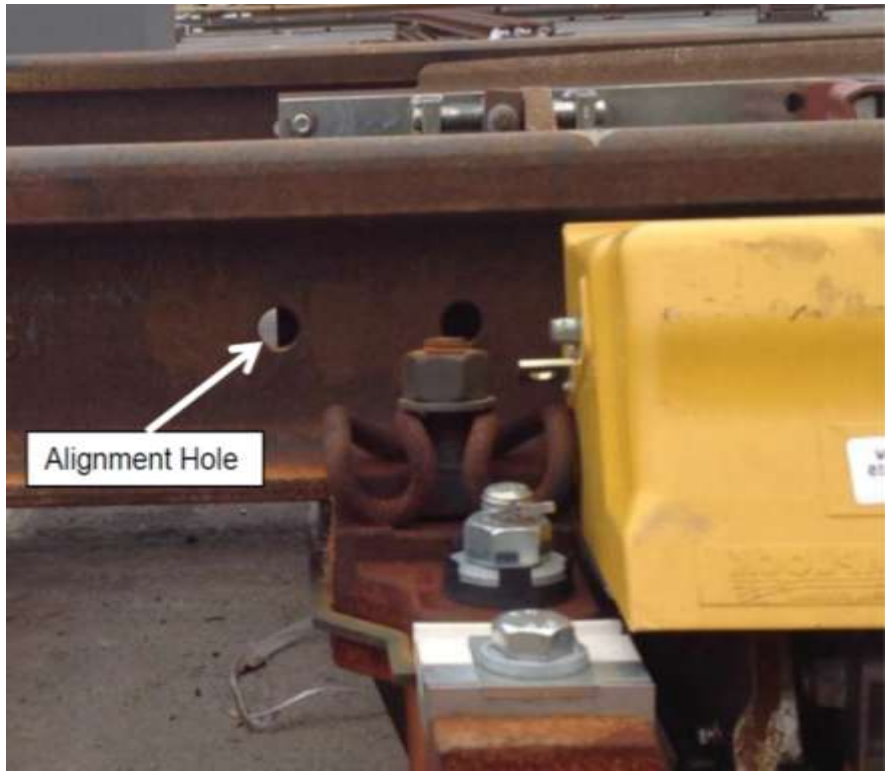
Module Number	Title	Issue No.	Date
NR/L2/TRK/3011/Mod01	Definitions of terms used in the manual, Design principles, Permitted stress free temperatures and Stress transitions	1	07.09.2026
NR/L2/TRK/3011/Mod02	Measurement of stress condition	1	07.09.2026
NR/L2/TRK/3011/Mod03	General Planning and preparation for stressing	1	07.09.2026
NR/L2/TRK/3011/Mod04	Stressing Methods	1	07.09.2026
NR/L2/TRK/3011/Mod05	Plain Line Stressing Principles and Process	1	07.09.2026
NR/L2/TRK/3011/Mod06	Stressing of Long Welded Rail (LWR) and transition lengths	1	07.09.2026
NR/L2/TRK/3011/Mod07	Stressing of Switches and Crossings	1	07.09.2026
NR/L2/TRK/3011/Mod08	Mod 08 – Stress Restoration	1	07.09.2026
NR/L2/TRK/3011/Mod09	Stressing of Structural Adjustment Joints	1	07.09.2026

Module 7 for S&C including a new section for NR60 MK2

The system takes some of the features of NR60 (Mark 1) S&C and incorporates them, along with other enhancements, into a design that can be used as a compatible (geometric footprint) replacement for existing CEN56 Shallow Depth S&C layouts (UIC54B / NR56V).

The stock rail through the moveable length of the switch should be considered as a fixed point as the stock rail is anchored to the bearers at the drive locations through this section of the track. When stressing, care needs to be taken to plan the stressing either side of the moveable length so that the stock rails stay aligned and square to each other.

The joints between the heel of the switch rails and the closure rails to the crossing shall not be welded until after the remainder of the S&C has been stressed and the switch toe creep monitors have been correctly set.



NR60 MK2

NR60 Mk2 S&C is designed with no transfer of stress between the switch and stock rail and the closure rails at the heel of the switches are installed without the need for stressing. Any compressive, buckling forces in unstressed lengths of rail behind the switch heel with be countered by the increased lateral resistance of the long bearers and additional rails secured to the bearers increasing lateral resistance.

In NR60 Mark 2 layouts with switch to creep monitors, thermal force “ramps up” along the closure rails from the toe towards the crossing. As there is no stress transfer blocks restraint between the switch and stock rails the thermal force during high rail temperatures in the closure rails will push the switches towards the toe.

Full details of NR60 Mark 2 geometries including turnout radii and maximum speeds, toe to heel and toe to crossing dimensions are detailed on RE/PW 4299.

Switch Details												
Switch Type	Natural angle 1 in	Turnout speed mph (kph)	Length of planing P	Planing radius R1	Switch radius R2	Toe to origin of switch curve T	Lead length Toe to IP L2	Heel offset H	Toe to heel L1	Heel angle 1 in	Entry angle 1 in	Toe tangent width W
B	8	20 (30)	3 527	234 000	184 398	1 624	21 336	0	0	0	78	
C*	9.25	25 (40)	4 464	242 326	247 563	1 807	24 879	344	11 378	19	145	
D	10.75	30 (50)	5 237	370 500	332 382	1 680	29 172	295	12 316	24	150	
E	15	45 (70)	7 426	710 000	646 468	2 222	40 828	345	18 893	31	224	
F	18	50 (85)	9 976	930 598	930 598	1 600	50 060	239	19 499	44	291	5.5
SG	20.25	60 (95)	11 394	1 177 597	1 177 597	1 628	56 490	234	21 867	50	362	4.5
G	23.5	70 (110)	13 445	1 585 675	1 585 675	1 666	65 779	230	25 341	59	476	3.5
H	32.365	90 (150)	17 805	3 007 023	3 007 023	3 004	89 884	292	38 901	72	500	6

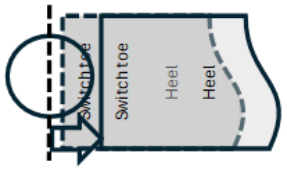
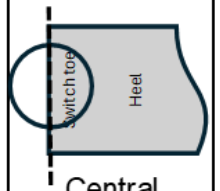
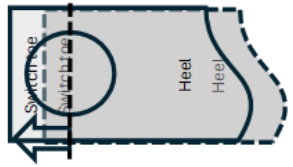
NR60 MK2

On NR60 Mk2 switches, there will be greater movement at the toe creep monitor for the same temperature because of the additional moveable length of the switch is monitored at the toe as opposed to the heel with (Ball and Claw).

Switch / Stock rail squareness at the toes shall be installed in line with NR/L3/TRK/4004. Stocks and toes shall be square to within +/-5mm. Initial set up and adjustment can significantly impact future performance.

The ideal alignment should be that switch toes should be square and approximately aligned with the centre of the hole when in service at between 27 to 30°C.

Table 2 – Switch Rail Alignment Position - NR60 Mark 2

Switch Toe at back of hole = +11mm			Switch Installation Temperature (°C)										
Switch Toe at front of hole = -11mm			0	5	10	15	20	25 to 30	35	40	45	50	55
Switch Designation	Crossing Angle	Lead Length (m)	 Behind the centre of the hole mm					 Central	 In front of the centre of the hole mm				
NR60C	9.5	25	9	7	6	4	2	Centre	2	3	4	6	7
NR60D	8.25	26	9	7	6	4	2	Centre	2	3	4	6	7
	11	29	10	8	7	5	2	Centre	2	3	5	7	8
	12.5	30	10	9	7	5	2	Centre	2	3	5	7	9

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RailEI
Formerly known as the PWI
RAILWAY ENGINEERING INSTITUTION

Many Thanks For Opportunity To Present

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