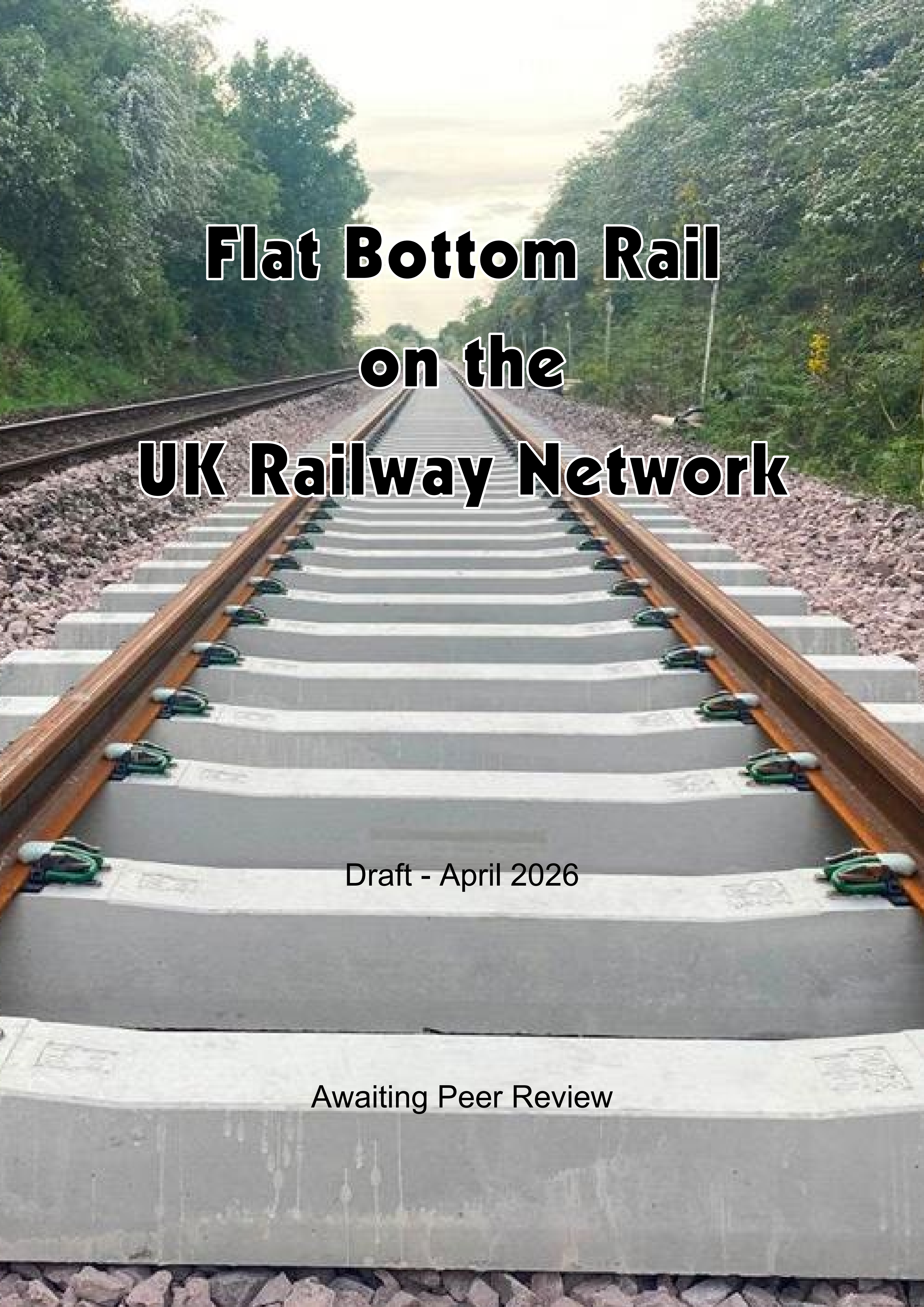

Flat Bottom Rail on the UK Railway Network

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Awaiting Peer Review

Abstract

This article traces the development of flat bottom (Vignole) rail on the British main-line railway network from the earliest pre-nationalisation experiments in the mid-1930s through to the present Network Rail CEN60 (NR60) standard. It examines the successive British Standard rail profiles — BS11-98, BS11-109, BS11-110A, BS11-113A — and their equivalent metric and European designations and describes in detail the changes to plain-line fastenings, sleeper and bearer technology, and Switches and Crossings (S&C) geometry that accompanied each transition. Particular attention is paid to the distinction between inclined and vertical S&C formations, the evolution of full-depth and shallow-depth (asymmetric) switch designs, crossing technology from fixed fabricated vees to weldable manganese cast crossings and swing nose crossings, and the Railtrack/Network Rail CEN60 era. Throughout, the implications for the fine-scale modeller — especially those working to P4 and S4 standards — are highlighted, since accurate representation of the correct formation for a given period and location is central to the fidelity of any layout depicting the post-1948 railway.

1. Introduction: Why Flat Bottom Rail?

The main-line railway track of Britain before the Second World War was characterised, almost uniquely among the world's major railway nations, by the exclusive use of bullhead rail seated in cast-iron chairs. While flat bottom rail — also known as Vignole rail, after Charles Vignoles, the civil engineer who popularised it in the 1830s — had become the international standard everywhere from continental Europe to North America, British railway companies clung to the bullhead system with considerable tenacity. Understanding why the change finally came, and how it unfolded over several decades, requires an appreciation of the technical, economic, and institutional factors that had entrenched bullhead practice so deeply in British railway culture.

Bullhead rail evolved from the even earlier 'double-headed' rail, which had been conceived in the belief that, once the upper running surface was worn, the rail could be turned over and its foot used as a second running surface. In practice, this was rarely successful: chair impressions and corrosion rendered the underside unsuitable for re-use. Nevertheless, the shape of the section persisted, modified so that the head was made larger than the foot — hence 'bullhead' — and the rail secured in cast-iron chairs with wooden keys (or, in later practice, steel keys). The system was codified by British Standard BS 9 (published 1905, revised 1924), which defined two standard sections: BS95R for main lines and BS85 for branch and secondary use.

The weaknesses of the bullhead system were well understood by railway engineers. The wooden keys that locked the rail into its chairs required constant attention; they worked loose under traffic, fell out, and — particularly in wet weather — could allow the rail to roll in its chair, disturbing gauge. The maintenance burden was significant. Flat bottom rail, by contrast, presented its broad foot directly to a baseplate, enabling much simpler and more robust fastenings. Its resistance to overturning under lateral load was inherently greater, and its section modulus — governing bending stiffness — was superior for a given weight per yard. As train speeds and axle loads increased during the 1930s, the case for flat bottom rail became increasingly compelling.

There were also fundamental reasons why the change had been delayed. Bullhead rail is easier to manufacture: the near-symmetry of head and foot sections results in more even cooling after rolling, reducing the tendency of the hot rail to warp. The degree of process control and the straightening technology needed to produce consistently straight flat bottom rail of high quality was not perfected until well into the twentieth century. Furthermore, the entire British railway infrastructure — chairs, keys, sleepers — was designed around bullhead, and the capital cost of change was enormous. The Southern Railway, pre-occupied with its electrification programme, made no moves towards flat bottom at all before nationalisation. The Great Western, proud of its established practices, showed limited interest. It was left to the London, Midland and Scottish Railway (LMS) and the London and North Eastern Railway (LNER) to take the first serious steps.

2. Pre-Nationalisation Experiments: 1936–1947

Flat bottom rail to British Standard sections had been available commercially for considerably longer than is generally appreciated, and small quantities had been used in industrial sidings and on light railways, but main-line use was essentially unknown in Britain until the 1930s. The LMS was the pioneer. In 1936, the company laid the first of several lengths of main line using BS 110 flat bottom rail — a section weighing 110 lb per yard — on a trial basis. Some lengths of American 131 lb rail were also evaluated during this period, but the heavier section was found too stiff and wasteful of metal for British conditions, and the trials were not pursued.

The LNER followed the LMS example in 1939, and the virtues of the flat bottom system became increasingly apparent as both companies accumulated service experience. There were, however, shortcomings with the BS 110 section: in particular, the geometry of the rail head was not entirely satisfactory in terms of wheel-rail interaction, and the web was considered marginal for the loads anticipated on post-war main lines. An improved standard was therefore developed, raising the weight to 113 lb per yard; this 113 lb section informed the subsequent post-nationalisation decision-making.

A significant milestone was reached in January 1944 when the LNER laid the first flat bottom turnout in a British main line. This event, occurring in wartime conditions when materials economy was paramount, demonstrated that the entire S&C system — switches, crossings, baseplates, and timbers — could be designed around flat bottom rail, and pointed the way for the standardisation that would follow nationalisation four years later. The GWR and Southern Railway took no equivalent steps; both entered the nationalised era as exclusively bullhead railways.

It should be noted that the choice between bullhead and flat bottom was not, at this stage, simply a matter of modernity versus tradition. On lightly used secondary routes and sidings, bullhead rail was perfectly adequate, its maintenance demands manageable with the labour available, and its lower initial cost attractive when renewals were infrequent. The shift to flat bottom was driven primarily by the demands of the busiest main lines — higher speeds, heavier axle loads, and increasing train frequency — where the superior rigidity and the opportunity for improved fastening systems offered real engineering and economic advantages.

3. Nationalisation and Standardisation: The 1948 Decision

3.1 The Transport Act and the Formation of British Railways

The Transport Act of 1947 brought the four main-line companies — the LMS, LNER, GWR, and Southern Railway — under unified public ownership as British Railways (BR) from 1 January 1948. The formation of a single national operator created, for the first time, both the opportunity and the imperative to standardise the permanent way across a network previously governed by the divergent practices of four independent companies. In February 1949, British Railways announced its decision: the standard rail section for new main-line construction and renewals would be 109 lb per yard, to be known as BS11-109. A lighter section of 98 lb per yard, designated BS11-98, was adopted for branch lines and sidings. Both designations follow the convention of the British Standard number (BS11) followed by the weight in pounds per yard.

The decision to standardise on flat bottom rail rather than on an improved bullhead section was not made lightly. Bullhead track was still widespread across large parts of the network, and enormous quantities of bullhead materials were held in stock or in service. The decision reflected the engineering consensus that, for the main lines on which the future growth of the railway would depend, flat bottom offered decisive advantages: greater stiffness for a given weight, simpler and more reliable fastenings, better resistance to lateral spreading, and lower long-term maintenance costs. In 1954 — a useful benchmark — bullhead rail was used on 449 miles of new track while flat bottom accounted for 923 miles, illustrating the rapid rate at which the new standard was taking over.

3.2 The Initial Rail Profiles: BS11-98 and BS11-109

The BS11-109 profile was designed specifically for British conditions and differed in important respects from the pre-war BS110 section that had been used experimentally. The most significant difference was the head: the 110 lb pre-war section had a relatively flat head profile, whereas the new 109 lb section incorporated a rail head with a slightly convex crown. The foot width was 139.70 mm and the overall height 158.75 mm. The head width was 69.85 mm. These dimensions placed the section broadly in line with the European UIC54 (54 kg/m) profile that was then becoming standard on continental railways, although the two sections were not dimensionally identical.

The BS11-98 section, intended for secondary and light-traffic duties, was lighter in all respects: height 142.88 mm, foot width 139.70 mm. Like the 109 section, it was mounted on inclined baseplates so that the rail was canted inwards at 1 in 20, matching the coning of the wheel tyre — a practice carried over from the bullhead tradition, in which the chair itself provided the inclination.

Table 1: Comparative Data — British Flat Bottom Rail Profiles (selected)

Designation	Period (approx.)	Weight lb/yd	Weight kg/m	Height (mm)	Foot Width (mm)	Head Width (mm)	Notes
BS11-98	1948 onwards	98	48.9	142.88	139.70	69.85	Branch/siding use; inclined mounting
BS11-109	1949–1959	109	54.4	158.75	139.70	69.85	First main-line BR standard; flat head crown
BS110 (pre-war)	1936–1948	110	54.7	158.75	152.40	73.03	LMS/LNER trials; wider foot; not BR standard
BS11-110A	1959–c.1968	110	54.7	158.75	139.70	69.85	Head sides inclined 1:20; matched UIC54 profile
BS11-113A	c.1968–2000s	113	56.4	158.75	139.70	69.85	Thicker web; became CEN56E1 under EN13674-1
CEN56E1 (BS113A)	1990s–present	113	56.4	158.75	139.70	69.85	European designation; same physical section
CEN60 / 60E1 (UIC60)	c.2000–present	121	60.2	172.0	150.0	72.0	Taller, stiffer; incompatible with standard sleepers

3.3 Initial Plain-Line Track Construction

At the time of nationalisation, all plain line was jointed, with a standard panel length of 60 feet. The rail was secured to the sleeper by baseplates — a significant departure from the bullhead chair system — and the baseplates themselves were fixed by elastic spikes. Two baseplates dominated early BR practice. The BR1 baseplate used a single elastic spike on the outside of the rail and two on the inside; the BR2 used a 'Macbeth' hooped spike on each side. Both are relatively straightforward in form and are readily found today on surviving sections of secondary and tertiary route, since many hundreds of miles of track were laid with these fittings between 1948 and the late 1950s. The BR3 was a variant developed for the third-rail electrified Southern Region lines, where working with spikes adjacent to the live rail was hazardous; it incorporated a lip to retain the outer edge of the running rail, with a single baseplate screw on the outside and two elastic spikes inside.

All three of these initial baseplates mounted the rail at an inclination of 1 in 20 towards the track centreline, continuing the practice established with bullhead track. This had the practical effect of presenting the rail head at an angle that broadly matched the conical tread profile of the wheel, improving the steering characteristics of the rolling stock. It also meant, as will be discussed later, that the switch rail design for S&C needed to accommodate this inclination in the design of the slide baseplate.

4. Plain-Line Development: 1948 to c.1968

4.1 The Transition to Continuously Welded Rail

The most significant single development in British plain-line track engineering during the 1950s and early 1960s was the introduction of Continuously Welded Rail (CWR). The logic was straightforward: the bulk of track maintenance work on jointed track takes place at the joints, and the elimination of joints would dramatically reduce maintenance requirements and improve ride quality. The fundamental engineering challenge — that welded rail, unable to expand freely with temperature, would generate very large compressive forces in summer (potentially causing buckling, or 'sun kink') or tensile forces in winter (potentially causing rail fracture) — was addressed by 'stressing' the rail at a predetermined 'neutral temperature' during installation, so that tension and compression forces were balanced across the expected temperature range.

Early experimental CWR was installed by British Railways in the late 1950s. A notable milestone was the laying of the first long-welded rail of nearly one mile in length on the East Coast Main Line just south of Carlton-on-Trent in 1957, resting on rubber pads to resist rail creep. At this pioneering stage, several design errors were made — primarily related to the adequacy of lateral restraint — and some catastrophic buckling failures resulted. From about 1968, however, the accumulated learning had been applied, and CWR became a reliable and universal standard for main and secondary route installation. The Thermit aluminothermic site-welding process was approved for use in the UK in 1958 and became the standard method of joining long-welded strings into continuous welded track in the field.

CWR placed entirely new demands on track fastenings. The simple elastic spikes of the BR1 and BR2 baseplates were inadequate to resist the longitudinal forces imposed by thermal stressing and by traffic. Two successive solutions were adopted. The first, introduced from the mid-1950s, was the Mills clip — a spring steel clip located in the baseplate with no facility for tension adjustment. The Mills clip proved prone to corrosion at its lower bearing point, with consequent loss of tension, and was superseded from the mid-1960s by the Pandrol PR clip. The Pandrol system, developed and patented in the 1950s and entering widespread BR use from approximately 1965, used a spring steel clip of characteristic 'e'-shape anchored in a cast housing in the baseplate; it was designated the exclusive BR standard fastening by the late 1960s. The Pandrol PR clip required no threaded fasteners and was effectively a 'fit and forget' solution. Several generations of Pandrol baseplate followed — Pan1, Pan2, Pan6, and Pan8, among others, each distinguished by the arrangement of their bolt fixings — and these can still be found throughout the network today.

The Pandrol 'e' clip, a later evolution of the PR clip using a differently shaped spring that clips into the same or compatible housings, was introduced in subsequent decades and appears on more modern trackwork. The 'Fastclip', another Pandrol product, requires no separate tool for installation and is commonly seen on modern concrete sleeper plain line.

4.2 The Concrete Sleeper Programme

The development of pre-stressed concrete sleepers was closely linked to the CWR programme, since concrete sleepers provided the mass and rigidity needed to resist the thermal forces in welded rail. Wartime timber shortages had already stimulated interest in concrete alternatives; the Great Western Railway had produced concrete 'pot' sleepers (two concrete pads linked by a steel tie rod) as early as the Second World War, primarily for sidings. Full depth monoblock pre-stressed concrete sleepers, following French and German practice, began to be manufactured in Britain from the late 1950s.

The first families of BR pre-stressed concrete sleepers — the F series — were introduced from about 1958 and are identified today by their type numbers (F10, F11, F13, F14, F16, F17, and so on). The earliest examples used proprietary fastenings including the BJB750 screw-in clip (F10/F11), the Dean system (F13/F14, primarily NE Region), and the RN clip (F16/F17, used extensively on the SNCF). All were subsequently updated to carry Pandrol housings. The F23 and F24 families followed in the early 1960s, and the F27 and the ubiquitous F40 — which became the most widely used BR concrete sleeper for main-line CWR — were introduced in subsequent years. The F40, still widespread on the network, uses Pandrol PR or 'e' clips and the NRS1 baseplate, which can accommodate both 113A and UIC60 rail sections.

4.3 The Introduction of BS11-110A (1959)

By 1959 the engineering experience accumulated under BR's flat bottom programme had identified a limitation of the BS11-109 section. The head profile — essentially flat-crowned — was less than ideal for wheel-rail interaction, particularly as continuously welded rail and higher train speeds became more prevalent. The standard was therefore revised to BS11-110A, the suffix 'A' denoting that the sides of the rail head were now inclined outwards at 1 in 20. This gave the head a more convex, 'mushroom' profile that closely matched the European UIC54 specification, facilitating better wheel guidance and a more gradual contact stress distribution. Despite the new designation, the weight per yard remained substantially similar (110 lb), and the foot dimensions were unchanged, so the same baseplates could be used. The change to 110A for all new main-line installations took effect progressively from 1959.

The 110A section also brought a change in the S&C slide baseplate arrangement, as will be described in Section 6. For plain line, however, the transition was relatively straightforward, and the difference between 109 and 110A profiles is largely invisible to the layman: it requires close inspection, or a purpose-made rail profile gauge, to distinguish the two sections on a length of track.

4.4 The Move to BS11-113A and the Foxhall Junction Accident (c.1967–1968)

The next change to the main-line standard — from 110A to 113A — was made in response to concerns about the fatigue performance of the 110A web under the stresses imposed by heavily trafficked CWR. The circumstances that catalysed the change are most clearly associated with the period around 1967. The MMRS technical series, citing contemporary sources, records that the change to BS11-113A (113 lb/yd) was made 'after a serious accident near Didcot which was attributed to a weakness in the central web'. The most significant accident near Didcot in this period was the derailment at Foxhall Junction on 27 September 1967, in which the 09:45 Paddington to Weston-Super-Mare express, diverted to the Down Relief line, passed through two facing crossovers at approximately 70 mph against a permitted maximum of 25 mph. One passenger was killed and 23 were injured. The subsequent investigation, published by the Ministry of Transport in November 1968, examined both the operational and infrastructure factors, and the episode — along with broader concerns about the robustness of the 110A section — contributed to the decision to adopt the stronger 113A profile as the new standard from approximately 1968.

The 113A section differed from its predecessor primarily in having a thicker web — increasing from 16 mm at its thinnest point to approximately 20 mm — and slightly different overall proportions, while retaining the same foot dimensions (139.70 mm wide) and head width (69.85 mm). The result was a stiffer, more resilient section better able to withstand the combined bending and shear stresses of heavily loaded CWR. Importantly, it is essential to distinguish BS11-113A from the pre-war BS113 (used by the LMS and LNER experimentally): these are different sections, the 113 lb/yd weight being the result of a different cross-sectional area. From the 1990s onwards, BS11-113A was re-designated CEN56E1 under the European standard EN13674-1, though the physical section is unchanged. Both designations remain in everyday use within the industry.

5. Switches and Crossings — Nomenclature and Classification

5.1 The Switch and Crossing System: Basic Principles

Before examining the specific history of flat bottom S&C, it is helpful to establish the terminology used in British practice. A turnout consists of four principal elements: the switches (or point blades), the common crossing (the 'vee' or 'frog'), the closure rails that connect them, and the check rails that guide the back of the wheel flange through the crossing gap. In British practice, the switches are described by a letter (A through G, with a supplementary SG between F and G) and the crossing by its angle expressed as '1 in n'. An 'E15' turnout, for example, uses an E-size switch pair and a 1 in 15 crossing angle.

The switch letter defines the length (and hence the radius) of the switch blades. In the British system, inherited from REA (Railway Engineering Association) bullhead practice and carried forward into flat bottom, the letter A denotes the shortest switch (sharpest curvature) and G or H the longest (shallowest). The switch radii associated with each letter vary between the bullhead, 109/110A inclined, 113A vertical, and CEN60 generations of design, reflecting progressive improvements in switch geometry and the introduction of tangential switch geometry for longer blades. The British practice of labelling switches A–G (with additions at both ends for special cases) and describing crossings in '1 in n' notation remains in use today.

Three types of switch planing pattern were used at different periods:

- Straight switch: the blade is straight over its full length; the rail foot is simply cut to a tapered tip. An older and simpler design, rarely used on post-grouping BR main lines in FB rail.
- Semi-curved (or 'curved') switch: the blade is straight only over the planed (tapered) section, curving to the switch radius for the remainder. This is by far the most common type on BR-era flat bottom main-line S&C.
- Undercut switch: the blade is machined to fit under the head of the stock rail, so that the tip of the blade guides the wheel flange before the blade itself carries load. Common in bullhead practice and carried over into 109lb flat bottom; discontinued for 110A and subsequent sections.

Additionally, in the 110A era, a 'chamfered' pattern was introduced: the blade is machined with a chamfer on its top edge to provide a gradual wheel transition. This pattern required a specific machining operation and is associated with the 110A generation of turnouts.

6. S&C Design: The Inclined Formations (109 lb and 110A, 1949–c.1970)

6.1 The 109 lb Turnout Family

Following the nationalisation announcement of February 1949, British Railways developed a complete range of S&C in 109 lb flat bottom rail. The design philosophy was strongly influenced by the existing REA semi-curved bullhead practice — indeed, the switch geometry for the 109-turnout family was essentially inherited from the bullhead tradition, with the P&C (Points and Crossings) drawings modified to accommodate the flat foot of the new rail section. The nomenclature of the switches — A through F, each with a specific planing length and radius — was retained.

However, the 109 lb section presented a challenge at the switch toe that had no equivalent in bullhead practice: the broad flat foot of the FB switch rail needed to pass beneath (or alongside) the equally broad foot of the inclined stock rail. With the stock rail canted inwards at 1 in 20, the gap between the underside of the stock rail foot and the baseplate surface was slightly greater on the gage side than on the field side, and this was used to accommodate the switch blade foot. The P slide baseplate, used with both 109 and 110A rail, incorporated a stepped surface — flat under the switch blade foot and inclined under the stock rail foot — with the foot of the switch rail being physically trimmed away (undercut) on its underside at the toe to clear the stock rail foot. This undercutting of the foot was necessary at the fine tip of the switch blade and was progressively reduced as the blade thickened along its length. It was a characteristic feature of 109 lb turnout manufacture.

Similarly, the initial 109 S&C design used only semi-curved switches with straight planing (i.e. the switch blade was straight over the tapered section, then curved). Fully curved blades — in which the curvature extends from near the toe — were not initially available for the stiffer flat bottom section (the A size switch, requiring the tightest curvature, was not available in 109 because the section was too stiff to form the tight radius), and the range started effectively at B size. In practice, BR also specified that B6 was the minimum standard turnout for main-line use.

The common crossing for the 109 turnout family had a nose width of 5/8 inch (approximately 16 mm), slightly narrower than the 3/4 inch (19 mm) used in the equivalent bullhead crossing — a direct consequence of the different foot geometry of the FB vee rail.

6.2 Changes with 110A Rail — The PX Baseplate

The introduction of 110A rail in 1959 brought a significant change to the S&C slide baseplate design. The foot of the 110A section was, in all three dimensions, essentially the same as the 109 sections, but the engineering assessment was that the foot was now too substantial at the switch toe for trimming (undercutting) to be carried out without unacceptably weakening the blade. British Railways therefore discontinued the practice of undercutting the switch rail foot entirely when 110A was introduced and designed a new slide baseplate — the PX — to accommodate the change.

The PX baseplate still incorporated the stepped surface that was characteristic of inclined S&C (one level for the stock rail, a lower level for the blade foot at the toe of the switch), but the blade was no longer undercut; instead, the blade foot was allowed to bear on the lower stepped face of the PX baseplate without any machining to its underside. This required a very slightly different geometry at the toe of the switch and a different relationship between stock rail and blade at the point of zero gap, but the overall appearance of the switch area was similar to that of the 109 design.

With 110A, a third planing option became available: the 'chamfered' blade (in addition to the original straight and curved types), involving a top-edge chamfer. Curved switches (with the blade curved to the switch radius over its full length beyond the planing) became standard for all sizes from B upwards. The P baseplate was used for stock rail fixing with both 109 and 110A sections; the PX was specific to 110A.

It is worth noting for modellers that distinguishing between 109 and 110A S&C visually is essentially impossible without close inspection of the blade tip or knowledge of the baseplate type. Both are inclined systems, both use semi-curved switches of similar letter designations, and both share the same broad family of timber bearer spacings and crossing angles.

6.3 Key Visual Characteristics of Inclined FB S&C

For those seeking to model flat bottom S&C from the period 1949 to approximately 1970, the following characteristics define the inclined formation:

- Rail is inclined 1 in 20 towards track centre on the plain-line baseplates (BR1, BR2) and on the running-rail fixing areas of the S&C layout.
- A distinct step is visible on the slide baseplate between the level of the stock rail foot and the level of the switch blade foot at the switch toe.
- The standard fastening on earlier (pre-mid-1960s) S&C layouts is the ST baseplate with bolted saddle clip or KT clip arrangement; later layouts use Pandrol PR clips.
- Timber bearers of standard cross-section (nominally 12 × 8.5 inches, or metric equivalent).
- Common crossings are fabricated (built-up from rail components); cast manganese crossings were not standard on BR until later.
- Adjustment switches (sometimes called expansion switches) were used at the interface between CWR and S&C, mounted on S&C timbers.

7. The Vertical S&C Formation (113A): A New Paradigm

7.1 Rationale for Vertical Rail in S&C

The adoption of BS11-113A as the new main-line rail standard from approximately 1968 brought with it a complete redesign of the S&C range. The decision to move from an inclined to a vertical rail orientation in the 113A S&C formation was driven by several engineering considerations. First, the thicker foot of the 113A section — though nominally the same width as the 110A foot — was more difficult to accommodate on the stepped surface of a P or PX slide baseplate while maintaining the 1 in 20 inclination, since the geometry of the blade-stock interface had become increasingly complex. Second, mounting both the stock rail and the switch blade vertically on a single flat surface simplified the slide baseplate considerably: the stepped profile was eliminated, replaced by a single horizontal face bearing both rails. Third, the wider bearing surface available to the vertical rail foot improved the stability of the rail in the lateral direction.

The consequential change at the interface between vertical S&C and the inclined plain line on either side was managed using 'twist rails' — short rail lengths in which the foot inclination was gradually twisted from the inclined plain-line angle to the vertical. These appear in the RE/PW drawing register as 'twist rails' and are in the approach and departure zones of S&C layouts, typically over two or three bearer spacings. In the field, they are identified by the transition from ordinary inclined plain-line baseplates to baseplates marked with the letter 'V' (for vertical), signifying that the rail is held vertically. The PAN V (cast iron baseplate V, drawing RE/PW/605) became the standard fastening for vertical S&C, and is a distinctive component of 113A-era layouts. The PAN V baseplate accepts the full width of the 113A foot on a single flat horizontal surface, and uses a Pandrol PR clip (or, later, a PR401 clip) for restraint.

7.2 The 113A Switch Range: Full-Depth (Vignole) Switches

The switch range for 113A vertical S&C was built around the same A–G letter system, retaining continuity of nomenclature with earlier generations. However, the radii associated with each letter were revised, and the full set of 'vertical' drawings (RE/PW/600 to RE/PW/613 and subsequent entries) replaced their inclined predecessors. Key aspects of the 113A vertical switch design were:

- Fully curved switch blades became standard throughout the range; the choice of straight-planed or straight-cut blades that had characterised 109 and 110A practice was largely eliminated for main-line work.
- The switch blade was no longer undercut and was no longer chamfered; the tip was machined in the 'straight-cut' or 'Vignole' manner, the full depth of the section being retained throughout the blade length. This is referred to as a 'full depth' or 'Vignole' switch.
- The flat horizontal slide baseplate surface accommodated both stock rail and switch blade without any step, simplifying manufacture and maintenance.
- The RE/PW drawing series for vertical switches ran from AV (A-size, vertical) through BV, CV, DV, EV (all using 'secant' or intersecting geometry, in which the stock rail divergence angle is set by the switch geometry alone), to FV, SG V (Special G), GV (longer tangential designs), and the HV switch for the longest (most gentle) applications.

7.3 Full-Depth Versus Shallow-Depth (Asymmetric) Switches

As the 113A vertical system matured and as continuously welded S&C became standard, a new requirement emerged from the operational experience of the network. Full-depth switches — in which the switch blade retains the full rail section depth throughout its length — were found to generate significant impact loads at the blade tip when wheels traversed in the trailing (blade-open) direction, because the tip of a full-depth blade presents a relatively blunt transition to the wheel. On heavily trafficked routes, this contributed to accelerated wear and damage to switch rails, particularly under trailing movements.

The solution, adopted by Network Rail from the 1990s onwards, was the 'shallow depth' or 'asymmetric' switch. In an asymmetric switch, the switch blade is machined from a specially rolled asymmetric rail section (designated, in the European system, 54E1A1 for 113A/CEN56 rail) in which the top of the head is at the same height as the stock rail head, but the overall depth of the blade section is less than a standard rail — hence 'shallow-depth'. The blade is thicker through the body of its section (giving it greater strength and resistance to bending) while the reduced total height means that the wheel transition from stock rail to blade is smoother, with a smaller vertical step at the tip. The asymmetric section has a large, battered face on one side and a reduced web depth.

Shallow-depth switches were introduced as part of the 113A vertical range and are identified in the drawing register by the specific roll of the blade section. They became standard for longer switches (EV size and larger) on the CEN56 (113A) vertical formation and are specified for all NR60 Mk2 (CEN60) layouts. The 'piggyback' fastening pad — a supplementary plate fitted to the stock rail baseplate to provide support for the shallower blade at the toe of the switch — is characteristic of layouts using shallow-depth switches sharper than an F design on NR60 geometry and provides a useful field identification feature.

The advantages of shallow-depth switches over full-depth in service are significant: reduced peak dynamic loads at the blade tip, lower rates of rail head damage, reduced risk of blade breakout under trailing wheel strikes, and — on high-speed routes — a measurably smoother ride for passengers.

7.4 Crossing Design in the 113A Era

The crossing (vee or frog) in 113A vertical turnouts evolved substantially from the simple fabricated crossings of the 109 and 110A generations. Initially, fabricated ('point and splice') crossings — built up from standard rail components — remained in use, but concerns about the fatigue life of such crossings under increasing traffic loads led to the adoption of cast manganese steel crossings as standard for main-line applications. Manganese steel, because of its work-hardening characteristics, offers significantly longer life under the repeated impact loading at the crossing nose than the carbon steel of a fabricated crossing. Explosive Depth Hardening (EDH) — a post-manufacturing process in which a controlled explosion on the railhead induces deep compressive residual stresses, greatly improving fatigue resistance — was introduced as a further treatment for cast manganese crossings and became standard for Network Rail high-traffic crossings.

The weldable manganese cast centre block (CCB) crossing, in which the body of the crossing is cast in manganese steel, but wing rails are welded on to standard rail sections, is the current Network Rail standard for CEN56 (113A) and CEN60 layouts. It allows full CWR welding continuity through the crossing, eliminates the need for jointing fishplates, and provides the best combination of fatigue life and repairability.

For very high-speed or very high-cant-deficiency routes, swing nose crossings (also called movable point crossings) eliminate the gap in the running edge altogether: the nose of the crossing is a movable component that swings to close against the wing rail on the route being traversed, providing continuous wheel support. Swing nose crossings are standard on the NR60 Mk2 G28 and longer (J and I switch) high-speed layouts, and were also used on Railtrack RT60 designs.

8. The Railtrack and Network Rail CEN60 Era (RT60, NR60, NR60 Mk2)

8.1 The Impetus for Change to CEN60

By the early 1990s, the limitations of the CEN56 (113A) vertical design were becoming apparent. The European Union's Railway Interoperability Directive was progressively requiring member states to adopt common standards, and the UIC60 (CEN60, 60E1) rail section — at 60 kg/m significantly heavier, taller (172 mm versus 158.75 mm), and stiffer than the 113A section — had established itself as the standard for high-speed rail throughout Europe. Network expansion plans, and the increasing desire to raise line speeds, particularly on the West Coast Main Line, created a direct incentive for the UK to adopt CEN60 for new S&C on its principal routes. The CEN60 rail section is incompatible with standard 113A sleepers (the increased height of the web means different bearing surfaces), and its introduction therefore required a completely new suite of S&C drawings, components, and bearers.

Between approximately 1996 and 2002, under the Railtrack era, four manufacturers developed competing RT60 S&C design systems — Edgar Allen, Balfour Beatty, Corus Cogifer, and VAE — all to a common geometry and crossing footprint specification. Despite sharing overall geometry, these systems had manufacturer-specific components, creating supply-chain complications and difficulties in like-for-like replacement. The RT60 generation used inclined running rails (reverting to the 1 in 20 cant of the pre-113A era), a 650 mm nominal bearer spacing (compared with 710 mm for CEN56 vertical layouts) and permitted higher cant deficiency on the diverging route.

8.2 NR60 Mk1 (2005–2017)

After Network Rail assumed control of the infrastructure from Railtrack in 2002, it rationalised the competing RT60 designs by adopting the Edgar Allen version as the basis for a standardised Network Rail product: the NR60 S&C range, introduced in 2005–2006. The Pandrol e-clip fastening system was adopted as the standard for NR60, and the Hy-drive hydraulic point operating equipment (POE) became the standard drive. The NR60 Mk1 switch range covered B through G designs, with 'secant' (intersecting) geometry for shorter switches and 'clothoid' transition curves specified for longer ones. The clothoid geometry of Mk1 switches was later found to create switch entry angle problems and was abandoned for Mk2.

NR60 Mk1 brought considerable performance improvements over CEN56 vertical in terms of ride quality, crossing life, and wheel-rail interaction, but it also introduced challenges: the unit cost was 15–25% higher than CEN56 equivalents, and the geometry footprint differed slightly from the CEN56 vertical standard, creating complications at transition zones. Crossing issues — particularly fatigue cracking at the base of the crossing — remained a concern that was not fully resolved until Mk2.

8.3 NR60 Mk2 (2017 onwards)

The NR60 Mk2 programme, developed from 2017 and entering regular service from 2019–2020, addressed the known limitations of Mk1. Its key features reflect lessons learned from service experience:

- Geometry: Switch geometry is now compatible with CEN56 Vertical (NR56V) layouts, with secant geometry for B through E switches and tangential geometry for F and longer switches — removing the clothoid and its associated entry angle issues.
- Shallow-depth switch blades throughout, machined from the asymmetric CEN60A1 roll section.
- Points Operating Equipment: the In-Bearer Clamplock Mk3 (IBCL Mk3) is standard for B–E switches, with the Hy-drive supplementary drive for longer switches; a tubular supplementary drive is used for additional reliability.
- Modular bearer joints with Vossloh NG screws and green inserts (rather than conventional bolted joints), reducing relative movement and bearer cracking.
- Switch toe position indicators — a hole in the stock rail — replacing the 'ball and claw' mechanism of Mk1.
- Improved crossing profile with a lower dip angle at the wheel load transfer point, significantly reducing impact forces and noise — qualitatively described by Network Rail engineers as making the crossing 'almost invisible' on track quality measurement traces.
- EDH pre-hardened castings as standard; the improved crossing profile combined with EDH has produced notably longer crossing life at pilot sites such as Thirsk (ECML, 125 mph), operational since April 2017.

Future developments in the NR60 Mk2 programme include higher-speed turnout variants: a 100 mph I switch and a 125 mph J switch (the latter partly funded by HS2 for use on connecting links), and extended double-junction layouts incorporating NR60 Mk2 switch diamonds.

9. Identification Summary: Which Formation, When?

A recurring challenge for the fine-scale modeller is identifying the correct formation to represent for a given period and location. The following table provides a broad guide, though it must be emphasised that the British railway's long tradition of recycling sub-life-expired materials, and the extended periods over which renewals took place, mean that considerable variety co-existed at any given period. A single signal box might have been associated with five different types of CWR sleeper, two or three turnout constructions, and several fastening systems — all within a mile and a half of railway — as Colin Craig memorably documented at Abergavenny Junction.

Table 2: Guide to Flat Bottom Track Formation by Period

Period (approx.)	Plain Line Rail	S&C Rail	S&C Type	Sleeper / Bearer	Key Fastening	Notes
1949–1959	BS11-109 (jointed, 60ft panels)	109 lb FB	Inclined; P slide baseplate; undercut blades	Timber; later early concrete	BR1/BR2 elastic spikes	Also some BS11-98 on secondary lines; rare A switches
1959–c.1968	BS11-110A (jointed then CWR)	110A FB	Inclined; PX slide baseplate; no undercutting	Timber then concrete (F10–F27 families)	Mills clip then Pandrol PR	CWR expanding from late 1950s; chamfered blades available
c.1968–c.1985	BS11-113A (CWR standard)	113A FB	Vertical; PAN V baseplate; full-depth blades	Concrete (F27, F40); timber on secondary	Pandrol PR / e-clip	Vertical S&C drawings RE/PW 600 series
c.1985–2005	BS113A / CEN56E1	CEN56E1 (= 113A)	Vertical; shallow-depth blades (longer types)	F40, 5F40 concrete; steel bearers in S&C	Pandrol e-clip	EDH manganese crossings standard; ST strengthened S&C
2005–present	CEN56E1 or CEN60 (60E1)	NR60 (CEN60)	Inclined; 650mm bearer spacing; asymmetric blades	Concrete bearers; steel hollow bearers at crossing	Pandrol e-Plus / Fastclip	Mk1 2005, Mk2 from 2017; swing nose crossings on G+ sizes

10. Relevance to P4 and S4 Modelling

For members of the Scalefour Society modelling to P4 or S4 standards — where the objective is accurate representation of the prototype at full scale — the history described in this article has direct practical implications. The choice of rail section, fastening system, baseplate type, sleeper form, and S&C geometry is a defining element of the period and location portrayed, and errors in any of these areas are immediately apparent to the informed observer.

Several points deserve particular emphasis:

- A layout depicting the nationalisation period (late 1948 to early 1950s) would show mixed infrastructure: flat bottom main line on new 109 lb jointed track alongside surviving bullhead in sidings, loops, and secondary routes. This mixing is historically correct and need not be apologised for.
- S&C from 1949 to the mid-1960s is inclined, with stepped slide baseplates and either trimmed (109 lb) or untrimmed (110A) blade feet. Both types have the stock rail and switch blade at different heights on the slide baseplate — the 'step' being a visual distinguishing feature from later vertical formations.
- The 113A vertical formation, from approximately 1968, is characterised by the flat horizontal slide baseplate surface, the PAN V casting (a distinctive trapezoidal component), and vertically standing rail throughout the S&C area. The transition zones — where rail changes from inclined to vertical — include the distinctive 'twist rails' and V-type baseplates.
- For those modelling the current-day main line, the NR60 range uses inclined rail (returning to the 1 in 20 cant), taller CEN60 rail, and shallow-depth switch blades throughout. The bearer spacing is 650 mm rather than the 710 mm of CEN56 vertical layouts, which subtly affects the visual rhythm of the trackwork.
- The Templot track geometry software, widely used by Scalefour Society members, encodes the geometry of the BR flat bottom switch range (A–G, vertical and inclined variants) with considerable accuracy; users should select the appropriate switch type for the period being modelled. For 113A vertical turnouts, users should note that the RE/PW drawings series (specifically the 600 series) is the authoritative source of switch dimensions and planing profiles.
- A new software is being developed by the Author specifically to support the modelling of post 1968 Flat Bottom trackwork and encodes the relevant track geometry and period specific bearers and baseplates.

In terms of available commercial rail sections, the C&L Finescale range has for many years offered code 82 rail as a close approximation to BS11-109 (head width 0.92 mm at 4 mm scale). The difference between 109 and 110A in the rail head profile is essentially undetectable at 4 mm scale, and both sections may be considered represented by the same commercial section.

The distinction between 109/110A and 113A is similarly marginal in scale representation, though the slightly different head profile of 113A (with a distinctly more rounded crown) may be of interest to those who wish to be fully precise. Suitable BS113A rail is of course now supplied by the Scalefour Society.

For UIC60, the deeper section would require a taller-section commercial rail, though at 4 mm scale the difference in visible rail height is of the order of 0.5 mm — technically significant but visually subtle except at very close range.

11. Conclusions

The history of flat bottom rail on the British main-line railway is a story of progressive engineering refinement driven by the twin imperatives of safety and economy. From the early LMS and LNER experiments of the mid-1930s to the current NR60 Mk2 system, the underlying trajectory is consistent: heavier, stiffer rail sections, more reliable fastenings, better concrete sleeper and bearer technology, and S&C designs that impose lower impact forces on track and rolling stock while offering longer service lives. The shift from inclined to vertical S&C with the 113A section, and the subsequent return to inclined geometry with CEN60, reflects both the learning that accumulated from operational experience and the influence of European harmonisation.

For the Scalefour Society modeller, the practical significance lies in the rich variety of track formations that have coexisted on the British network at different periods — a variety that rewards careful observation and accurate modelling. A main-line running connection dating from the 1960s may still be in service in the 2020s, its 110A inclined geometry preserved alongside newer CEN56 or CEN60 plain line.

The 'recycling ethos' of the railway, combined with the long service lives of well-maintained S&C, means that the full spectrum of flat bottom formations described in this article can, in principle, be found on the national network today.

That is both the challenge and the fascination of modelling the post-1948 British railway in fine scale.

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Recommended Further Reading (Books)

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A Note on Sources and Accuracy

This article has been compiled primarily from publicly available technical sources, forum discussions by practising and former permanent way engineers, the RE/PW drawing index, and Network Rail engineering presentations. Wherever possible, dates and technical specifications have been cross-referenced between sources. Some uncertainty remains around the precise dates of transition between rail sections and S&C generations, since the British practice of extended renewals programmes means that 'introduction' dates and 'universal adoption' dates could be decades apart.

Readers who have access to original BR departmental circulars, the successive editions of 'British Railway Track', or RE/PW drawings are encouraged to verify specific technical details against those primary sources, and any corrections from those with direct professional knowledge of the permanent way are gratefully welcomed.