



Turnout Geometry

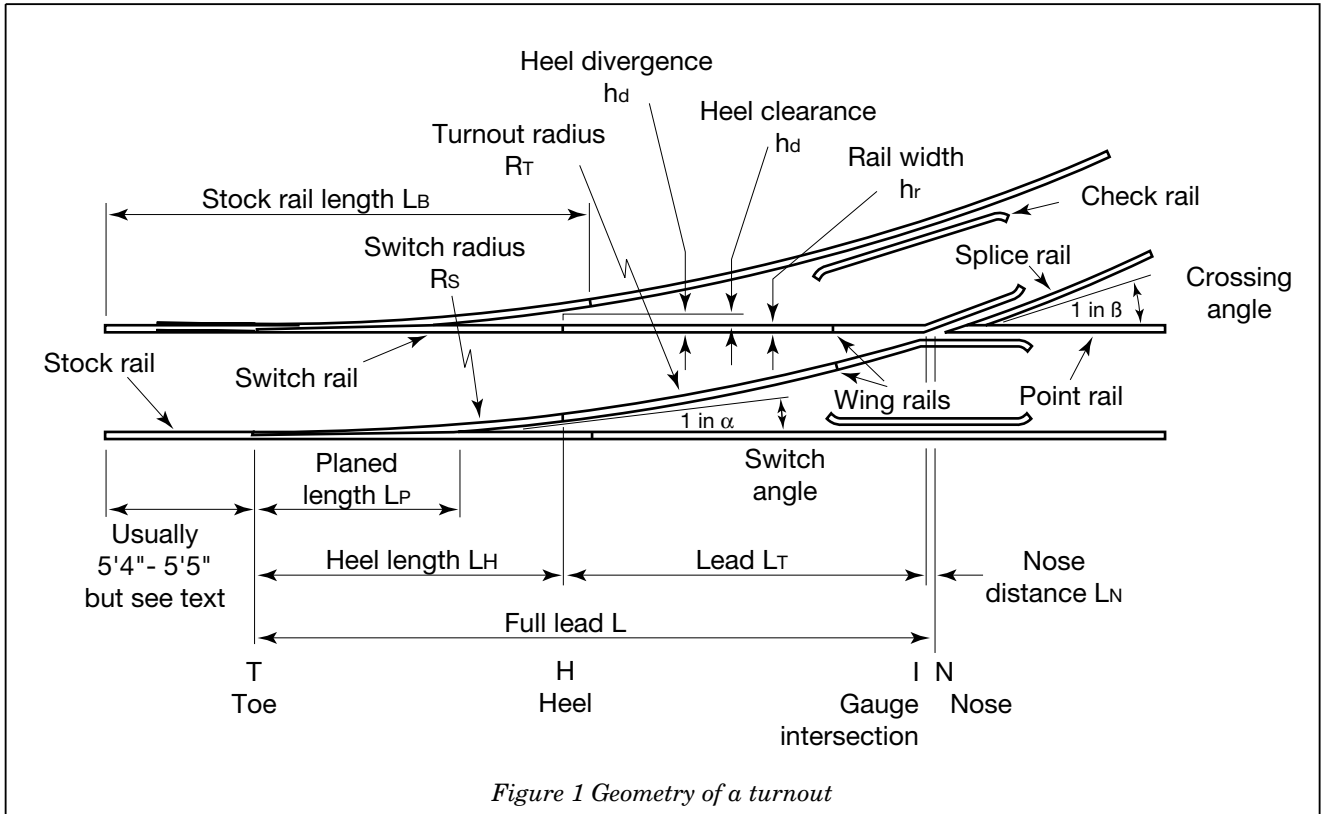


Figure 1 Geometry of a turnout

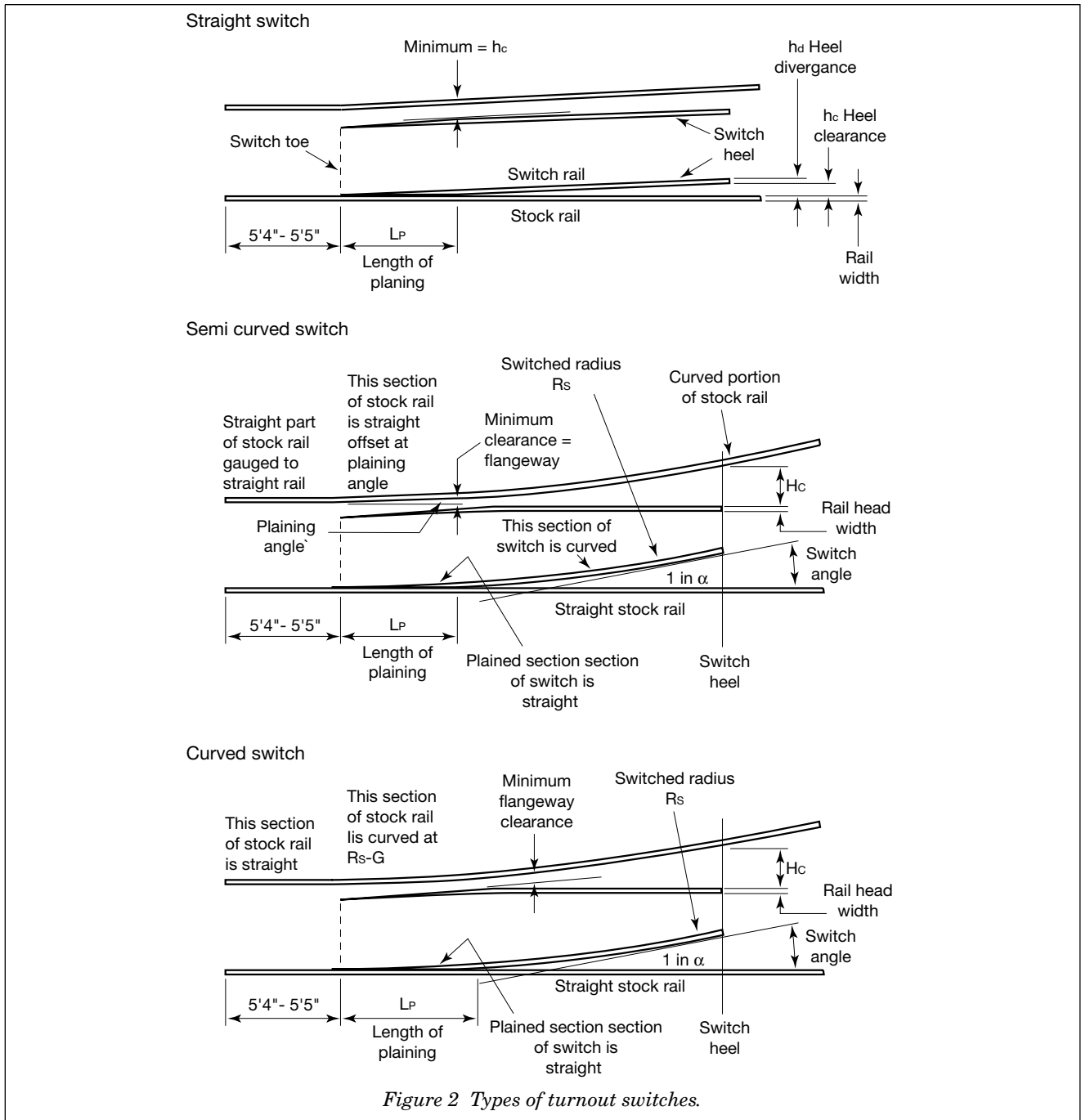
1 General

The terms used in 'Point and Crossing Work' are illustrated in Figure 1 and defined in the table below.

Note in particular that there are two definitions that include the term "Lead". Throughout this work, the definition of "Lead", symbol L_T , is the distance between the **Switch Heel** and the Intersection of the **Gauge Lines**. The other definition, symbol L , is the distance from the **Switch Toe** to the **Nose** of the crossing and is

referred to as the "**Full Lead**". The omission of the word "Full" can often cause confusion. The "**Switch Heel**" is the point about which the switch blade theoretically pivots; this may be a true pivot or merely a point at which the switch blade becomes free to bend. The location of the heel is determined by the amount of clearance required by wheels passing along the Stock Rail when the Switch Blade is open. The complete list of symbols is as follows:-

SYMBOL	DEFINITION	DESCRIPTION
L	Full lead	Toe T to crossing nose N.
L_T	Lead	Heel H to gauge intersection I.
L_H	Heel length	Toe T to heel H.
L_N	Nose distance	Gauge intersection to crossing nose N.
L_P	Planned length	Toe T to end of switch planing P.
L_B	Stock rail length	Between joints with plain line.
L_S	Switch rail length	Toe T to closure rail joint.
h_r	Rail head width	
h_c	Heel clearance	Distance between adjacent faces of stock & switch rails.
h_d	Heel divergence	Distance between running faces of stock and switch rails.
R_s	Switch radius	Radius of curved portion of switch.
R_T	Turnout radius	Radius of turnout (closure rail) curve.
α	Switch angle	Between stock and tangent to switch heel.
β	Crossing angle	Between gauge lines at intersection I.



2 Switch Types

There were three types of traditional switch, although modern developments are creating variants. They are the straight switch, the semi-curved switch and the curved switch. See Figure 2.

2.1 Straight switch

Note: the term "Straight" refers to the appearance of the whole switch blade, and should not be confused with the term "Straight Cut" which defines the cross section of the planed area of the switch blade, see Figure 4.

This type was used by most of the pre-grouping companies. Three variants (see Figure 3) for pivoting it exist, of which the most popular was the **Tongue Switch**. Here the fishplate by which the switch blade is attached to the Closure Rail provides the pivot. In the **Heel Switch**, the blade meets its closure rail in a Heel Chair that permits it to pivot while preventing it from sliding out. This type was not in common use in bullhead track but is met in some FB track using a Heel Block. The **Spring Switch** was a later development, in which the switch rail is secured in one or more chairs

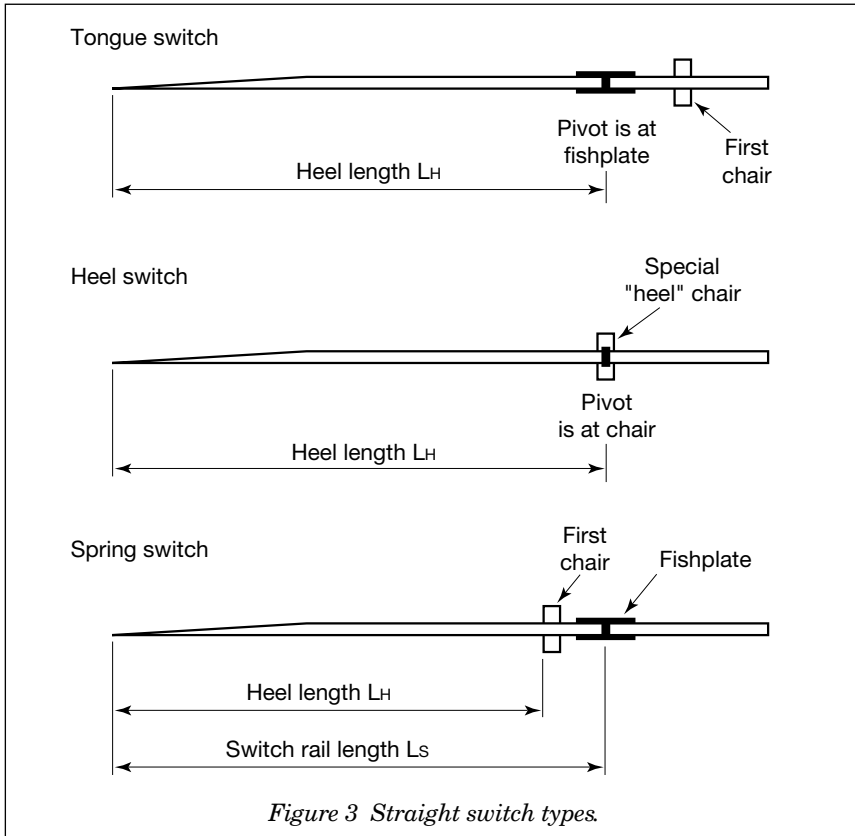


Figure 3 Straight switch types.

before the joint with the closure rail and therefore the heel length L_H is less than the switch rail length L_S . In some installations, the switch rail began to curve in these chairs and thus became an ancestor of the semi-curved switch. On main railways, the straight switch only existed in "bullhead" form, although there are "flat bottom" installations in industrial sidings and light railways.

Straight switch sizes are in heel lengths of 6, 9, 12, 15, 18, 24 and 30 feet, although the shorter ones are too rigid to be used as "spring" switches.

2.2 Semi-curved switch

This type began to be used after 1923 by the LPTB and all the mainline companies except the GWR. The blade is straight for the length of the planing, after which it curves at the nominal radius of the turnout, to the point at which it is joined to its closure rail. These switches were always of the sprung type and so L_S exceeded the **Heel Length**, L_H by at least 2ft 6in. Semi-curved switches were designated A, B, C, D, E and F and largely superseded the 9, 12, 15, 18, 24 and 30 feet straight switches respectively. A "flat bottom" version exists in all but "A" size.

2.3 Curved switch

This was used by the GWR instead of the semi-curved switch. In this type the entire switch was curved from toe to heel. They were designated B, C and D, and corresponded to the semi-curved switches of the same designation. A, E and F sizes were not used. For its long leads the GWR used a 30ft straight switch. British Railways used all six sizes in "flat bottom" form, albeit with slightly different geometry. More complex forms with transition curvature and planing are in current use to accommodate the higher speeds of today.

3 Switch Profiles

3.1 Straight-cut switch

This term, often confused with the "Straight Switch" does not refer to the switch geometry, but to the vertical profile of the switch planing as viewed looking on the toe. (Figure 4) The switch rail is planed to a thickness of 0.375in at the toe and, in order to avoid entry shock at a facing point, the stock rail is joggled also by 0.375in. A later development is to

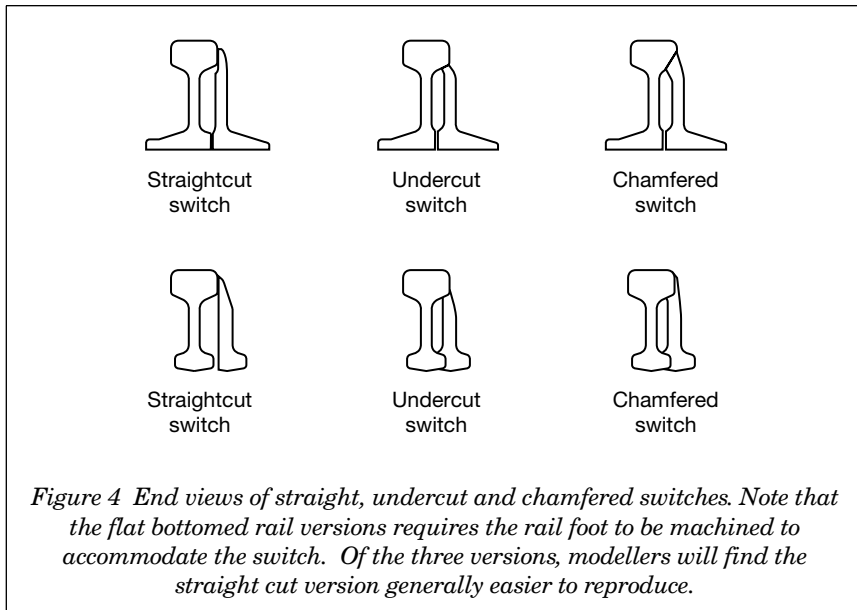
plane the switch toe to 0.75in and then chamfer the top 2.5in down to 0.375in. Flat bottom rail has too much lateral stiffness to joggle and a housing is usually machined in the stockrail instead.

3.2 Undercut and chamfered switches

Another principal type of switch end profile is the "Undercut", in which the switch toe is planed down to a fine edge at the top, the 0.75in thickness being attained lower down by the switch rail fitting under the head of the stock rail. More recently, both switch and stock rail are being chamfered to provide greater strength at the toe. (Figure 4)

All three profiles are used for bullhead rail, but flat bottom switches are usually undercut or chamfered.

Generally, the straight cut profile is the easiest for the modeller, using only hand tools, to produce. Many joggles to house the switch, particularly in bullhead track, are overdone, thereby spoiling the appearance of the trackwork and some may prefer to file a tapered housing in the stock rail to correspond with the planing of the switch rail as for flat bottom track.



4 Types of Turnouts

There are three types of turnout relevant to curved and semi-curved switches, namely 'natural', 'compound' and 'natural plus straight'. A natural turnout is one where the turnout radius R_T and switch radius R_s are equal. A compound turnout is one where R_T is less than R_s . A natural plus straight turnout has R_T equal to R_s , but has a length of straight inserted between the end of the turnout curve and the gauge intersection to increase the lead. Despite what many modellers believe, in the majority of cases the turnout curve continued through the crossing. A straight crossing is easier for the model suppliers to produce and for the modeller to set out, but those who do attempt a curved crossing will be rewarded with track work that flows more readily.

Turnouts with curved and semi-curved switches are designated by combining the switch type with the crossing angle, i.e. B8 is a B switch and a 1 in 8 crossing, similarly A7, C12 etc.

For straight switches, there were several suitable crossing angles for each switch, typical examples being shown at Figure 2-8 on page 2-2-7. Although this represents North British Railway track, that of other companies was not significantly different. Even so, those wishing to model a specific prototype and period are recommended to study works covering the subject in greater detail than is possible here.

5 Compromises

With the exception of Scale 7, where the only compromises are due to minor differences in railhead width compared with the prototype, there are significant geometrical variations between model and prototype. Depending on the standards adopted these prevent strict adherence to scaled down versions of full sized pointwork.

Both Fine and Coarse standards are under scale gauge by 1mm. As a result, a turnout curve equating to a prototypical radius will generate an incorrect crossing angle and to maintain the 'correct' radius, the crossing angle would have to be altered. It is more practical to use the prototypical angle and change the turnout radius and this is the recommended method upon which the accompanying calculations and tables have been based.

The straight switch presents particular difficulties. Its prototype heel clearance, h_c , cannot be less than flangeway clearance which is, prototypically, $1\frac{3}{4}$ in.. This equates to 1.02mm in Scale 7 but for Fine standard the value has to be increased to 1.75mm and for Coarse standard to 2.2mm. This increases the heel

divergence and changes the switch angle, spring of the turnout curve and turnout radius for a given crossing angle. The effect is increased further when the wider code 200 bullhead or code 220 flat-bottomed rail is used for Coarse standard trackwork. To illustrate the problem, in Scale 7, a 6ft straight switch deflects an approaching vehicle though 3.6° (1 in 16) at the toe, while in Fine standard the deflection is 4.6° (1 in 12.5). For Coarse standard with a railhead width of 1.6mm the angle is 5.2° (1 in 11) and this rises to 6.2° (1 in 9) if the 2.35mm wide code 200/220 rail is used. This would have such an effect both on smooth running through the turnout and on its appearance that some straight switches cannot be recommended although data has been given for those who wish to use them.

It is significant that ready made pointwork supplied in earlier times for Coarse standard and using the heavy section rail, approximated to fully curved switches, thereby giving a smoother run through the formation.

For curved and semi-curved switches, the heel clearance exceeds the minimum flangeway for both Fine and Coarse standards where a rail head width of 1.6mm is used, and can be used satisfactorily, but B semi-curved and GWR fully curved bull head switches can give problems of flangeway clearance when 2.35mm wide rail is used due to its greater rigidity.

Restrictions on space generally prevent most modellers from using all but the shortest switches and crossing angles. (To keep the data sheet tables within bounds the longest turnout listed is a B8, which has a closure rail radius of about 4270mm or 14ft). Once the basic design of a layout has been completed the types of turnouts required can be determined. This can be done by measuring the crossing angle and selecting a suitable pair of switches from the range suggested in Table 1 opposite. Table 2, on page 6, covers the range of switches in greater detail.



DATA SHEET

TURNOUT GEOMETRY

Compiled by M. Holland

**Table 1
Recommended blade and crossing angle combinations**

Switch type	Crossing angle β			
	Scale Seven *	0 Fine *	0 Coarse *	0 Coarse **
6ft Straight	3 to 5½	3 to 5 ‡		
9ft Straight	4½ to 7	3½ to 6	3½ to 5 ‡	
12ft Straight	6 to 8	4½ to 7	4½ to 7	3½ to 6 ‡
15ft Straight	7½ upwards	6 to 8	5 to 7½	4½ to 7
A - all types	4 to 7	4 to 7	4 to 7	4 to 7
B - all types	6 to 8	6 to 8	6 to 8	6 to 8 §

* Assuming either code 124 bullhead rail or code 143 flat bottomed rail, having a rail head width (h_r) of 1.6mm.

** Assuming either code 200 bullhead rail or code 220 flat bottomed rail, having a rail head width (h_r) of 2.35mm.

‡ These switches have a significant angle of deflection at the toe and should only be used where limited space prevents the use of longer turnouts. (See 5, Compromises)

§ See note opposite re clearance problems with B switches.

6 Other Data Sheets

The layouts of the various switch types are detailed in Data Sheets D2.2.2.1, 2 and 3.

The suitability of the chosen combination of switch and crossing angle can be checked with the Turnout Curve Tables on Data Sheets D2.2.3.1/2/3/4 that show the overall length and turnout (closure rail) radius. The figures from these tables can then be used to produce drawings as described in Part 2, Section 2.5.

Crossing information is listed on Data Sheets D2.2.4, Common Crossings and D2.2.5, Obtuse Crossings.

Timbering information is listed on Data Sheet D2.2.6.

7 Sources of information

Information on prototype practice:

A Century of Permanent Way	B land	1927
Railway Theory and Practice	Hepworth & Lee	1922
GWR Standard Permanent Way Practice	Bowler	1923
GWR Switch and Crossing Practice	David L. Smith	2002
Check Rails & Chairs	LNER Chief Engineers Dept	1945
British Railways Track (1st Edition)	Permanent Way Inst.	1943
British Railways Track (3rd Edition)	Permanent Way Inst.	1964
British Railways Track (6th Edition)	Permanent Way Inst.	1993
BRT. Flat Bottom Track Supplement	Heeler	1951
Track Design Manual	British Railways Board	1974

(now incorporated in the Industry Standards System)

For the best pictures of real pointwork, with some complex combinations, from 1900 to 1940:

Great Eastern In Town and Country I	Hawkins	1990
Great Eastern in Town and Country II	Hawkins	1991
Great Eastern in Town and Country III	Hawkins	1997

An alternative guide intended for 4mm scale but with much information suitable for all modelling scales:

An Approach to Building Finescale Track in 4mm	Rice	1991
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Many articles on track and point-work have appeared in the model railway magazines, most being listed In the Magazine Digest section of this Manual. Other useful articles have appeared in magazines dealing with the prototype for which no easily accessible general index is available. A visit to the National Railway Museum or a good city library will usually be helpful to those hunting for precise Information. For computer users, with the growth of the Internet, information of this nature can often be found on specialist web sites.

Table 2
Switch lengths and heel divergence details

Switch type	Scale Seven * Rail head 1.6mm			0 Fine * Rail head 1.6mm			0 Coarse * Rail head 1.6mm			0 Coarse ** Rail head 2.35mm		
	LH	β	hd	LH	β	hd	LH	β	hd	LH	β	hd
6ft Straight	42	16	2.62	42	12.6	3.35		Note 1				
9ft Straight	63	24	2.62	63	19	3.35	63	16.6	3.80			
12ft Straight	84	32	2.62	84	25.3	3.35	84	22.1	3.80	84	18.5	4.55
15ft Straight	105	40	2.62	105	31.6	3.35	105	27.6	3.80	105	28.1	4.55
A semi curved	140	13.96	7.33	140	13.96	7.33	140	13.96	7.33	140	13.96	7.33
A semi-curved (SR) Note 2	132.4	14.36	6.82	132.4	14.36	6.82	132.4	14.36	6.82	132.4	14.36	6.82
B semi-curved Note 3	157.5	17.84	6.23	157.5	17.84	6.23	157.5	17.84	6.23			
B semi-curved (SR) Note 2	150	18.43	5.83	150	18.43	5.83	150	18.43	5.83			
B semi-curved (FB rail)	189	15.77	8.12	189	15.77	8.12	189	15.77	8.12	189	15.77	8.12
A fully curved (FB rail)	172	13.24	8.61	172	13.24	8.61	172	13.24	8.61	172	13.24	8.61
B fully curved (FB rail)	206.5	15.77	8.12	206.5	15.77	8.12	206.5	15.77	8.12	206.5	15.77	8.12
B fully curved (GWR) Note 3	157.5	19.01	5.83	157.5	19.01	5.83	157.5	19.01	5.83			

- Note:** 1) Although the 6ft straight switch has been included for 0 Fine, the 9ft switch for 0 Coarse * and the 12ft for 0 Coarse **, the use of these cannot be recommended in other than exceptional circumstances due to significant angular deflection at the toe. Any such use should be restricted to sidings traversed at low speed.
- 2) Southern Railway semi-curved bull head switches of A and B size differ slightly in that the heel divergence, Hd, is measured at the last chair instead of the end of the switch rail, i.e. 1ft 1in before the joint with the closure rail. Consequently the values for heel divergence and switch angle are slightly different. The switch rail lengths are still 20ft (140mm) and 22ft 6in (157.5mm) respectively but the measured heel length, LH, is shorter by 7.6mm, while the lead Lt is increased by the same amount.
- 3) The B semi-curved bullhead and B fully curved GWR switches cannot be recommended in 0 Coarse (**), i.e. Code 200 rail, where the rigidity of the rail is likely to lead to inadequate clearance between switch rail and stock rail at the 'pinch point'.