GAUGE WIDENING IN P4

It's well known that P4 track gauge is 18.83mm. Not so widely known, especially for beginners, is what is the tolerance of the gauge? - in other words, what is the margin of error allowed in the likely event of imperfections in our track laying?

A brief look at the Track and Wheel Standards does make the answer clear: 18.83 is the *minimum*, for *maximum* "see GW". The separate GW column gives the easily overlooked and for beginners somewhat mysterious incantation:

Gauge Widening 0.22mm max @ 528mm radius.

Dimension	4′ 8½″ gauge	
	min.	max.
TG Track gauge	18.83*	see GW
GW Gauge widening (at 528mm radius)	--	0.22

So what is that all about?

On the real railway, on sharp curves the gauge of the track is widened by a tiny amount. The sharper the curve, the more the widening.

Why? Basically, to ease the passage of vehicles through the curve. The Permanent Way Institute puts it like this:

MOVEMENT OF VEHICLES ON CURVES.

The movement of a train of railway vehicles or of only one vehicle on a curve introduces many very complex problems.

There are for instance wheels of many different sizes, tyres of different stages of wear, and vehicles of various wheel bases or distance between axles. The amount of 'play' in the axle boxes is also subject to considerable variation.

In recent years a great improvement has been made in the reduction of the length of rigid wheel bases of passenger vehicles by the substitution of bogie trucks. Steam locomotives are now generally the vehicles with the longest rigid wheel bases, but it is usual to thin out or remove altogether the flanges of the middle wheels where the total wheel base is long.

When a bogie truck or any vehicle with two parallel axles is on the straight it can be assumed that the flanges are both clear of the rails and central between them as in Fig. 128.

FIG. 128.

When the tangent point is passed the truck continues in a straight line until the flange of the leading outside wheel rubs against the side of the rail, as in Fig. 129. It continues to bear against the rail for the whole length of the curve, and is therefore running on a tread which is slightly larger in diameter than that of the inside leading wheel, owing to the coning of the wheels.

FIG. 129.

If this axle could adjust itself to be always radial to the curve, and if the effect of the coning exactly compensated for

the difference in length of the inside and outside rails, the axle would run smoothly round the curve and there would be no tendency to slip.

Actually, however, neither of these conditions can be realised and slipping between the tyre and rail has to take place.

In making up the difference in length of the rails, the inside wheel must slide backwards or the outside wheel must slide forwards along the rail. It is possible also that both wheels may slip, but it is fairly certain that if one starts to slip, it will continue to do so.

In addition to this slipping along the rail there must be slipping across the rail in keeping the front axle always at right angles to the line of motion.

If the radius of the curve is sharpened a stage will be reached when the flanges on both axles begin to touch the rails and the curve is then of the minimum radius to accommodate the vehicle.

In the case of six-wheeled vehicles, the middle axle is usually given lateral play or the flanges are thinned off so that they can run over curves sharper than would otherwise be the case.

It will be clear that wear of flanges will ease the passage of a vehicle round curves as it has the effect of increasing the play, and, similarly, widening of the gauge has the same effect. Also the easier the passage of a vehicle on a curve the less will be the wear and tear on both vehicles and track.

It is, therefore, common practice to widen gauge on sharp curves, i.e. those of less than about 10 chains radius.

On curves of between 10 and 7 chains radius the gauge should be widened by ¼″, on those of radius between 7 and 5½ chains the gauge should be widened by ½″, and on those below 5½ chains the gauge should be widened by ¾″.

One chain is 66 feet. In 4mm scale those numbers become: 1/4” at 10 chains = 0.08mm at 2640mm or 8ft 7 inches; 1/2” at 7 chains = 0.16mm at 1848mm or 6ft 0 inches; and ¾” at 5.5 chains = 0.25mm at 1452mm or 4ft 9 inches.

Nowadays on Network Rail there are 5 increments of widening, to a smaller maximum two thirds of an inch.

Thus we have a prototypical excuse for up to plus 0.25mm tolerance. But note that there is no minus tolerance! 18.83 is the *minimum* track gauge.

Ah ha you may say - the figure in the Standard quoted above is 0.22 not 0.25mm! Well of course in practice this difference is pretty much meaningless. So please, just forget that discrepancy for now till I try to explain later.

On a model railway, if the fit of the wheels between the rails was exactly the same (in scale) this gauge widening on curves probably would be equally desirable. However it is only the case in S4 that the wheels fit between the rails exactly as does the prototype.

P4 was designed back in the 1960s to be able to cater for sharper more model railway like curves, the norm in those days. In P4 we have an amount more slop between wheels and rails because the wheels are more than 0.1mm closer together than in S4, and the flangeways of points are 0.1mm wider - a scarcely visible difference. Thus about half the prototypical widening (or 'easing') of the track on curves is catered for by the wheels being 0.1ish closer together. Nevertheless from the beginning gauge widening was built into the specification of P4 track. Given typical model railway curves the need for it could still arise at the then typical smaller radii.

A pukka approach would see us, as per the prototype, knowing exactly the radius of each curve and widening it the appropriate amount. It is perfectly possible to do this, and this invaluably useful set of track gauges made by C&L are available, though in the rather more practical increments of 18.83, +0.1, +0.2, +0.3mm.

However, a much easier way of doing it was thought up many years ago, originally for 00 gauge. I think most people reading this will understand that a rectangular block of metal 18.83mm wide and, say 30mm long, will fit between the rails when they are straight, but on a curve will only fit by pushing the rails slightly further apart.   As the curve sharpens, the more the rails will separate, not in steps like the prototype, but in a gradual and continuously progressive manner.

Thus a rectangular (or triangular) track gauge will give automatic gauge widening (the triangle must be the right way up!) - the only question being how long it should be? This will be determined by how much the maximum widening should be, and at what radius that should occur, using the versine calculation.

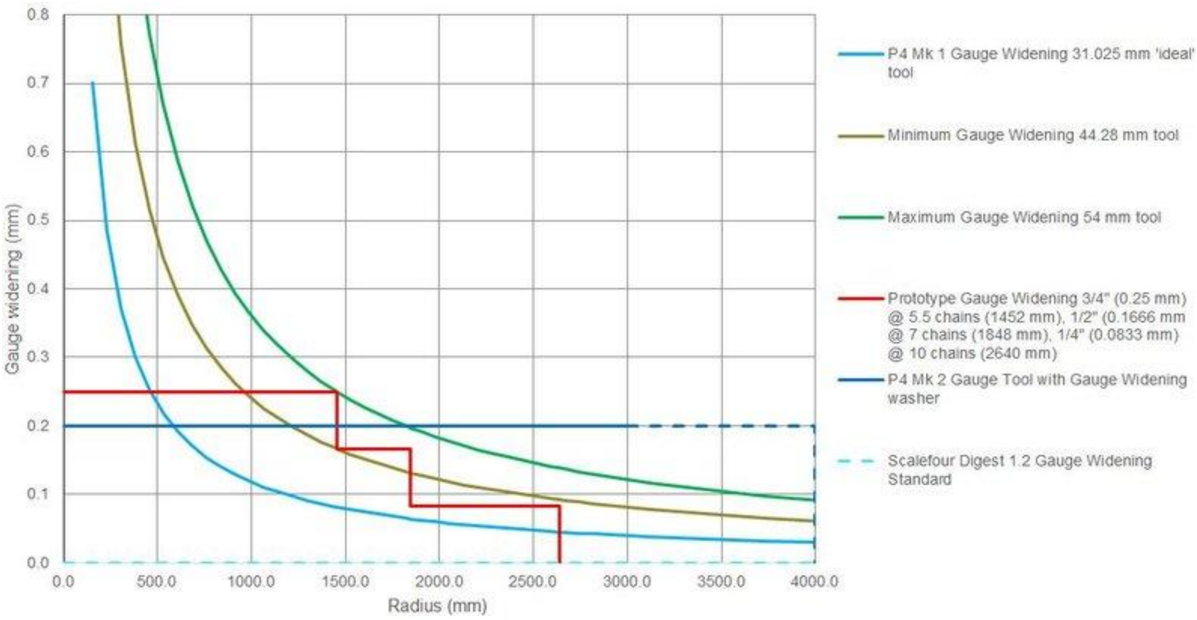
The answer to that question at the inception of P4 in 1967 was to keep pretty much the same length as the tool that had already been designed for 00 and EM, around 30mm, which gave a bit of widening at the then accepted minimum reasonable radius of 1ft 9ins, which equates to 2 chains. This (in theory at least) gives in P4 an adequate widening of 0.22 at that radius. Here is an original Studiolith triangular gauge:

Although few of us make models to go round that sort of curve, and the general advice nowadays is to keep to a minimum radius of 4ft, this formula has been found to work perfectly well for those who make their trains take curves appreciably sharper than the prototype, though it doesn't obviate the necessity that we build in adequate sideplay.

A different approach was introduced after a while in the Protofour days. An 18.83mm roller type track gauge tool (the "much improved" Mk2 Track Gauge) was designed to incorporate a detachable 0.2mm washer. The instruction now became to install the washer for *all curves*, given the fact (it said) that nearly all curves on a model railway are of less than the 10 chains prototype equivalent.

The subtlety of the triangular gauge transition as a curve sharpened was lost, but that was no big issue and the new gauge was probably much easier to manufacture. What the new approach meant was that the widening was quite a bit more than the triangular gauge, and more than the prototype equivalent, except on curves sharper than 5.5 chains or 1452mm. Today this approach is continued in one flexi track product - Exactoscale 18.83 gauge Fast Track is also available in a plus 0.2mm (19.03mm) gauge version for curving track, continuing the same idea as the Mk2 track gauge.

Really these tiny amounts and differences between one type of gauge and another are of little or no significance especially in P4. Below the blue and red lines in the graph illustrate these tiny differences, and a spreadsheet puts the same information in numbers.



Tool length (mm)	Unknown**	44.28*	54	Prototype Gauge Widening
Gauge, G (mm)	18.8300	18.8300	18.8300	
Chord length, c (mm)	31.0250	44.2800	54.2394	
Side length, s (mm)	24.3969	29.0646	33.0159	

*Tool required for 0.1666 mm widening at 1452 mm radius
**Tool required for 0.22 mm widening at 528 mm radius

	Radius, R1		Widening, w			
	ft	mm	mm			
	0.50	152.4	0.7012	1.4254	2.1343	0.2500
	0.75	228.6	0.4858	0.9886	1.4818	0.2500
	1.00	304.8	0.3716	0.7564	1.1343	0.2500
	1.25	381.0	0.3008	0.6125	0.9187	0.2500
	1.50	457.2	0.2527	0.5146	0.7719	0.2500
(1' 8.8")	1.73	528.0	0.2200	0.4480	0.6721	0.2500
	1.75	533.4	0.2178	0.4436	0.6655	0.2500
	2.00	609.6	0.1914	0.3899	0.5849	0.2500
	2.25	685.8	0.1707	0.3477	0.5217	0.2500
	2.50	762.0	0.1541	0.3138	0.4708	0.2500
	2.75	838.2	0.1404	0.2859	0.4290	0.2500
	3.00	914.4	0.1289	0.2626	0.3940	0.2500
	3.25	990.6	0.1192	0.2428	0.3642	0.2500
	3.50	1066.8	0.1108	0.2257	0.3387	0.2500
	3.75	1143.0	0.1036	0.2109	0.3165	0.2500
	4.00	1219.2	0.0972	0.1980	0.2970	0.2500
	4.25	1295.4	0.0915	0.1865	0.2798	0.2500
	4.50	1371.6	0.0865	0.1763	0.2645	0.2500
	4.75	1447.8	0.0820	0.1671	0.2507	0.2500
(4' 9.1")	**4.76**	**1452.0**	**0.0818**	**0.1666**	**0.2500**	0.2500/0.1666
	5.00	1524.0	0.0780	0.1588	0.2383	0.1666
	5.25	1600.2	0.0743	0.1514	0.2271	0.1666
	5.50	1676.4	0.0710	0.1446	0.2169	0.1666
	5.75	1752.6	0.0679	0.1384	0.2076	0.1666
	6.00	1828.8	0.0651	0.1326	0.1990	0.1666
(6' 0.75")	**6.06**	**1848.0**	**0.0644**	**0.1313**	**0.1970**	0.1666/0.0833
	6.25	1905.0	0.0625	0.1274	0.1911	0.0833
	6.50	1981.2	0.0602	0.1225	0.1839	0.0833
	6.75	2057.4	0.0579	0.1180	0.1771	0.0833
	7.00	2133.6	0.0559	0.1139	0.1708	0.0833
	7.25	2209.8	0.0540	0.1100	0.1650	0.0833
	7.50	2286.0	0.0522	0.1063	0.1595	0.0833
	7.75	2362.2	0.0505	0.1029	0.1544	0.0833
	8.00	2438.4	0.0490	0.0997	0.1497	0.0833
	8.25	2514.6	0.0475	0.0967	0.1452	0.0833
	8.50	2590.8	0.0461	0.0939	0.1409	0.0833
(8' 7.9")	**8.66**	**2640.0**	**0.0453**	**0.0922**	**0.1383**	0.0833/0
	8.75	2667.0	0.0448	0.0913	0.1369	0.0000
	9.00	2743.2	0.0436	0.0887	0.1331	0.0000
	9.25	2819.4	0.0424	0.0864	0.1296	0.0000
	10.25	3124.2	0.0383	0.0780	0.1170	0.0000
	11.25	3429.0	0.0349	0.0711	0.1067	0.0000
	12.25	3733.8	0.0321	0.0653	0.0980	0.0000
	13.25	4038.6	0.0297	0.0604	0.0906	0.0000

The most significant aspect of this to me is that what on the prototype is a very sharp curve, 5.5 chains, is a quite ordinary looking curve of 4'9" on the average model railway. Indeed I have found, with fellow club members building a new layout, that it is really quite difficult to lay convincingly smooth gentle curves of a radius greater than 10 chains equivalent, and careful marking out is required, confirming the Protofour comment that nearly all model railway curves are of less than 10 chains radius in scale. The pictures of part of the layout show these curves which, on the main line to the left of the sidings, are some 60 chains radius. Needless to say, gauge widening was not needed - Exactoscale Fast Track normal gauge was used.

It interested me to speculate how long a triangular or rectangular gauge should be to give a widening more equivalent to the prototype. This might be useful for S4 modellers, though perhaps not fully pukka. The answer, I concluded, is roughly 45mm length, (brown on the diagrams above), which meets the prototype minimum widening of 1/2” at 5.5 chains (1452mm), and where the maximum widening of 0.25mm would occur at roughly 3ft. On even sharper curves such a gauge tool would give too much widening in terms of strict prototypical accuracy. The green lines and figures represent a triangular or rectangular tool that meets the prototype maximum widening of ¾” at 5.5 chains (1452mm), and clearly while correct for that radius gives too much widening on sharper curves.

If one thinks hard about these things all kinds of questions present themselves. I am trying here to distil what I know down to what is reasonably certain and adequate information. It can be easy to forget how very tiny the plus tolerance of the track gauge actually is. For example if you look at this magazine with two pages open, as you would normally read it, the width of the two A4 pages together is 420mm. One 226th (that's the number of quarter inches in 4ft 8 and a half inches) of 420 is just under 2mm. So if this open magazine represents the track width the three extra quarter inch increments of prototypical gauge widening would each be slightly less than 2mm, 5.5mm in total. It is so tiny as to be scarcely worth talking about - the three increments, in 4mm scale, are each about the thickness of a human hair! Yet as we probably all know it is this sort of amount that will make all the difference between an interference fit and a sliding or running fit of an axle in a bearing for example.

UNCERTAINTIES

Thus far I've tried to stick to certainties and, I hope, the above is all straightforward and true - as far as I know from 11 years modelling in P4! However there are always interesting points of debate in our Society as we mutually try to get better results.

In view of Roger Sanders recent articles here, where the cause of poor running is ascribed to there being too much slop between wheel flanges and rails in P4, it might be wondered how helpful this article is. Indeed the Scalefour Digest states:

"In P4, where BBmax is less than the 4mm scale equivalent, and where adequate sideplay can usually be given to inner axles, gauge widening should not be necessary unless using long-wheelbase stock around sharp curves."

...how long is "long" and how sharp is "sharp" is, helpfully, not defined!

A similar related issue is that a popular brand of P4 flexitrack is often undergauge by about 0.1mm.

Meanwhile it is often said that what is important is that track should not be undergauge, as per the Standard quoted at the start here.

My own view is that making trains heavy, with all wheels given some sort of suspension, and multi-wheel locos and stock adjusted for weight bias as per my article in SN 199, will have the most effect in keeping them on the track, and that imperfections in Back to Back and Track Gauge become less important. Given this condition the extra slop in P4 gives quite a big margin of error, and making track with the triangular tool, as described in the Protofour instructions, will give completely reliable results, though bought flexitrack 0.1mm undergauge can work adequately on the straight.

However where there cannot be any flexibility is that a Back to Back greater than 17.75mm is outside the Standards and on pointwork the Check Rail will not function in its purpose of keeping the opposite wheel from hitting the crossing V. That derailment does not necessarily ensue is simply a matter of chance, depending on whether the wheel in question on the rail leading to the V has its flange against the rail. To set our wheels to exactly 17.75 takes a high degree of skill and, surely, an optimistic view of Murphy's Law!

GAUGE WIDENING IN PRACTICE

Whether the triangular gauge we buy today gives exactly the theoretical 0.22mm at 528mm widening is debatable. Some people say it is slightly overgauge. The four legged design may change the degree of widening somewhat. What matters is that it works well enough. This I proved to my own satisfaction and not a little surprise, when I made a 2ft radius reverse curve test track using the triangular tool. An 0-6-0T Barclay Tank zipped up and down this track both pulling and propelling a short train of 4 wheel vehicles, including a long wheelbase CCT van, at a good scale 30mph with not the slightest hint of derailing, as you can see for yourself at

http://youtu.be/rPiVz1vDYhQ

There are a few other videos to prove the point, if you search Julian Roberts 600mm curve, for example

https://www.youtube.com/watch?v=WT07OjFIKic

It might in conclusion be instructive to recount the problems the club had with part of the layout referred to earlier, a scenic section of a flowing reverse curve some 4ft 6ins radius, with a short straight section between the curves. Like the rest of the layout, it had been laid with a wellknown brand of flexitrack that was a little undergauge. While much of the layout is relatively straight, on this curving section there were persistent problems of derailment, not with all stock, but with a significant proportion.

On discovering the undergauge problem the first remedy tried was to relay one of the rails of the curve, soldered to screws embedded in the plastic sleepers at regular intervals, with the triangular gauge. At the next exhibition the performance of the newly laid section was disappointing. However as the new section of 60 chain reverse curves made with Exactoscale Fast Track behaved immaculately, we decided to pull up all the track on this troublesome section, and relay it with Exactoscale +0.2 Fast Track for curves. Come the next exhibition outing, we were completely satisfied that the effort had been worthwhile – only one item of stock derailed there the whole weekend .

Does this mean that 0.2mm widening is preferable to using the triangular gauge? Yes, that is a possible conclusion – but I don't think it is wholly proven by this example. In all likelihood the new track, which has good thick sleepers, is much more level and free of twist than the previous adulterated track – quite possibly equally beneficial. One cannot know for sure. I think what this shows, and what this article is trying to show, is that there are not always simple answers: there is more flexibility than we might think in the prototype iron road "permanent way" that we can usefully apply in 4mm scale; that we need to think about what is going on if we get problems, be open minded in searching for solutions, and that we all can learn useful things from each other. Some of us will agree with one recipe and disagree with another. My weight bias recipe mentioned earlier, which I have proven in practice to my satisfaction over ten years on the challenging trackwork of the group layout, received considerable scepticism on the Forum – not from anyone trying it out to see if it worked, but from theorization that it would or could not work. Unfortunately we tend not to be objective, to be suspicious of new different ideas, and equally to be dismissive of old proven ideas that are seen as outmoded, and to be persuaded by a climate of opinion rather than hard facts. Does that remind you of another debate?

What is generally true is that derailments happen when two or more faults that in themselves are not that serious combine. It is the combination that causes the problem and can be difficult to trace. One fault might be on the train, the other on the track.

The greater the number of possibilities of faults and recipes we know about the more likely we are to get to that nirvana, *zero derailments!* – a prerequisite of being able to say "*got it* alright".

[I must acknowledge my son Matthew's invaluable assistance creating the graph and spreadsheet, and the many contributors to the Forum discussion on this subject from whom I learnt much of the above.]