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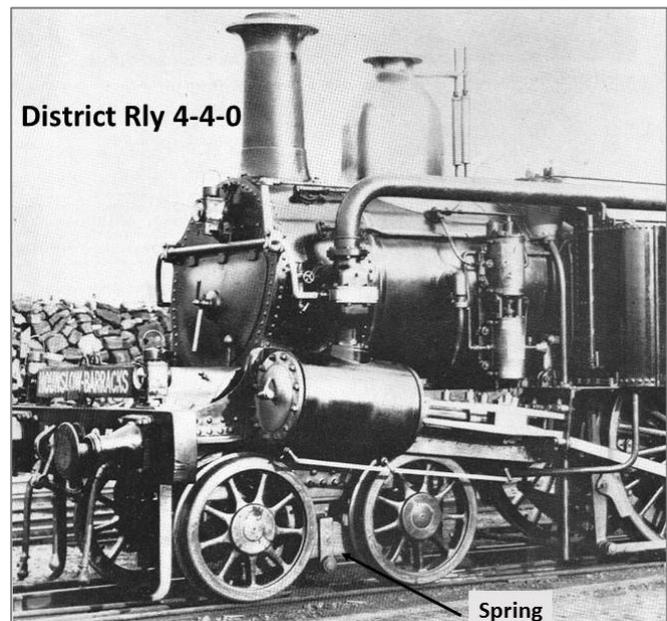
## Locomotive bogies and springing

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Autumn of 2016.

**As we saw some time ago** super-elevation is the practice of raising the outer rail on curves to provide centripetal force and assist the train in following a curved path, but it is difficult to arrange properly on 5" G track due to the variation in speed and type of vehicle. We have the habit of running relatively fast on tight curves: 8 mph in 5" G  $\equiv$  100 mph full size and 50ft radius is equivalent to 8 chains; curves only found in yards and very restricted access lines. Nevertheless, we run big engines round these curves and they do not usually "come off". This is mainly thanks to the cornering force being reduced by scaled-down speed to a much greater extent than it is increased by sharp curvature. Even so a considerable force is exerted on the rails via the overscale flanges and it is comforting to have a correctly loaded bogie at the leading end to guide the engine.

**For most of the 19<sup>th</sup> century** passenger engines had two small carrying wheels at the front, first in the 2-2-2 arrangement and later on as 2-4-0s, although the majority of goods engines had 6 coupled wheels with no guiding axle their speed rarely exceeded 25mph. As locomotive size and speeds increased some designers arranged for the leading axle to turn into the bend, they were known as Radial Axles and were mounted in a curved slide with lateral clearance and centred by springs. When the front of the engine ran into a curve the side thrust on the flanges pushed the whole assembly against the spring and by carefully laying out the design, the swing of the axle was just sufficient for it to remain at right angles to the curved track. The spring softened the sudden blow when entering the bend and transmitted the force sideways to the frame easing the front of the engine into the curve and the radial alignment of the axle had the effect of reducing the friction of the flanges so they were less likely to ride up the rail. One patent design (by Webb) was adopted by several railways and it was perpetuated long enough to be used at the back of a few engines built by BR at Swindon.

**When things got bigger** some locomotives appeared with two leading axles but it quickly became apparent that a four wheel swivelling truck would be more effective as the wheels were tangential to the curve. Like the radial axle, it was provided with side control and so the bogie came into being. Locomotives with experimental leading bogies were tried out in the 1850s but the first extensive use of them in this country was on the Metropolitan Railway 4-4-0T, supplied by Beyer Peacock in 1864 for underground service and based on engines built for a Spanish line a couple of years earlier. At this stage the wheelbase of the bogie was only 4 ft and the whole thing swung about a pivot further back, rather like a 2-wheel truck. The shape of the frames was already established as being a sort of "U" with a central stretcher low down under the smokebox to take the weight and the load was

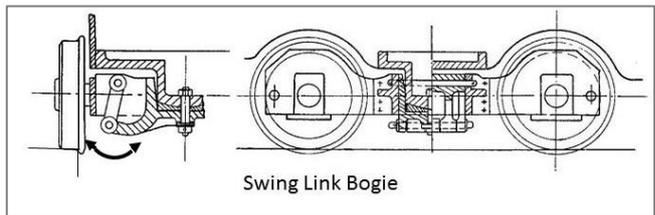


transferred to hangers below the axleboxes through an inverted leaf spring at each side as can be seen in the photo of a similar engine on the District Rly. This arrangement ensured that each wheel carried the same weight since the spring was a flexible equalising beam.

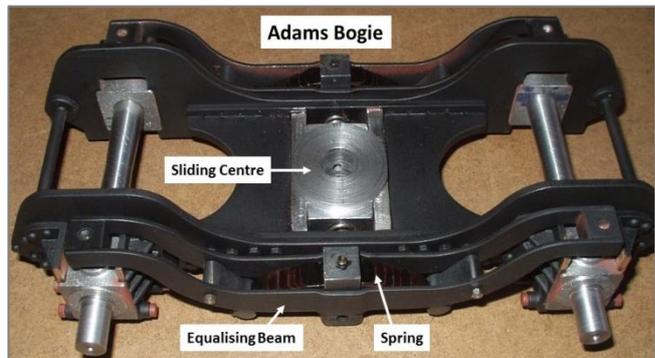
**Bogies were soon given central pins** and longer wheelbases, 6ft or more to reduce the tendency to twist on straight track, and frames followed the original Met Tank U-shape but with a central bolster carrying a sliding block to permit some lateral movement. When the engine runs on to a curve the bogie swivels so as to align itself with the rails and its centre moves to one side applying a lateral force to the engine main frame to start the guiding process. In most designs the sideways movement of the sliding block is resisted by springs that apply force to the pin. The strength of the springing varied according to individual railway companies and different classes of engine, it usually ran to a few tons so the actual movement of the sliding centre was small.

**The spring arrangement was quite critical** as it had a significant effect on the smooth riding of the engine at speed. Some classes were notoriously rough and all sorts of combinations were tried in an attempt to calm things down. Another type of bogie was called Swing Link as the centring force was provided by swinging links instead of springs, the sliding block no longer rested on the bogie centre but instead it carried brackets straddling the centre and extending down to a position below it, these were connected to lugs on the bogie centre by hanging links (see figure). Effectively the front of the engine hung on the links suspended from the bogie centre and when the bogie moved to one side the lower ends swung in an arc with some vertical rise, this pushed up the engine front thereby increasing the load on the bogie as well as providing the force for side control.

**The springing of locomotive bogies** falls into two types, equalised and individually sprung, the original Met. Tank bogie was equalised as the load on each side was divided between the two axleboxes by the inverted spring and this idea was further developed by using a double U-beam straddling a leaf spring. In the case of non-equalised bogies, the load from the bolster was taken directly by the frames and from there it passed to each axlebox through individual springs; the frame was made stronger as it had to withstand carrying the load. It was rather like a miniature well wagon, and as each axle was sprung separately any undulations in rail level caused the loading on each wheel to vary, for example a small "dip" would produce a momentary unloading of a wheel. In the case of the equalised bogie there is no change since the beam always distributes the weight evenly.

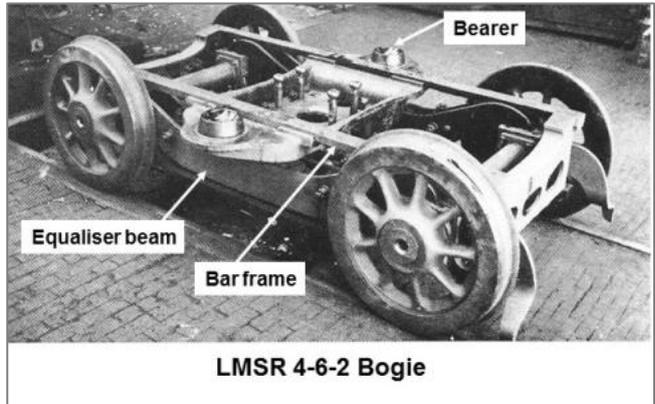


**Perhaps the most commonly used bogie**, and in my opinion the best, was the one invented by William Adams when he was Locomotive Engineer of the GER, it went with him to the LSWR and thereafter it was extensively adopted by other railways. It was equalised as described above with the load transmitted to the axleboxes on each side by a bar resting on top of them that curved down in the middle and the weight was applied by a hanger at each end pulled down by an inverted leaf spring. Luckily this type of bogie is a feature of three 5" G locomotives I have built based on engines of the NBR, LNWR & MR and as the arrangement is not easy to visualise the picture of the Midland bogie may be of some help in understanding how it works.



**By arranging sufficient loading**, 30lbf at least and providing really strong side control they are very steady entering curves at speed. The side control springing needs to be stiff if it is to give the front of the engine a shove into the curve since the displacement of the centre block is relatively small. Consider a typical 5" G 4-6-0 with the bogie centre about 17" ahead of the middle axle: if we assume that the engine frame lies centrally on a straight track with the front already on to a 50 ft radius curve the centre line of the track will lie about 1/4" to one side of the bogie pin, so this small compression of the side control spring must generate a force of many pounds. Strong 3/8" OD springs pre-loaded to about 5lbf seem to work well and the centre block just moves a bit when entering a curve.

**The GWR was different** as it used outside plate-framed bogies with individually sprung axleboxes on Dean's double-framed 4-4-0s, albeit with an unusual arrangement of upward facing centre pin to facilitate removal of the bogie for accessing the underslung steam chest. These continued into the Churchward era but his standard engines were provided with the American bar-framed equalised bogie, an equivalent of the plate-framed Adams bogie, in which the equalising beams straddled each frame and the inverted springs were located in the openings in the frame structure. The axleboxes were central to each frame rather than offset outside as in the Adams type although I doubt whether there was any significant advantage: Stanier brought the bar-frame bogie to the LMS for his 4-6-2s and details can be seen in the photo, but the MR Adams-type bogie continued in use on other classes although one feature was "imported" from Swindon. Churchward's engines had at first used the normal American equalised bogie but after experience with the French compounds it was modified to incorporate bearers on "outriggers" on the engine frames to transfer the weight to projections on the bogie via hemispheres and "spittoons": this improved stability by reducing the tendency for the front of an engine to rock on the stretcher. The LMSR used this "outrigger" system on all bogies and of course eventually it became a BR standard.



The Coronations had the bar-frame version and I have heard opinions expressed that it probably saved the day on the record breaking high speed trip when No. 6220 ran into Crewe at 50 mph through a crossover restricted to half that speed. I have great confidence in my engines with their well loaded Adams bogies and stiff side control but have no intention of going through a crossover at 4 mph.