Measuring axle weight on locomotives

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Autumn of 2014.

Some while ago I discussed the effect of springs on weight distribution in locomotives, both large (4' 8½") and small. Calculation shows that the position of the centre of gravity is the dominant factor in the distribution of weight among axles and the adjustment of springs (pre-tension) is used to set the frame horizontal while altering spring stiffness only results in a minor transfer of load from one wheelset to another. Doubting Thomas should have a look at the development of the LMS Class 8F that carries a 3C boiler rather than the longer 3B used on the Class 5P5F: at first sight it would seem to be sensible to use the same boiler, but the design of the freight engine came out "backside" heavy so the barrel was shortened by 12" and the boiler moved forward to get an even weight distribution.

Now let's have a look at the practicalities of sorting out the weight on a 5"G engine using my Midland Compound as an example, it is a particularly challenging example because model 4-4-0s are notorious for being front heavy, thereby losing valuable adhesion weight, and in this prototype the extra front end weight of the third cylinder is obviously going to make things worse. The solution is to put in ballast as far back as possible while keeping an eye on weight as the construction progresses. I made a first estimate of finished weight and position of the centre of gravity (c-o-g) when I was at the stage of wheeled frames with cylinders, by weighing what I had already made and estimating the weight and c-o-g of boiler, motion, smokebox and platework.

At that point I had not yet designed the boiler, so as a guide I calculated the weight of the one in Martin Evans's "Ivo Peters" S&D 2-8-0 that in full size carried the same boiler as the Compound. In the end the actual boiler turned out at 32 lb with c-o-g 1" ahead of the throatplate, just 4lb less than estimated, so the calculation was not too far out. The engine looked like finishing up at 108 lb with c-o-g located $^5/_{16}$" ahead of the driving axle which would have given me an even loading between coupled axles and bogie: say 36 lb each. An adhesive weight of 72lb looked a bit light so I hammered 10 lb of lead sheet into the dragbox at the back and worked another 6 lb into the rear splasher boxes over the trailing axle. Then I weighed the engine minus the platework and cab (yet to be made): 117lb, c-o-g lying ½" <u>behind</u> the driving axle, all told, about 7lb less than my estimate with extra ballast but it looked promising.
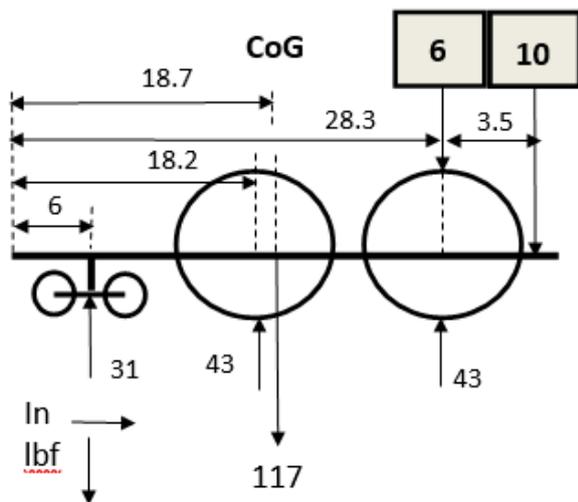
How was the weighing done? If you witnessed the faffing around at IMLEC a few years ago with bits of movable rail and bathroom scales that produced figures showing enormous differences between axles of equalised bogies, you will be surprised at how easily and accurately it can be done by other means. First, I determined the total weight of the engine and the location of its c-o-g, very simply by putting a wooden block under each beam in turn and holding up the other beam while standing on scales. Obviously, the weight at each end is what is shown on the scales minus my weight, and the total weight is found by adding both ends together. The position of the c-o-g along the frames is logically nearer to the heavy end and in inverse proportion to the weights, e.g. If the front were, say, 60 lb and back 40 lb the c-o-g would lie at $^4/_{10}$ of the distance from the front

to the back. Then I measured the individual axle loads merely by using a rule, three bits from the scrap box, and BMS stock; precise dimensions are not important. In the photo the engine is standing on a board with rails made from thin angle so that the tyres overhang the rail, then a strip of something like $^3/_{16}$" x ½" is slipped under a tyre and supported on a fulcrum. A metal block of known weight (say about 1½ lb), previously weighed in the kitchen at an opportune moment (your judgement), is then used to counterbalance the other end of the strip so that it just begins to lift the wheel. The load on the wheel is of course merely the counterbalance weight multiplied by the relative lengths of the strip each side of the fulcrum. After getting the loads for all the wheels they can be added up and checked against the total weight: don't expect a perfect match but I found it easy to get within 5% and then each axle load was adjusted by the overall error to get a consistent result.
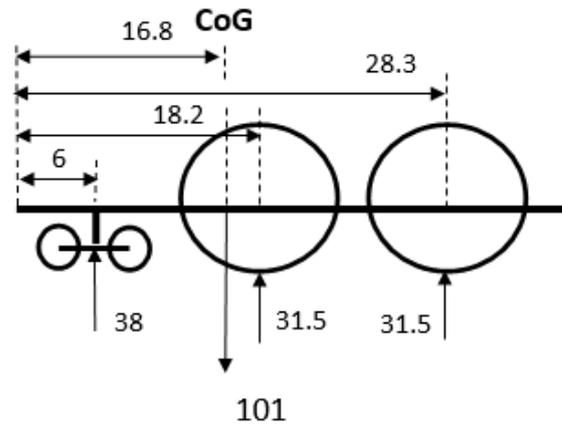
The first diagram (over page) shows the loading after putting in ballast, the c-o-g is ½" behind the driving axle. Coupled wheel axle loads were equalised at 43lb, leaving 31 lb on the bogie, by having the rate of the two bogie springs about ¾ that of the four springs of the coupled wheels (about 70 and 90 lbf/in) and applying a bit of pre-tensioning to the trailing springs to set the frames horizontal.

The 31 lb load on a well-made bogie with strong side control is adequate to lead the engine into quite tight curves. The other diagram shows what would happen without the ballast, the c-o-g is 1.4" in front of the driving axle and coupled wheel load is only 31lb: note that the effect of increasing the total weight by using ballast is to decrease the weight taken by the bogie. The comparative figures can be seen from the table below, I have included the empty prototype locomotive for the sake of interest (units for this are feet and tons), it's very slightly nose heavy but Derby's problem was keeping the axle loads within the 18 ton limit of the line so they definitely couldn't use ballast. Our Chief Engineers are much more obliging so the limit is finding where to hide the lead.

5" G Model: with   5" G Model: Est. no ballast

	Bogie	Dr Axle	Trail axle	TOTAL	C-o-G ref Dr Axle
Midland Railway Compound	19	18.2	17.8	55	0.9 ahead
5"Gauge model no ballast	40	30	30	101	1.4 ahead
5"G model with 16lb ballast	31	43	43	117	0.5 behind