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“Setting Stephenson's Valve Gear Eccentrics”

This document was written by Ron Head and was originally published by Oxford SME and republished by the FMES in the Spring 2026 Newsletter.

Having renewed the driving axles on my 5" gauge LSWR Adams loco, I was faced with the problem of how to set the eccentrics to the correct angular position on the axle. This article describes the method I used, which I hope will be of interest to builders.

The usual advice is to assemble the valve gear with the eccentrics loose on the axle, put the engine in full gear, turn the forward eccentric until the steam admission port is just showing a hairline crack when the piston is at front dead centre, and lock the eccentric in position with its grub screw. Then repeat for reverse. There are three objections to this method. Firstly, it assumes that the valve is in its correct position on the valve spindle, which it probably won't be at this stage. Secondly, it requires the eccentric strap to be dismantled each time an adjustment is made, with the risk that the eccentric will shift before the grub screw can be tightened. Thirdly, setting the reverse eccentric will alter the forward valve setting slightly.

A far better method is to set the eccentrics to the correct advance angle with the driving wheelset out of the loco, but how do you do this? First, we need to understand the basic principles. An eccentric is basically 90 degrees out of phase with the crank, but it's advanced to an angle greater than 90 to take account of lap and lead.

Most people's faces go blank whenever lap and lead are mentioned, so here is a basic explanation (skip this part if you already know). Lap is the amount by which the valve overlaps the admission port, when the valve is sitting in its central position, and is usually between 75% and 100% of the port width. It's what allows the steam to expand in the cylinder when the valve has cut off the steam supply and without it, the port would be open for the whole stroke of the piston, which would be very wasteful of steam:

(Figure 1)

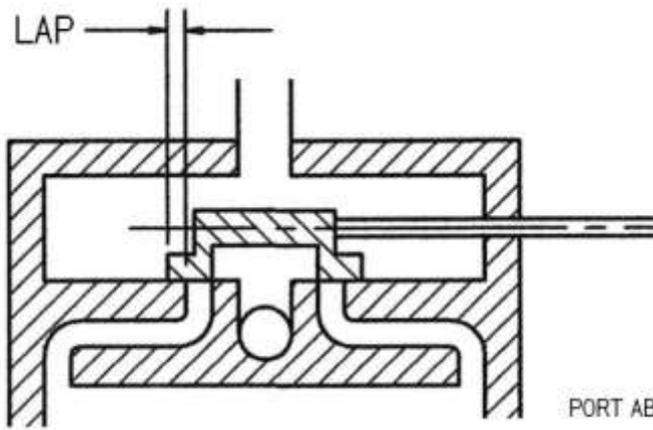


FIGURE 1
SLIDE VALVE WITH LAP

(pronounced *lead*, not *led*) has nothing to do with the physical shape of the valve, but is a function of timing. The valve starts to admit steam before the piston reaches the end of its stroke and in this way, lead can be likened to the BTDC point in an internal combustion engine. Its purpose is to give a charge of steam to cushion the piston and ensure the return stroke is started at full pressure. While not really necessary for a shunting engine, lead is essential in engines designed to run at high speed. When the piston is ready to start its stroke, the amount by which the port is already open is called the 'lead' dimension as shown:

For the valve with lap to be on the point of opening when the piston is about to start its stroke, the eccentric needs to be rotated on the axle by an increment beyond the initial 90 degrees. Here the piston is on front centre, and the valve is about to open the port:

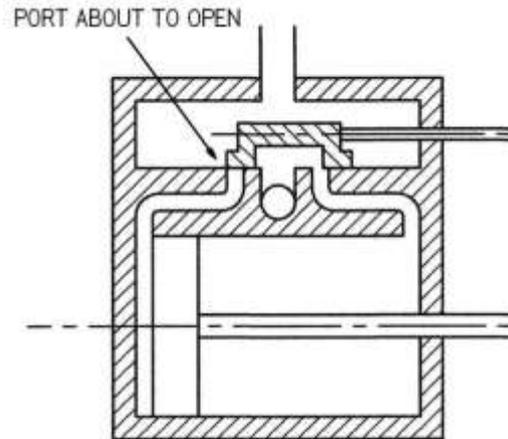


FIGURE 2
SLIDE VALVE WITH LAP

Lead
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piston,

piston

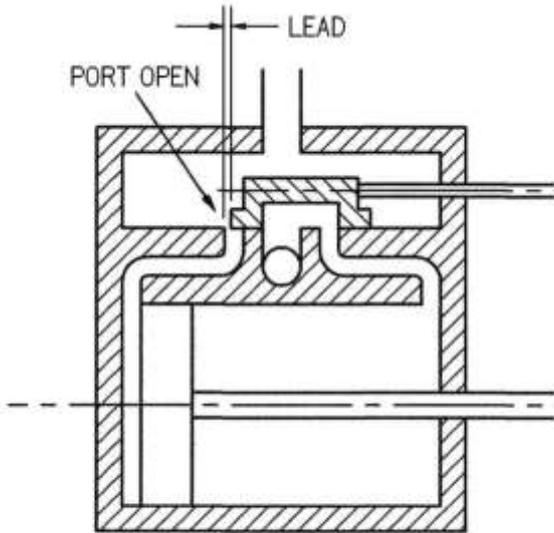
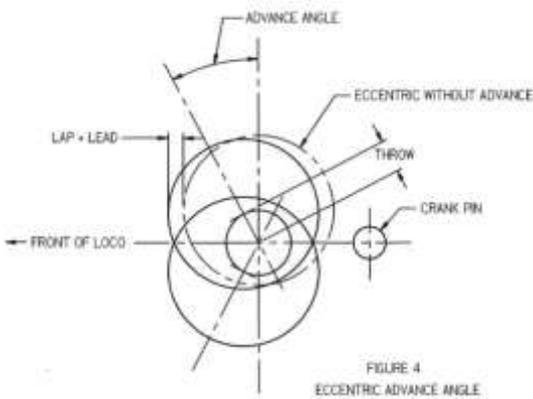


FIGURE 3
SLIDE VALVE WITH LAP + LEAD

For the port to be open by this amount when the piston is at dead centre, the eccentric now needs to be rotated even more. The lap and lead thus determine the angle of advance, as shown in figure 4:

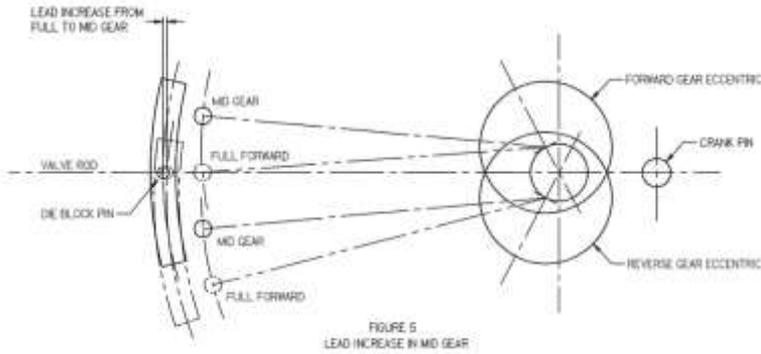


The angle of advance can be calculated from:

$$\alpha = \sin^{-1} ((\text{lap} + \text{full gear lead}) / \text{eccentric throw})$$

For an engine with a radial valve gear, such as Walschaerts, the amount of lead is virtually constant throughout the full range of cut-off, and can be set to anything up to about 10% of the lap. However, with

Stephenson gear, which we are dealing with here, nothing is quite so simple! Unlike a radial expansion link which pivots about a fixed point, the Stephenson expansion link is floating around in space, under the control of the eccentric rods and the lifting link. This causes the lead to increase towards mid-gear, as figure 5 explains (notice that I have shown a 'launch' type expansion link, which my loco uses):



This increase in lead can be counter-productive. The steam cycle at each end of the cylinder is ADMISSION - CUT OFF - EXPANSION - EXHAUST - COMPRESSION - LEAD. If the lead is increased, the compression part of the cycle occurs earlier and this can produce jerky running at short cut-offs. Maybe you've noticed a fore-and-aft surging

motion when travelling behind a full size loco with Stephenson's gear? Having experienced this effect on my own engine, I wanted to know just how much the lead increase might be. There is a formula for calculating the increase:

$$\text{Lead increase} = (c/l) \times t \times \cos p$$

Where c is the distance between the pins on the expansion link, l is the length of the eccentric rods from the centre of the eccentric to the expansion link pin, t is the throw of the eccentric and p is the angle of advance.

My engine was designed with a lap of 5/32", 30 degrees advance angle, zero lead in full gear, and (by calculation) a massive increase of lead to 0.045" in mid-gear. Now it was fairly common in full size practice, to set eccentrics for a negative lead in full gear, so that the mid-gear lead would still be within reasonable bounds. Starting the engine from rest didn't suffer to any extent, because the piston can't produce any torque from front or back dead centre.

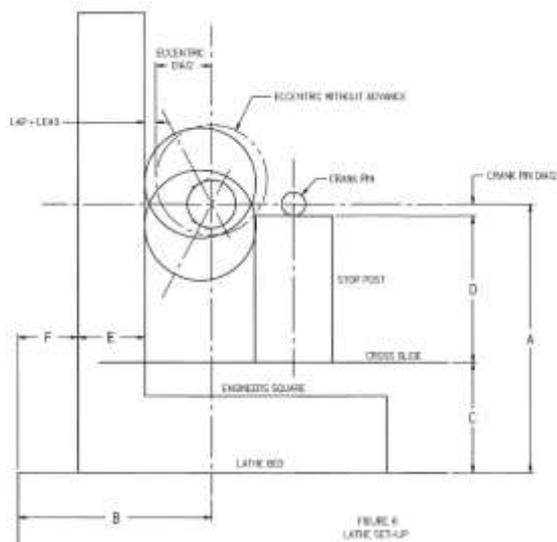
By playing around with the figures, I found that reducing the advance angle to 27.5 degrees gave a 0.012" negative lead in full gear, while the mid-gear lead would now be a more reasonable 0.030" positive. At most running positions of the reverser, the lead should be zero-to-positive by a small amount, which is what I was seeking.

I'm sorry if I've bored anyone with science, and will now get onto the point of this article: how I actually set the eccentrics. I used my lathe, an engineer's square and a depth micrometer to carry out the setting, but before I could begin, I needed to obtain three basic dimensions from the lathe:

The height of the lathe centre above the bed (A).

The horizontal distance from the front of the bed to the lathe centre (B)

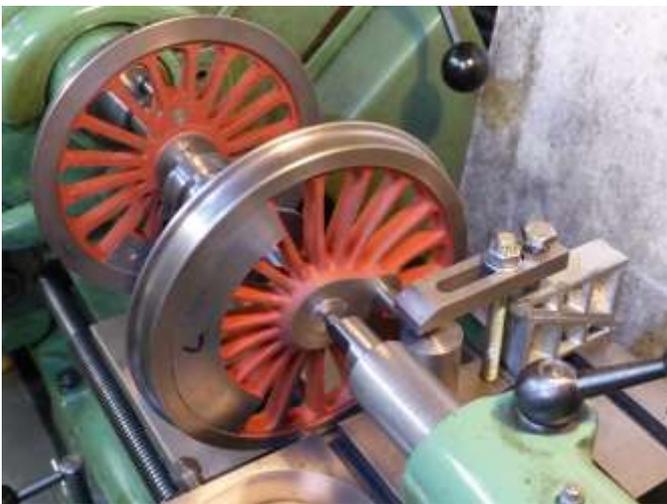
The height of the cross slide above the bed (C).



At this point I should explain that in the above diagram, we are looking at the left hand side of an engine with outside admission valves, the front of the engine being to the left. The crankpin appears immediately behind the axle, but if the engine happens to have inside admission valves, then the crankpin will be ahead of the axle.

The wheelset was mounted between centres in the lathe, with the left hand wheel nearest the tailstock, and a stop was placed on the cross slide, under the left hand crank pin which was set to be behind the axle. The height of this stop had been machined to a precise dimension calculated to hold the crankpin exactly horizontal (D in figure 6). A clamp was fitted to the

crank pin firmly in contact with the stop:



The left hand forward gear eccentric was positioned at the correct distance from the wheel, using a spacer block machined to the correct width. Normal practice is for the outer eccentric to be the forward one, the inner one the reverse:



Next, I took my 6" engineers square, and measured the width of its blade (E in figure 6). This was then placed on the bed:

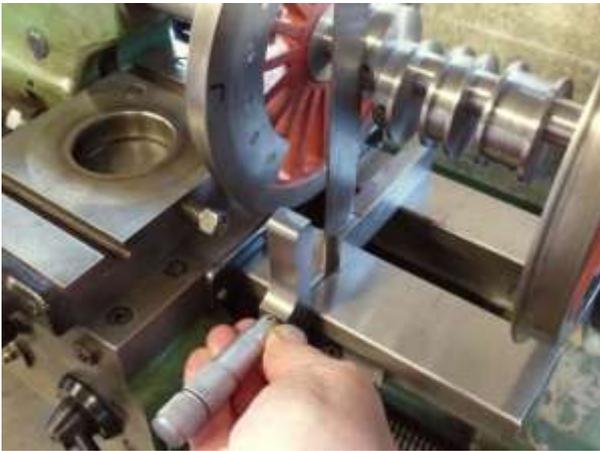


I was now able to calculate the all-important dimension from the edge of the bed to the edge of the square blade (F in figure 6):

$F = B - ((\text{eccentric dia}/2) + \text{lap} + \text{lead} + E)$, bearing in mind that lead is negative in this case and needs to be subtracted.

A depth micrometer was set to the calculated figure (F) and the eccentric rotated until the clearance between the square blade and micrometer was taken up. I used two cup point grub screws per eccentric, set at 90 degrees to each other, as this

gives a much more secure fixing than the single screw shown on most published designs. Taking care to keep the eccentric in contact with the square blade, the grub screws were fully tightened. Notice that the forward eccentric is 'up' and the reverse eccentric 'down':



The reverse gear eccentric was pushed up against the forward one, and the process was then repeated to set the reverse gear eccentric, both eccentrics of course being set to the same dimension. The right hand eccentrics and the pump eccentric were still waiting their turn, and are just hanging loose in the photos:



To set the right hand eccentrics, I turned the wheelset over end-for-end in the lathe, so that the right hand crank pin was now over the cross slide. However, it's easy to fall into a trap here! Having done this, the wheelset is now upside-down compared to how it was before (yes, I had to think about this!). Therefore, the forward eccentric now has to be set in the 'down' position and the reverse eccentric in the 'up' position. When turned the right way up, everything looked as expected.

The effect of the altered advance angle on the engine's performance was impressive. The pole reverser has five notches either side of mid gear, and previously the engine protested if I tried to notch it up beyond notch three. It will now run happily on notch four and I can even use notch five if I want to, with the regulator wide open, although I have to watch the speed! The success of the alteration can be judged by the fact that the engine has covered well over 100 actual miles on four different tracks since the work was carried out, and is regarded as a consistent and reliable runner at my club, regularly pulling myself and up to five adult passengers