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Link motion types

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Summer of 2011.

By mere chance the locomotives I have built are all fitted with radial valve gears of one sort or another so getting to grips with Walschaerts valve gear has been part of the learning process. The link motions were really only of academic interest to me until lately when I found myself building engines with Stephenson and Allan valve gears: suddenly I was faced with looking at them in depth and they have turned out to be quite fascinating. Stephenson's Link Motion had a virtual monopoly in this country in the 19th century and its use continued right up to the end of steam largely due to the sheer number of inside cylinder 0-6-0's and also because the GWR favoured it exclusively for 2-cylinder locomotives, including engines built by British Railways. In 1843 Howe invented a method of reversing engines by simply moving a lever on the footplate and with that the last piece of basic steam locomotive technology fell into place. As the patent was registered by Robert Stephenson & Co it was thereafter known as Stephenson Link Motion (Fig 1).

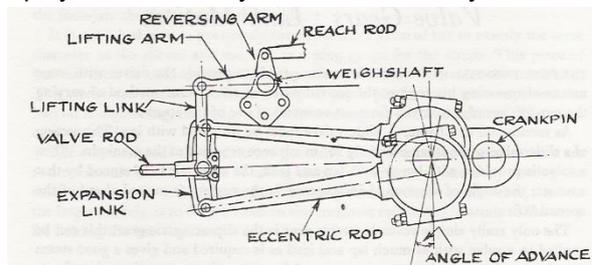


Fig. 1 Stephenson Link Motion

The whole thing is absurdly simple, the motion comprises two eccentrics set to give forward and backward running, each being attached to the ends of a link with a slot in which the end of the valve spindle runs. The link is raised or lowered so as to transmit one or other of the eccentric movements to the valve. Then, to quote Tuplin, "providence intervened to find good use for the intermediate positions", in which the combination of the movement of both eccentrics causes the valve travel to reduce thereby cutting off the steam supply earlier in the stroke leading to expansive working. The Stephenson LM can be designed to give almost perfect cylinder events as in the GWR-Churchward arrangement, nevertheless many railway DOs seem to have had only a hazy notion of the finer detail and there were many examples of rather poorly designed SLM to be found on railway engines in this country, including some on the GWR.

In the same year Gooch invented a different link motion in which the expansion link is suspended at a fixed height and the forward-reverse change is achieved by moving an arm connected to the valve spindle (Figure 2), this requires the curvature of the link to be the other way round.

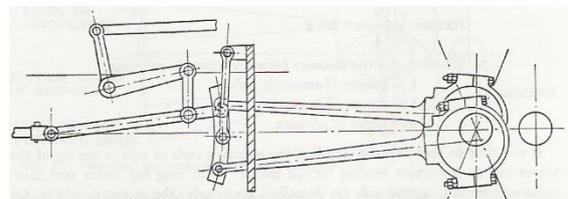


Fig. 2 Gooch Link Motion

At first glance it might seem to be an equivalent alternative to the Stephenson arrangement but it suffers from disadvantages both in mechanical layout and in the events it gives so I can only assume that the GWR went for it at that time due to its dislike of paying royalties, and especially to the Stephensons! A third variant appeared in 1855 when Allan patented an arrangement that is effectively a combination of Stephenson and Gooch, both the link and a radius rod are moved when reversing and as they are supported from arms on opposite sides of the weighshaft they move in opposite directions (Figure 3).

If the relative lengths of the arms are correctly proportioned the path of the die block in the link can be made to approximate to a straight line and the curvature of the link can be eliminated, hence the name of Allan Straight Link Motion. I am not sure what advantages were claimed by Mr. A for his gear, possibly ease of operation since the opposing components balance each other, but although model engineers might rejoice in only having to machine a straight slot, I cannot believe that this would cut much ice at places like Crewe and Swindon.

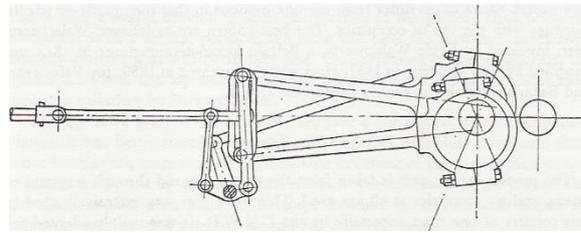


Fig. 3 Allan Straight Link Motion

It seems as though Allan's invention was not exactly welcomed with open arms, certainly judging by its very limited application in this country, as apart from one exception it was rarely used although Beyer Peacock employed it in some designs and the Highland Railway had a fling (!) with it at the end of the 19th century. The exception was however a big one, for over 500 engines built at Crewe between 1874 and 1894 used Allan SLM.

Why on earth would the LNWR spend more money on the Allan arrangement when Stephenson had done them so well up to then? A close look at the GA of Webb's 2-4-0 Precedents of 1874 gives us a clue. These engines had quite an innovative arrangement of cylinders, up until that time the traditional British inside cylinder locomotive had 2 cylinders with a common steam chest between them (Fig 4 A) but as engines grew larger the diameter of cylinders increased and things began to get very crowded in the steam chest. When a port opens to steam there is a large gulp which tends to reduce the steam chest pressure momentarily and it is a well-established principle that snappy engines need large steam chest volume. The usual solution is to move the valve chest to above or below the cylinder block but the former no longer allows a direct drive to the valves (with link motions) and the latter introduces other undesirable complications in design. Webb picked up the idea of using a V-shaped steam chest partly above and partly between the cylinders and inclined upwards (Figure 4 B).

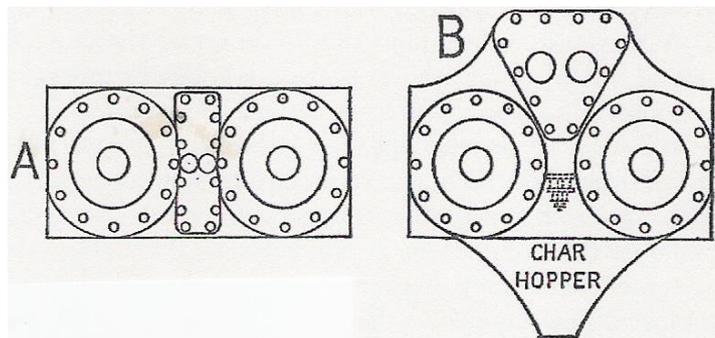


Fig. 4 Steam Chest Arrangement

This gives a huge steam chest volume while retaining the direct action to the valve spindles but it means that the whole link motion is inclined and the expansion link when raised gets rather close to the underside of the boiler on these small Victorian locomotives. With the Allan SLM the movement of the link when reversing is less than half that of the Stephenson link so it was ideal for this design but note that in the Beyer Peacock and Highland versions the weighshaft lies above the motion so the space advantage is lost. Crewe used the V-chest in 2-4-0s of the Precedent, Precursor, Improved Precedent and Whitworth express locomotives as well as in three classes of 2-4-0T and 2-4-2T tank engines so the use of Allan SLM was extensive. One curiosity lies in the difference in operation of the Stephenson and Allan motions since the reach rod pulls back to put Allan gear into forward. The screw reverser logically should have a right-hand thread but standardisation at Crewe (the home of the engineering skinflint) stopped any thoughts of a change so on the Straight Link engines the hand wheel rotates anticlockwise for forward gear. I suppose it is one way of keeping drivers on their toes! I am curious to see what happens when I finally get Whitworth into steam...