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Steam Locomotive Repair and Overhaul

Module LM5

Steam Locomotive Valve Gear & Motion

Richard Gibbon & Tony Simons

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Module BESTT LM5

Steam Locomotive Valve Gear & Motion

Aim

This unit will give learners an understanding of how Locomotive Valve gear and the associated motion operates and how to examine for wear.

The learner will consider: -

* Valve Gear
* Eccentrics
* Expansion Links
* Different types of Valve Gear
* Setting of valves
* Motion
* Examination and reporting

Learning Outcomes

LO1 General Valve gear operation

LO2 Stephenson's Valve Gear

LO3 Walschaerts Valve Gear

LO4 Other Valve Gear

LO5 Valve Setting

LO6 Routine Examination for Valve Gear

LO7 Locomotive Motion

LO8 Locomotive Motion Examination

INTRODUCTION

Valve Gear is the name we give to the mechanism that imparts movement to the valve of a steam engine whether it be the simple slide valve or more complex piston valve, or even poppet valves. The valve gear moves the valve in such a way as to control the steam entry and exit from the cylinder.

Those interested in understanding valve gear further to design their own valve gear would be well advised to visit Don Ashton's Model Locomotive valve gear website

www.donashton.co.uk/html/simulation.html

Or the Dockstader website where simulations of valve gear of various types are available

www.billp.org/Dockstader/ValveGear.html

We also recommend the MAP booklet called *Locomotive Valve Gears* by Martin Evans.

For our purposes it is important to understand what the elements of valve gear do and how they perform the task for which they were designed.

The creation of this module draws substantially on the Chapter 8 of *Locomotives and their Working* by Simpson and Roberts Vol I (pub 1952 Virtue & Co)

In design and construction there has been more variety of valve gears than any other part of the locomotive although today there are only a few in common use that we need to cover.

Ideally the drive to the valve should be such as to provide independent adjustment of admission, cut off (see later) release and compression, and the gear should be easy to maintain and not liable to work slack in service. A valve gear with independent variation of the valve events is possible but such variation can only be carried out when the locomotive is out of service. True it permits finer control than say a conventional Walschaerts or Stephenson valve gear but even if the events could be varied independently on the road, to use it to the greatest advantage would require a full knowledge of the action of the steam at each and every moment throughout the journey.

With the Walschaerts and Stephenson gears particularly we have serviceable compromises. In both cases the CUT OFF (the point at which steam stops being fed to the cylinder expressed as a percentage of the stroke travelled so far) cannot be altered without altering the other events, and in the case of Walschaerts gear the LEAD (see Module 4) of the valve remains constant at all cut offs, We may set against this disadvantage, the fact that the gears are simple in construction, not costly, not liable to work slack quickly and not heavy on maintenance charges. Further the steam distribution they give, though not perfect, is good enough for most purposes provided the driver regulates the cut off intelligently.

Leaving aside gears which are generally only of historic interest we deal with Stephenson, Walschaerts, Joy and Baker valve gears, all of which can be used in conjunction with slide or piston valves. British- Caprotti Poppet valve gear is discussed briefly also.

STEPHENSON VALVE GEAR

The most widely used link motion is the Stephenson Valve Gear. In its basic form it was invented by George Stephenson and William Howe for Colliery Winding engines in 1841 and was improved by William Howe who worked for Stephenson at the Clay Cross Company in Derbyshire, and added the expansion link.

Note that the original winding engine on which George Stephenson and William Howe did their experimental work is available for viewing at Kelham Island Industrial Museum in Sheffield.

The gear is shown in general arrangement in Fig 1. It uses two eccentrics to drive each valve. One drives the valve when the locomotive is in forward gear and the other drives the valve when the locomotive is in reverse gear, and a combination of the two movements gives variations in the cut -off.

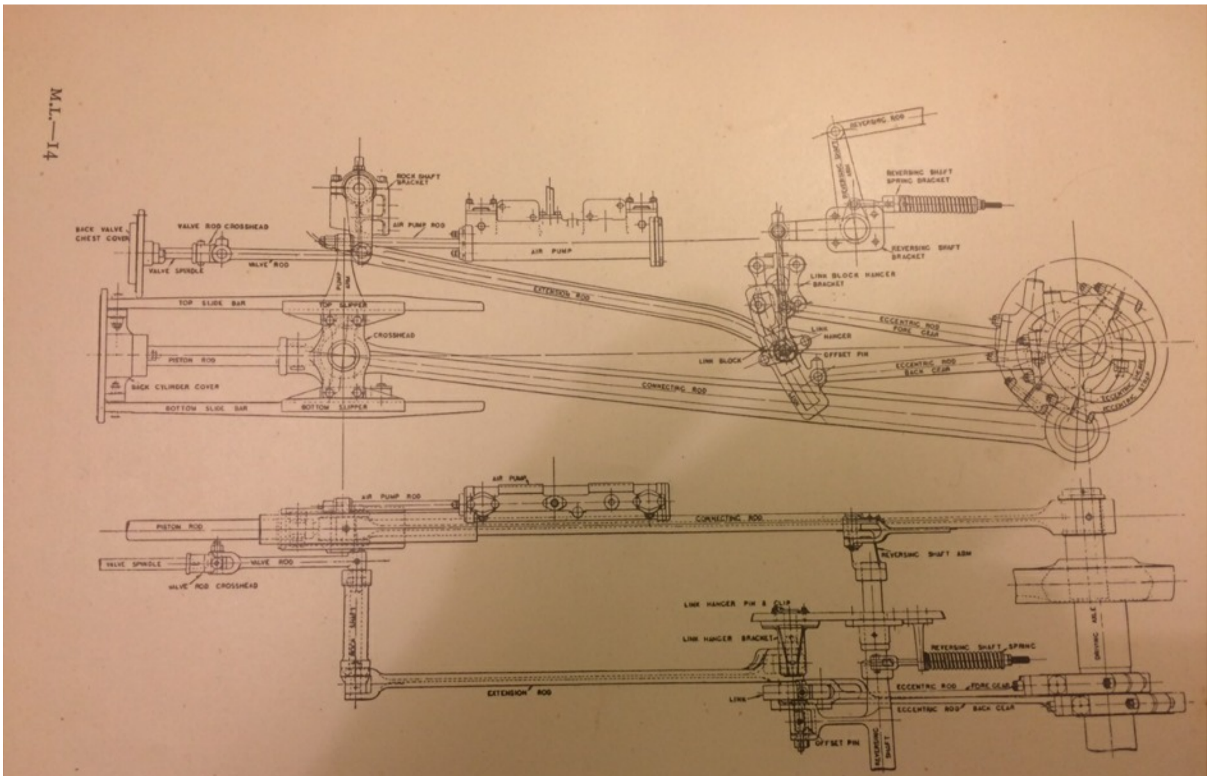
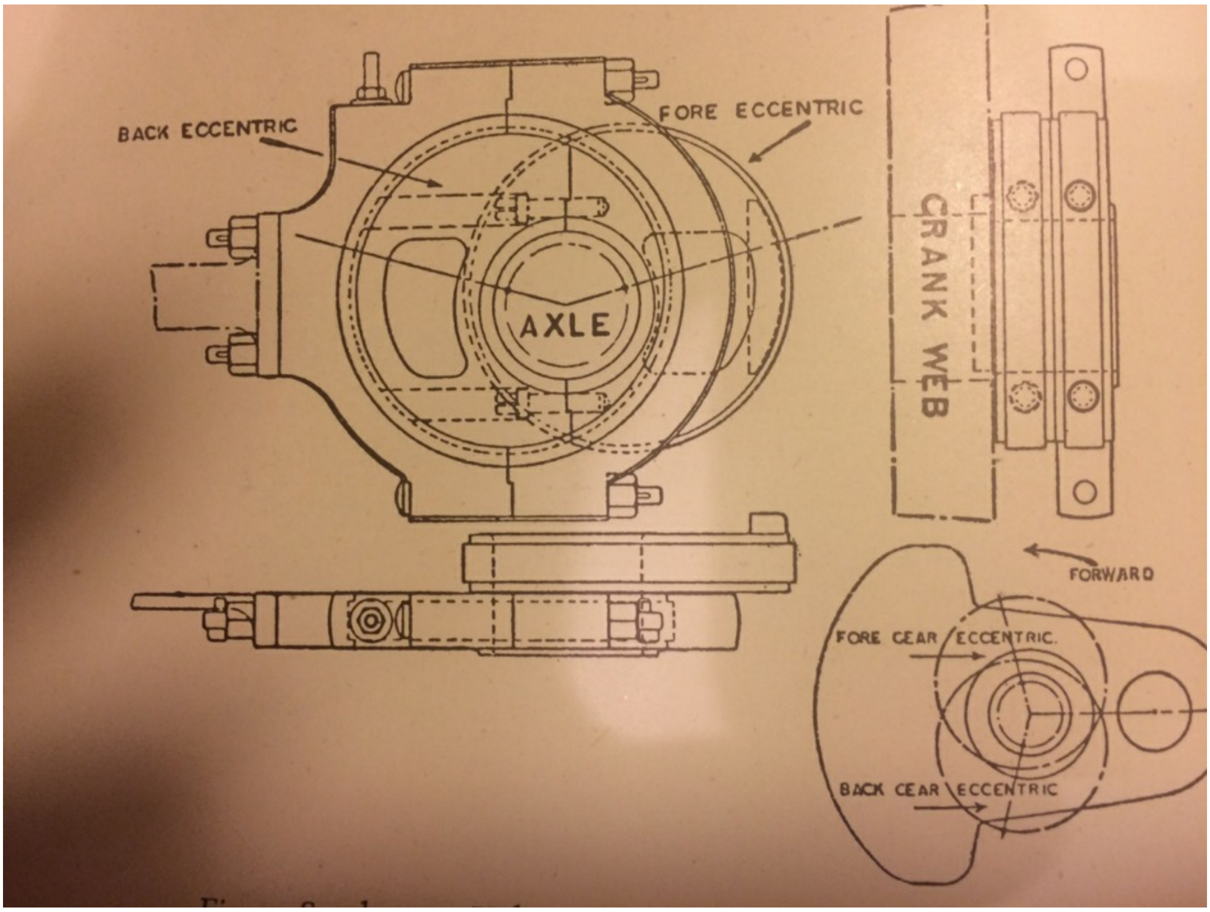


Fig. 1. Western Region. Standard Stephenson Valve Gear.

A complete eccentric consists of a sheave, a strap and a rod. The sheave is mounted eccentrically on the axle or crankshaft, i.e. so that its centre is not the same as that of the shaft. The strap is made a good free fit around the sheave and the eccentric rod is attached to the strap. The outer end of the rod is pinned to an expansion link (see Fig 1) so the strap cannot turn; the motion of the sheave as it rotates causes the eccentric rod to reciprocate backwards and forwards. The total movement of the rod is equal to twice the “throw” of the eccentric the throw being the distance between the centre of the sheave and the centre of the axle. An eccentric is in fact a crank of changed proportions. The “crankpin” (sheave) and “big end “ (strap) are just very large in relation to the axle. Owing to its proportions an eccentric will convert rotary motion to reciprocating motion but not vice versa. The wearing surfaces are large, and an axle fitted with an eccentric is not appreciably weakened by that, as it would be if fitted with a crank to provide the reciprocating motion.



As shown in fig 2 the two eccentrics are fixed approximately opposite each other (exact positions are defined later). The two eccentric rods are pinned to the upper and lower ends respectively of the expansion link. This has a curved slot into which is fitted a die block which is pinned to the end of the valve spindle. The expansion link can be raised or lowered relative to the valve spindle, by lifting links, which are pinned to it and coupled to the reversing screw or lever. The weight of the expansion link is supported by the lifting links, but its position is determined by the position of the eccentrics as well as the position of the lifting links.

In the Stephenson link motion shown in Fig 1 the upper eccentric rod drives the valve in full forward gear and the lower eccentric rod drives the valve in full backward gear. Thus, if by moving the reversing screw or lever to full forward gear, the expansion link is lowered to its full extent and the upper eccentric rod is almost in line with the valve spindle and die block. Under these conditions the motion of this eccentric rod is transmitted to the valve; meanwhile the lower eccentric rod oscillates the expansion link, but this has no effect on the movement of the valve spindle and block. Similarly, if the expansion link is raised to its fullest extent, the lower (back gear) eccentric rod drives the valve spindle quite independently of the upper eccentric rod. In addition to providing a simple means of reversing the locomotive as described in the previous paragraph, the Stephenson link motion also enables the valve gear to be set for variable rates of cut-off.

Consider the engine in full forward gear; as already explained, the upper eccentric rod is in line with the valve spindle

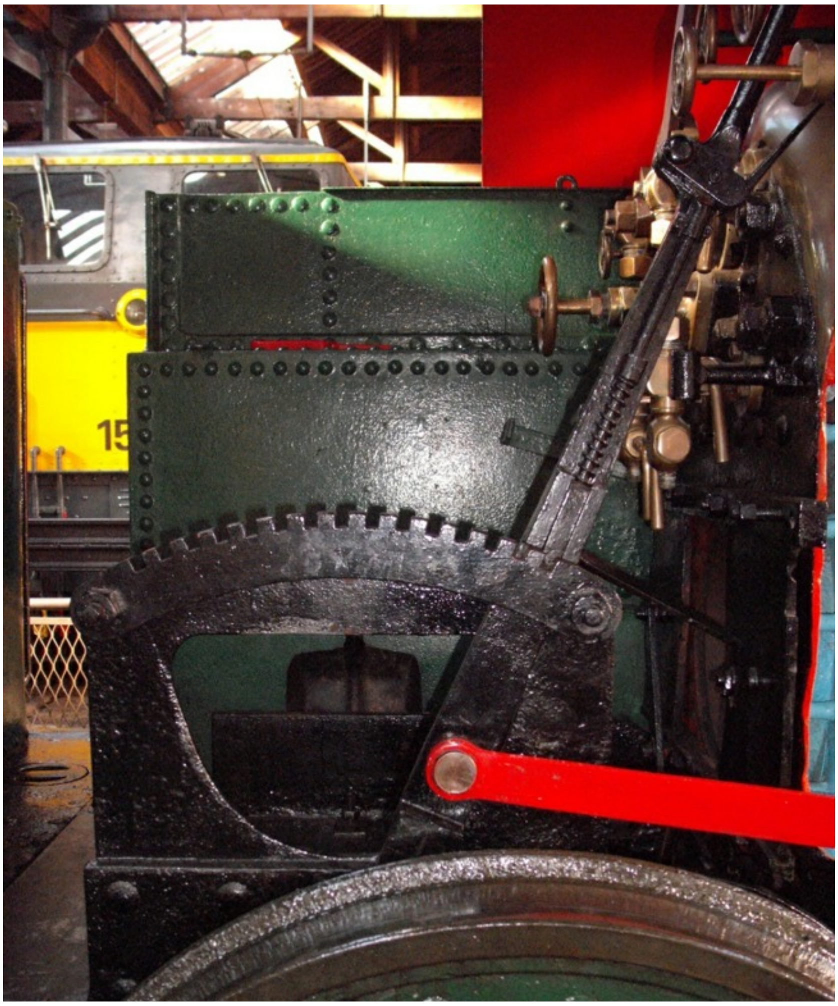
If now the expansion link is raised slightly, the motion of the lower eccentric rod is partially transmitted by means of the link, to the valve spindle, which thereby ceases to be moved entirely by the action of the upper eccentric rod. As the expansion link is lifted further, the influence of the upper rod is progressively reduced, and that of the lower rod increased. When the expansion link reaches the mid position (i.e. the valve spindle block is in the centre of the link and the rods are equidistant from the block, the engine is in mid gear. The valve spindle movement is then very small and is derived equally from both eccentrics. A further upward movement of the expansion link places the engine in back gear.

The combined effect of the two eccentrics on the valve is most readily appreciated by handling a model of the valve gear such as is commonly used for instructional purposes or using one of the simulations on the internet discussed at the start of this chapter. Turning the handle of the model and varying the setting of the gear enables the whole action can be studied at leisure and will be remembered more easily than by studying any amount of descriptive text.

We have previously discussed (Chapter 4) lap and lead for a valve and shown how important those two features are for performance. This will help in the understanding of how to set the eccentrics and valves for Stephenson's Motion.

With the crank on back dead centre and the engine in full forward gear the valve must be open to "lead" steam according to the definition of lead. For the valve to be in this position it must be displaced from its central position by an amount equal to the sum of the steam lap plus the lead. It is necessary for the forward gear eccentric to be not at right angles to the crank (as this would place the valve in the central position) but at some angle greater than a right angle. Actually' the angle is 90 degrees plus an angle (*known as the angle of advance*) equivalent to the lap plus the lead. The eccentric is in advance of the crank by this amount. Bearing in mind that the crank rotates in one direction when the engine is in forward gear, and the opposite direction when the engine is in back gear, it is clear, that the two eccentrics, each being in advance of the crank in their respective directions of rotation, are placed approximately diametrically opposite each other, but not exactly so owing to the angle of advance of each.

"Notching -up" is the act of moving the reverse lever or screw from the full gear position towards the mid-gear position; the term arose from the use of notches in the sector plate of the reversing lever, a spring-loaded catch fitting into the notch required. The principal effect, regardless of the type of valve gear, is to reduce the cut-off, and it is normally carried out shortly after starting as the locomotive gains speed. This action of reducing the cut off allows the steam in the cylinders to start working more expansively and more economically.



REVERSING LEVER ON BEYER PEACOCK ISLE OF MAN LOCOMOTIVE “PENDER” IN MUSEUM OF SCIENCE & INDUSTRY IN MANCHESTER SHOWING NOTCHES BETWEEN FULL FORWARD AND FULL REVERSE

THE EFFECT OF REDUCING CUT-OFF AS NOTCHING-UP TAKES PLACE

With Stephenson’s valve gear the reduction of cut-off means that the travel of the valve is reduced, so that release, compression and admission occur earlier in the stroke of the piston. These earlier events are desirable for running at higher speeds. At the same time the lead is increased as the cut-off of Stephenson’s gear is reduced. When the mid gear position is reached the valve travel is at its minimum, being equal to the sum of twice the lap and twice the lead. I.e. the valve opens to lead at each end of its travel.

In some ways this action is similar to and paralleled by the automatic advancing of the ignition spark as a petrol engine runs faster and needs the spark timing to advance to allow for the time of flame propagation within the combustion process. In earlier times this was achieved by a centrifugal system of bob weights, which advanced the spark timing but of course nowadays is all catered for by the ECU.

“OPEN” & “CROSSED” ECCENTRIC RODS, AN IMPORTANT DIFFERENCE.

The figures and descriptions above refer to Stephenson's Valve gear with "open " rods. This is the usual arrangement on locomotives; with the eccentrics in the position shown in Fig 1, the eccentric rods are "apart" from each other though it should be noted that if the crank were turned through 180 degrees the rods would be crossed. This however is not the same as "crossed" rods where the rods are crossed when the crank and eccentrics are in the positions shown in Fig 1.

A TRAP.

The illustration and description also apply only to OUTSIDE ADMISSION valves- in particular, slide valves. With inside admission valves and "open" eccentric rods the lower eccentric rod is used for the fore gear drive and the upper rod for back gear drive. Furthermore, since the valve moves in the opposite direction to that required for outside admission, each eccentric FOLLOWS the crank by an angle equal to 90 degrees minus the angle of advance. With this arrangement lead is reduced as the engine is notched up.

The straightforward arrangement of Stephenson link motion that has been described is particularly suited to inside cylinders having the steam chest and valves at the sides such as we would find in an Austerity tank engine such as a J 94, since the two eccentrics are mounted to one side of the crank.

Owing to restrictions in the width available between the frames, however, it is sometimes necessary to arrange the steam chest above the cylinder so that the alignment of the valve spindle is not on the centreline of the motion. In this case the valve gear drive to the valve spindle is transmitted through a series of levers and links. The die block is pinned to one end of a horizontal connecting link, the other end of which is connected to the lower end of a rocking lever. This lever is more or less vertical and pivots at its centre on the rocking shaft; its upper end is connected to the valve spindle. The connecting link is constrained to remain horizontal while reciprocating by being connected to a swing link as well as the rocking lever. In this manner the die block is held while the expansion link is raised or lowered by the reversing gear.

An incidental but important effect of introducing a rocking shaft is to reverse the alteration of lead due to notching-up. Thus for example whereas with an outside admission valve and open eccentric rods, the lead is increased as the engine is notched up, the same arrangement in conjunction with a rocking lever causes the lead to be at a maximum in full gear and a minimum in mid gear.

There are EIGHT possible arrangements of Stephenson's Gear these being due to the various combinations of outside or inside admission valves, open or crossed rods, with or without a rocking lever

The most generally used combination consists of inside admission (piston) valves, open rods and a rocking lever. This arrangement gives the desired increase of lead, as the engine is notched-up.

POINT OF SUSPENSION OF THE LINK with STEPHENSON LINK MOTION

The way the link is suspended might seem a trivial issue to a novice, but it becomes hugely critical in the way the valve gear performs. It is hardly mentioned as significant in the book discussed at the start of this section.

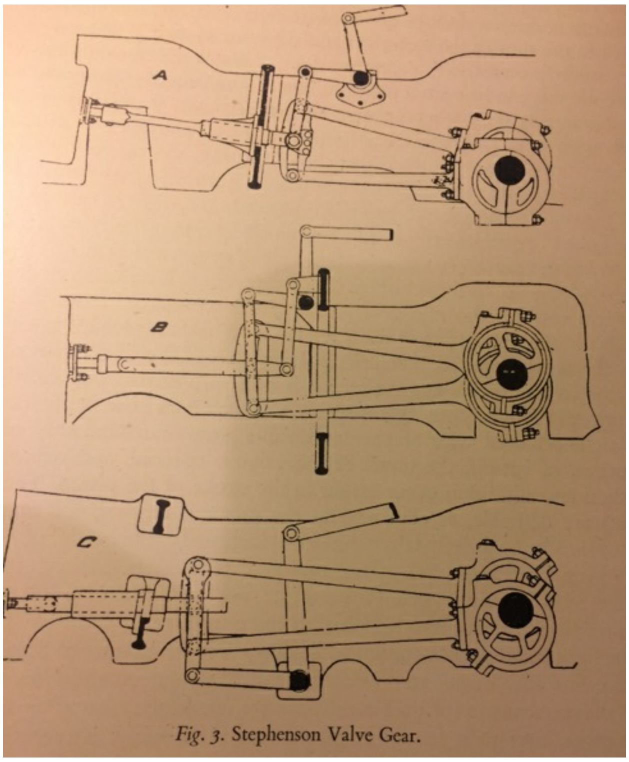


Fig. 3. Stephenson Valve Gear.

Fig 3 Image of three different methods of link suspension.

The way the Stephenson link is supported so it can swing freely affects the way it performs and the amount of slippage there is between the die block and the link.

This would be a good place to open one of the Stephenson Link Motion computer simulations and watch what is meant by die-block slippage. It is important because a high degree of slippage induces wear on both the link and the die block lessening the life of the valve gear in service.

Have a look at several Stephenson valve geared locomotive and steam driven machines and observe where the link is suspended in each case and think why that might be so.

Centre suspension as at A. is what we would find on a well-designed passenger or freight tank engine used or steam winding engine where the engine is designed to run equally well in forward or reverse gear. Compared with what follows in the other two options the suspension is complicated by having to provide a lifting system with trunnions attached to the link such that the mechanism can still allow the link to be lifted the full travel from forward to reverse without fouling the die block mechanism as the link passes through the mid gear point.

If we now consider the sort of steam engine where there is a natural preference for the engine to run largely in one chosen direction such as an express passenger locomotive, a traction engine or ship's engine then it is possible to simplify the valve gear construction considerably by doing away with trunnions and supporting the link at one of its existing pivoted ends as at B&C in Fig 3. This enables those who set the valve gear up to concentrate on getting all of the errors concentrated into the non-preferred direction of travel. Not only that but the amount of die block slip can be minimised at the preferred travel end of the link and maximised at the non-preferred direction end. Watch for die block slip on the computer simulations with the 3 different suspension methods.

LAUNCH AND LOCO TYPE LINKS with Stephenson Valve Gear

Details of the gear differ principally in the arrangement of the expansion link. In early locomotive practice, the eccentric rod ends were pivoted at the ends of the link while, in marine engines, the eccentric rod pivots were set behind the link slot (or below on a vertical engine). These became known respectively as the 'locomotive link' and the 'launch link'. The launch link superseded the locomotive type as it allows more direct linear drive to the piston rod in full gear and permits a longer valve travel within a given space by reducing the size of eccentric required for a given travel. Launch-type links were pretty well universal for American locomotives right from the 1850s but in Europe, although occurring as early as 1846; they did not become widespread until around 1900. Larger marine engines generally used the bulkier and more expensive marine double-bar link, (effectively a sophisticated loco type link) which has greater wearing surfaces and which improved valve events by minimising geometric compromises inherent in the launch link.

There is a good explanatory You tube film on https://www.youtube.com/watch?v=f4xJsulRq2c

It shows how LAUNCH type links allow the valve to be more perfectly aligned with the chosen eccentric rod rather than with the LOCO type link, which allows it to get close to alignment, but not fully aligned. I commend it to the reader.

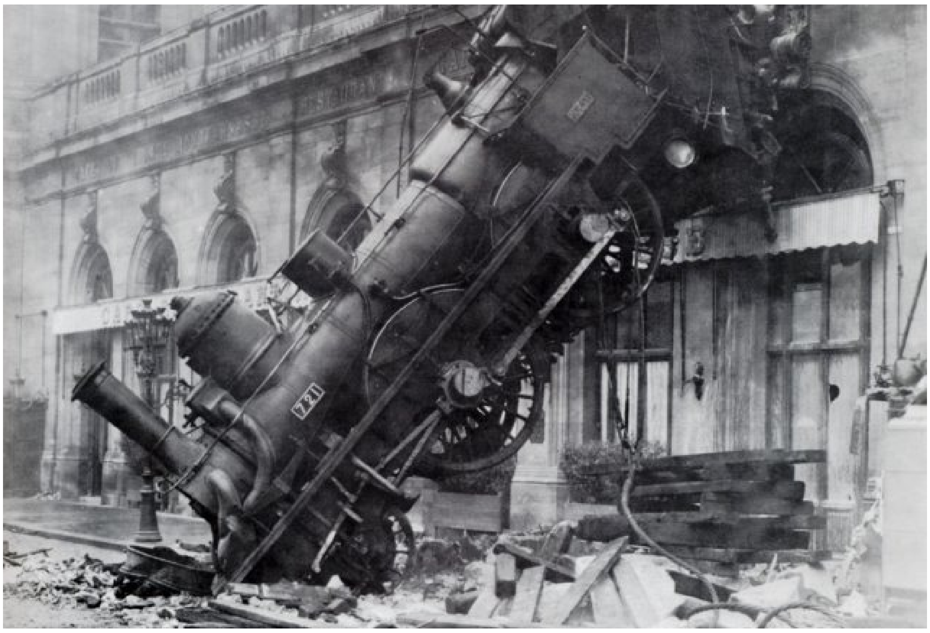
I

CONSTRUCTION

From a constructional viewpoint Stephenson link motion suffers from certain disadvantages. With two inside cylinders the crank axle must carry four eccentrics and these must be fitted within the limited width between the axleboxes after allowing for the width of the cranks. With two such sets of motion occupying so much space it is difficult to provide adequate bracing for the frames and maintenance and lubrication are not easy.

The use of outside cylinders with inside valve gear such as is common on the locomotives of the GWR partly overcomes these difficulties, but for many years the general tendency is to use outside cylinders and Walschaerts gear. Stephenson’s link motion is not well suited for use outside the frames owing to the problems of arranging two eccentrics or return cranks, but one of the few British examples is shown in the image below. In all other respects the locomotive was the same as its sisters built with Walschaerts valve gear so that comparisons could be made. This Class 5 locomotive is preserved and appropriately named *George Stephenson*.

The famous poster of the *Gare de Montparnasse* accident shows a very good example of outside mounted eccentrics driving a valve gear, which is strictly not Stephenson’s, but a variation discussed later



The Class 5 locomotive 44767 “George Stephenson” fitted with Stephenson’s valve gear driven from two return cranks on the end of the crank axle rather than two eccentrics.

WALSCHAERTS VALVE GEAR

This valve gear in its original form was invented by Egide Walschaerts of the Belgian State Railways in 1844. A few years later it appeared in the form in which it is seen today, and it is now the most widely used type of valve gear.

Some of the disadvantages of Stephenson's Valve gear were indicated in the previous section. Walschaert's gear is less troublesome and less costly to maintain; it is particularly suited to outside cylinders, which owing to the absence of the crank axle and to easier maintenance are now more general than inside cylinders. It can also be applied to inside cylinders in which case it requires only one eccentric whereas Stephenson's has two.

Fig 7 shows the arrangement of the gear as applied to an outside cylinder. Its action is readily understood if it is considered to be a mechanism in two distinct parts. (1) The main drive to the valve spindle which can be varied so as to alter valve travel and cut off etc. and (2) the "lap-and-lead motion which is not variable.

The main drive to the valve spindle is from a return crank on the driving wheel crankpin in the case of outside valve gear or from an eccentric in the case of inside gear. The return crank is simply an arm secured at one end to the crankpin, and having at the other end a pin, which fits in the so-called eccentric rod. The distance from the centre of the pin to the centre of the axle is called the throw of the return crank, corresponding to the throw of an eccentric. The eccentric rod in turn is connected by a pin to the lower end of the expansion link, which unlike the expansion link of Stephenson's Gear is free to rock on fixed horizontal trunnions at its centre. Thus the link oscillates through about 40 degrees (Each way????)

The radius rod as shown in figure 7 is pinned at one end to a die block which fits in the curved slot of the expansion link, and at its other end is connected to the valve spindle by means of the combination lever, the action of which may be ignored for the moment.

The main drive to the valve works like this. The expansion link is oscillated through a fixed angle independent of notching up, by the drive from the return crank or eccentric, and the die block moving with the expansion link, acts on the radius rod, which in turn reciprocates the valve spindle.

Reversing and variation of travel, admission and cut-off, are obtained by raising or lowering the rear end of the radius rod so as to alter the position of the die blocks in the link.

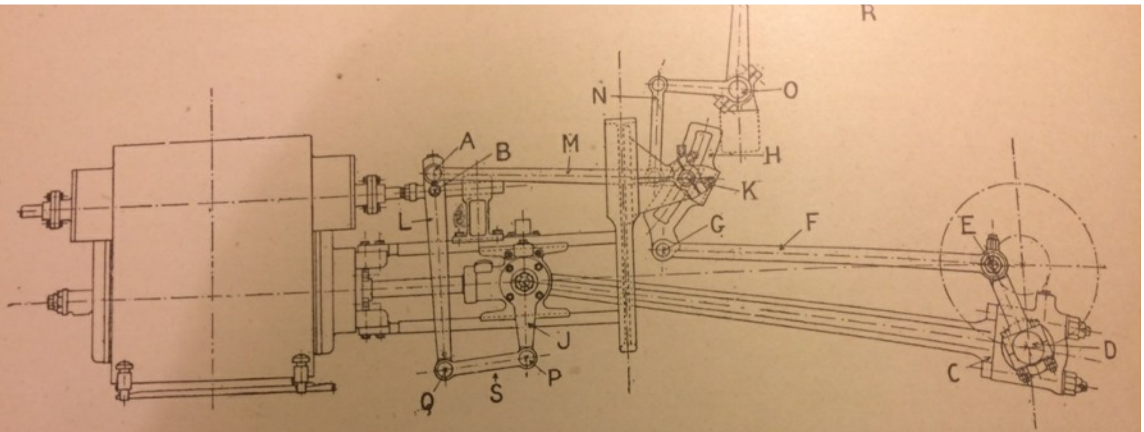


Fig. 7. Walschaerts Valve Gear.

A Joint between combination lever and radius rod.
B Joint between combination lever and valve spindle.
C Connecting rod.
D Main crankpin.
E Return crankpin.
F Eccentric rod.
G Joint between eccentric rod and end of link.
H Link
J Crosshead arm.
K Link trunnion.
L Combination lever.
M Radius rod.
N Lifting link.
O Reversing shaft.
P Joint between crosshead arm and union link.
Q Joint between combination lever and union link.
R Reach rod.
S Union link.

Assuming the locomotive is fitted with inside admission valves and that the arrangement of the gear is as in fig 7, the engine is in full forward gear when the die block is at the bottom of the curved slot. I.e. below the trunnions. It is in full backward gear when the die block, being now above the trunnions, move forward when before it moved back, and vice versa. When the die block is in the centre of the link, i.e. in direct line with the trunnions centre, it imparts no motion to the radius rod and the engine is said to be in mid gear

Clearly when the die block is moved slowly from either full gear position to the mid gear position while the engine is running (by means of the reversing screw or lever), the motion it imparts to the valve through the radius rod, is progressively reduced. Thus the engine is notched up to use the steam more expansively.

The “Lap-and Lead” part of the motion is derived from the crosshead by means of a crosshead arm (fixed rigidly to the crosshead) a union link and a combination lever. The combination lever as shown in Fig 7 is pinned at its lower end to the union link and at its upper end to the radius rod; A short distance below its upper end it is pinned to the valve spindle crosshead. In order to understand the lap and lead motion it is helpful to assume that the radius rod does not move. (This can be achieved with the computer simulation by putting the valve gear into mid gear and observing the valve events. As the crosshead reciprocates in the slide bars it causes the combination lever to swing like a pendulum about its upper end, thus by leverage imparting a small movement to the valve spindle.

With the crankpin on either dead centre, the length of the eccentric rod and the size and disposition of the return crank is such that if the reversing lever is moved from full back gear to full forward gear or vice versa, the front end of the radius rod where it is connected to the combination lever does not move. In other words the curve of the expansion link slot corresponds exactly to the arc described by the die block as it swings about the front end of the radius rod.

This is the central position of the expansion link. The return crank pin is at its bottom centre. The valve however is not in its central position. It is displaced backward from this by an amount equal to the lap plus the lead, as it must clearly be if the valve is to remain open to lead whilst the crank is on dead centre. Similarly with the main crank on front dead centre, the return crank is on top centre, the expansion link is again in its central position, and the valve is displaced forward to open the other steam post to lead. Since the piston stroke never varies it is evident that the lap and lead which is derived from it, never varies whatever the cut off. In consequence Walschaerts Valve gear is said to be *a constant-lead valve gear*.

Having considered the two parts of the motion separately, we must visualise the two acting together to move the valve. Although the valve events and travel can be affected by notching up and reversing, the lead is always the same. I.e. the position of the valve when the crank is on front or back dead centre is constant.

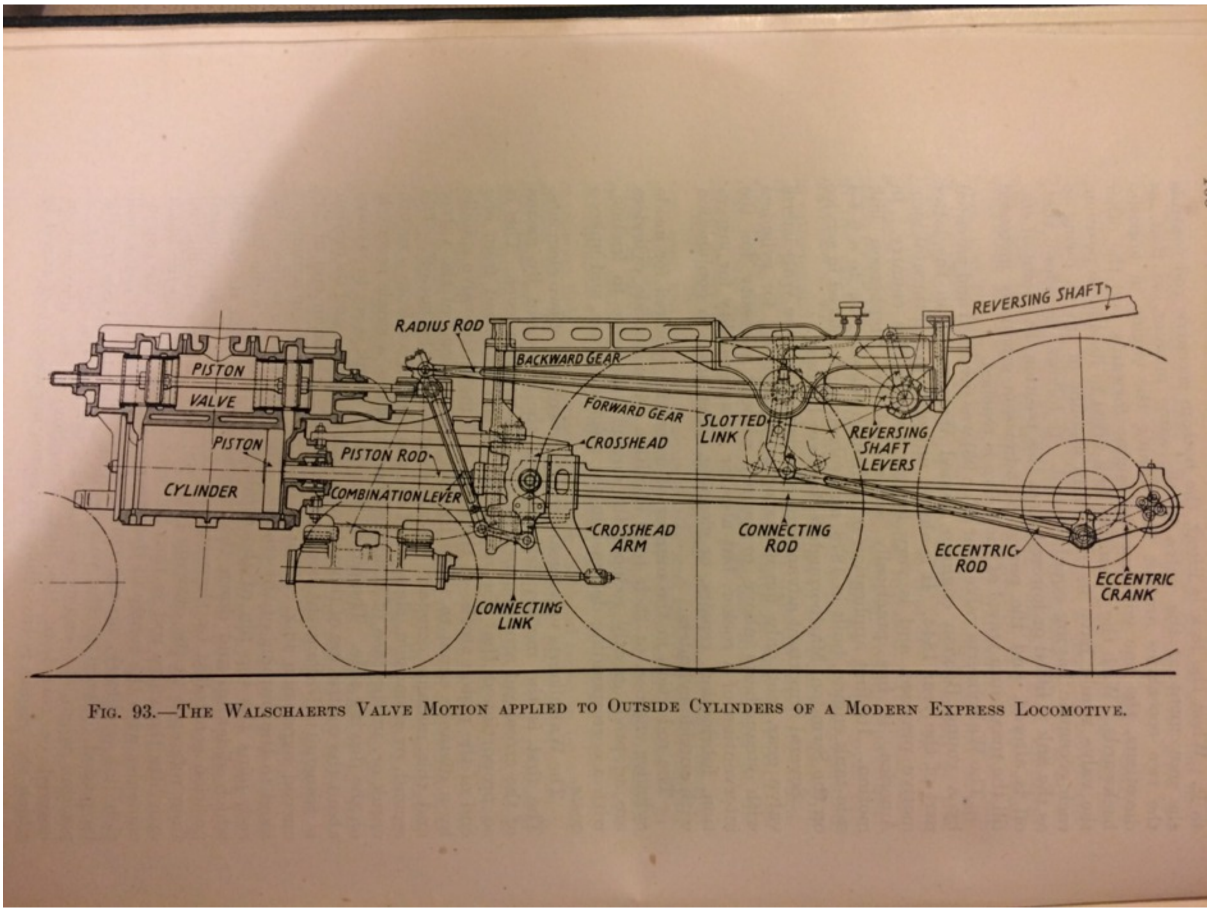


Fig. 93.—The Walschaerts Valve Motion applied to Outside Cylinders of a Modern Express Locomotive.

For the sake of clarity we have only considered Walschaerts gear suitable for inside admission valves with the die block at the bottom of the expansion link when the engine is in full forward gear. This arrangement is the most commonly used since inside admission valves are general in modern designs. ```Also it is desirable for the die block to be at its lowest position when in forward gear because then the drive from the eccentric rod to the radius rod is direct and the expansion link is not subjected to as much strain as when the die block is at the top. This is preferred only for those engines (the majority) which are generally worked in forward gear.

There is another reason why the die block is preferred to be in the lower end of the expansion link for forward gear. If some part of the die block lifting mechanism or reversing gear was to fail it would mean that the die block and radius rod would fall by gravity to the full forward position enabling the locomotive to be able to get home.

In the case of outside admission valves, such as Bulleid Pacific locomotives or slide valves, the connections to the upper end of the combination lever are reversed and the return crank leads the main crank when travelling in forward gear. The valve spindle is now connected to the upper end of the combination lever with the radius rod connection a short distance below. This modification is necessary because the displacement of an outside valve to open say the rear of the cylinder to lead steam must be in the opposite direction to that of an inside admission valve assuming the crank to be on back dead centre.

It will be remembered that in the case of Stephenson’s gear, the eccentric is set at a certain angle of advance corresponding to the sum of lap and lead. With Walschaerts gear however the combination lever provides for this need, and the return crank or eccentric is set at 90 degrees to the main crank either leading or following as previously explained.

CONSTRUCTION

The return crank being fastened on the end of the crankpin must be rigid in itself and rigid in its mounting. It is of steel with the eccentric rod pin formed integral with it. The attachment to the crankpin may be by either of two methods. In one design the crankpin is provided with a square end. The return crank fits over this having a square hole and it is split at the end so that it can be clamped to the crankpin by bolts and nuts. In another design the return crank is flat like a thick plate with an integral pin and is attached to the end of the crankpin by four studs and nuts. A spigot formed across the inside face of the return crank is a good fit in a groove in the end of the crankpin so that the return crank is accurately registered and prevented from shifting.

The ”eccentric” rod used in conjunction with the return crank is of conventional construction. It is made of steel or special alloy steel and is slightly tapered being wider at the return crank end. Bronze bushes are pressed into the ends and accurately finished to receive the motion pins which are of steel generally case hardened. A roller or ball bearing is fitted between the return crank and the eccentric rod. Needle roller bearings are often found in the motion pin assemblies.

GRESLEY CONJUGATED VALVE GEAR

Three cylindered locomotives are considered to offer certain advantages over two cylindered locomotives, such as lighter reciprocating parts (leading to reduced hammer blow and therefore allowing greater axle loads), more uniform starting torque, an earlier cut off in full gear, reduced coal consumption and reduced overall width over cylinders. On the other hand three cylinders normally require three sets of valve gear. This difficulty was overcome by Nigel Gresley by inventing a 2 to 1 lever or “Conjugate” gear to drive the valve of the inside cylinder with the design shown in Fig15 the outside cylinders are provided with the normal Walschaerts valve gear, but the inside cylinder valve is driven by a simple gear consisting of two levers coupled to forward extensions of the outside cylinder valve spindles.

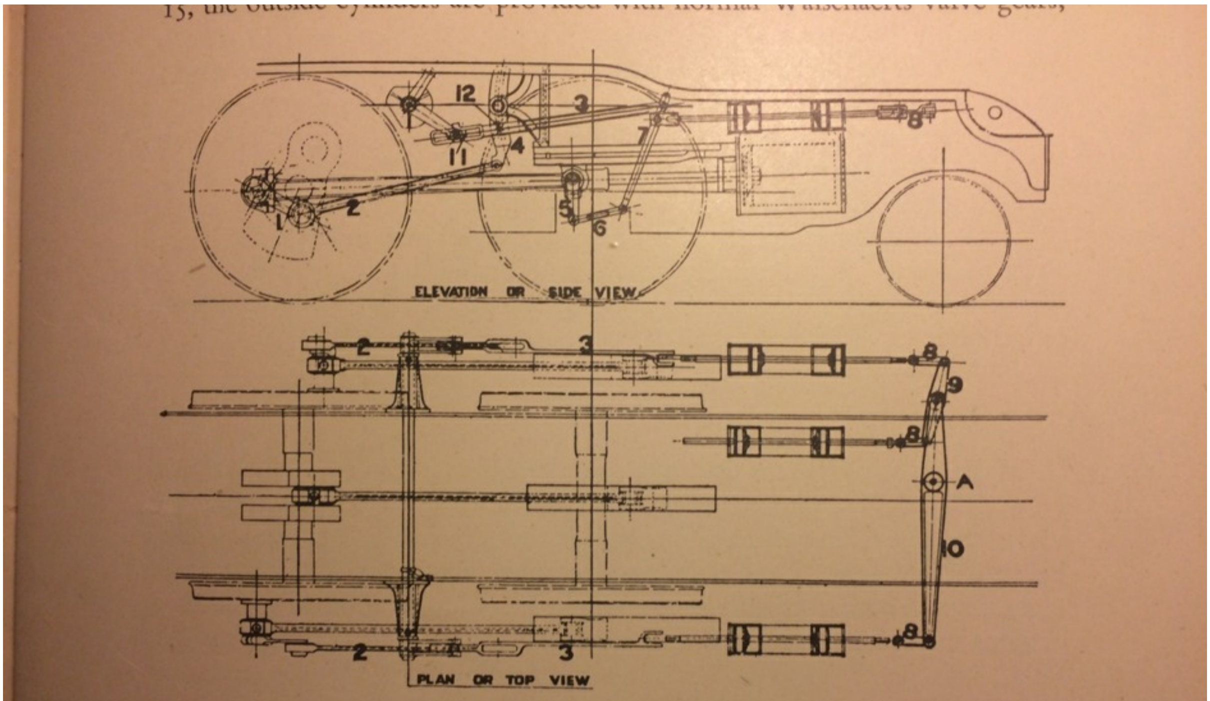


Fig. 15. Gresley Conjugate Valve Gear.

1 Return crank.
2 Eccentric rod.
3 Radius rod.
4 Expansion link.
5 Crosshead arm.
6 Union link.
7 Combination lever.
8 Valve spindle link.
9 Equal lever.
10 2 : 1 lever.
11 Reversing dieblock.
12 Dieblock.

The three cranks are at 120 degrees to one another (with the allowances for any inclination of the inside cylinder) with the left-hand crank following 120 degrees after the right-hand crank. A 2-to-1 lever arranged transversely through holes in the main frame pivots about a point A on a cross stay, the end of the longer arm being connected to the right-hand valve spindle and the end of the shorter arm to the centre pivot of an “equal” lever. The longer arm is of course twice the length of the shorter arm. The “equal” lever so named because its pivot is at its centre, is coupled at one end through a link to the left hand valve spindle and the other end through a link to the inside cylinder. The motion thus derived by the inside spindle is practically the same as that of each outside valve, though of course it differs by 120 degrees phase shift.

Clearly it is important to reduce any lost motion due to clearances to a minimum and for this reason the levers are mounted on ball and roller bearings. With the gear arranged as shown forward of the cylinders, an allowance must be made for the expansion of the outside valve spindles.

Lost motion throughout the gear is multiplied in its effect on the inside valve and it is therefore important to maintain the gear in good condition.

This Gresley conjugated valve gear is fitted to LNER locomotives like “Flying Scotsman”, “Mallard” and “ Green Arrow” and has proved extremely successful.

BULLEID-WALSCHAERTS VALVE GEAR

An interesting form of Walschaerts gear and inside motion, totally enclosed and lubricated by pumps was introduced by Mr O.V.S Bulleid in his Merchant Navy Class of locomotives for the Southern Railway when he was Chief Mechanical Engineer of that company. The design of the locomotive as a whole embodies several novel features of which the valve gear and motion represent the most marked change from conventional practice.

Mr Bulleid felt that the time had come to enclose as much of the motion as possible so that it could be lubricated continuously by flood lubrication instead of the driver with his oil feeder. The parts might be less accessible if enclosed, but (he considered) if the results desired, namely no attention between general repairs, reduced wear and freedom from overheating, were achieved, this would not matter.

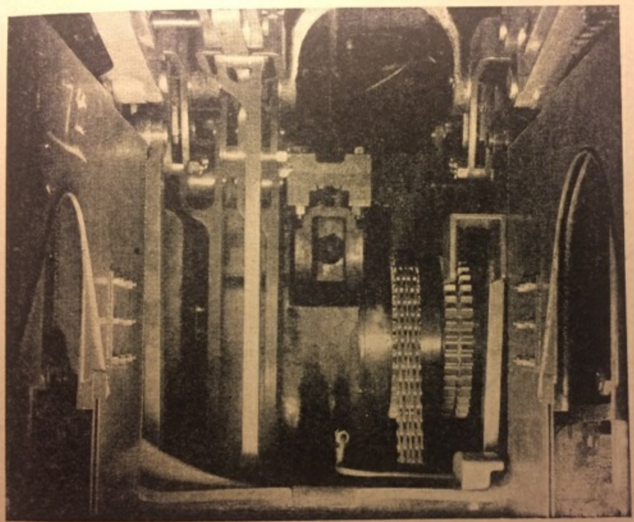


Fig. 14. Inside motion of “Merchant Navy” Class Locomotive. Southern Region.

Fig14 shows the partially stripped gear between the frames. It is similar to Walschaerts except that the eccentrics and return cranks have been dispensed with. Also the union link to the crosshead, and are replaced by a crankshaft, which is chain driven from the main crank axle, and in turn drives the expansion link and combination lever. These modifications were necessitated by the desire to enclose the three sets of valve gear for the three cylinders in a casing between the main frames.

The whole of the motion and valve gear including the inside crosshead and little end as well as the three valve guides is enclosed. The piston rod passes through a gland in the casing in addition to its normal gland to prevent ingress of steam. A small three-throw crankshaft is mounted transversely low down between the leading coupled axle and the driving axle. Above it and on the same level as the main crankshaft is a transversely mounted layshaft. The crank axle drives the layshaft through a chain and chain wheels, and the layshaft drives the three-throw crank through a similar chain and chain wheels. All the wheels have the same number of teeth so that the three-throw crankshaft rotates at the same speed as the crank axle.

When the crank axle has to be dropped, it is only necessary as far as the motion is concerned to disconnect the first chain drive and the connecting rod after opening up the casing.

The crank and connecting rod of the inside cylinder are arranged on the longitudinal centreline of the locomotive. To the left of them are the valve gears for the inside and left hand outside cylinders and to the right the valve gear for the right hand outside cylinder as well as the chain drive. Each expansion link is provided with an integral arm at the rear, which is coupled to the appropriate crankpin of the three-throw crankshaft by a small vertical connecting rod. Thus the drive to the expansion link is equivalent to that obtained from a normal return crank or eccentric. A horizontal link pinned to the big end of the vertical connecting rod drives the foot of the combination lever here also the derived motion is generally similar to that provided by a union link coupled to a crosshead. The motion from the combination lever is transmitted through a plunger working in guides and a valve rod to a valve -operating rocker shaft.

The piston valves are of an unusual design, being outside admission types, driven at a point between the heads by a rocking shaft working in the exhaust cavity. It is sealed through the wall of the casting by a conventional lip seal around the rocking valve shaft. That way there are no reciprocating gland assemblies to be troublesome and the seal is only subject to exhaust pressure.

OTHER VALVE GEAR TYPES

The use of the difficult to make curved link in both Stephenson and Walschaerts valve gear combined with the difficulty of die slippage and associated wear caused the USA to look to a different solution from UK and Europe. Whereas the GWR created the Pendulum Grinder as an aide to easy manufacture of the link to tight limits, The Baker Company in USA decided that the curved link needed to be replaced by pin joints which could all have grease lubricated rolling contact bearings

BAKER VALVE GEAR

Rare in the UK but nevertheless interesting

The Baker Locomotive Valve Gear was produced by the Pilliod Co. of Swanton, Ohio. Subsequent versions were produced up to the end of steam service. It was particularly popular on the Norfolk and Western Railway, and almost all later N&W engines used it (notably NW 611). Other extensive users included the Chesapeake and Ohio Railroad and the Nickel Plate Road. The Railroad and the Baltimore and Ohio Railroad also had large classes, which used Baker gear.

There was always debate about the advantages of Baker gear, the main criticism being the number of pin joints and possible lost motion. Western United States and British railroads tended to continue with the Walschaerts pattern, as did the Pennsylvania Railroad. In Britain Baker gear was popular amongst model engineers but in full-size practice the length of the yoke and the width of the assembly may have been difficult to accommodate within the restricted loading gauge.

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A good animation is available at

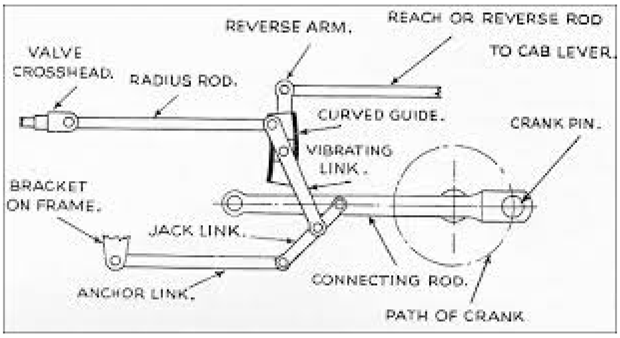
https://www.youtube.com/watch?v=BxIpOYra5QY

When you watch it you will see how this gear is so difficult to understand how it works in practice when the two dimensional drawing finds it difficult to delineate the bell crank at the heart of the mechanism.

JOY VALVE GEAR

Joy valve gear works on the principle of harnessing the vertical component of the motion of the connecting rod linking the reciprocating crosshead to the rotating crankpin, as that motion is approximately out of phase with the piston by 90 degrees and it is therefore appropriate to use this to drive the valves.

Its great virtue lies in the fact that it needs no eccentrics and it leaves the crank axle on an inside cylindered locomotive free of encumbrance which leaves more room for main bearings crank webs and support. This appealed to the former L&NWR, which used the gear widely. One of two surviving examples of the gear which can be seen in steam on a railway is the Super D locomotive 49395 which is part of the National Collection and was brought back to steam by Pete Waterman around 2000 following a catastrophic hydraulic cylinder failure in service at Buxton, during its life on British Railways. The second is the LNWR Coal Tank owned by the National Trust and cared for by the Bahamas Locomotive Society



Joy Valve Gear

SUPER D 49395

COAL TANK 1054

A good simulation of the gear is available on You Tube

https://www.youtube.com/watch?v=BuC7qg9_NeY

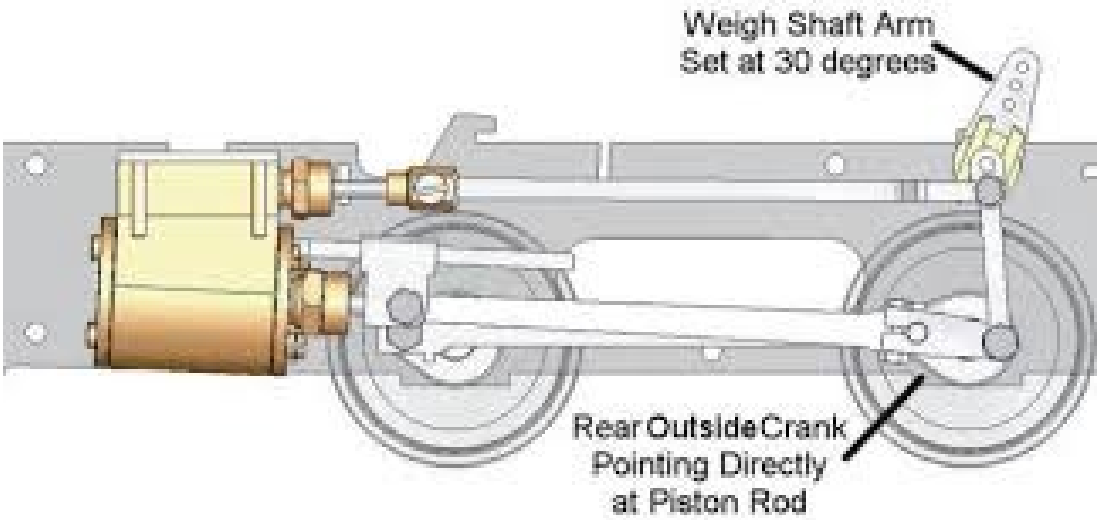
Although the valve gear appealed because of its simplicity and lack of eccentrics it suffered from a major drawback by needing a pivot hole through the centre of the connecting rod which is a highly stressed structural component. Inevitably this led to fatigue problems, which caused the connecting rod to break in half in service. Although this might be seen as a problem that could be managed, the connecting rod on an inside cylindered locomotive once broken in half is faced with two choices; It can either fold downwards towards the track as happened in the case of the Super D tearing the motion plate away, or else it can go upwards or backwards towards the boiler as happened with an LNWR Locomotive at Furness Vale Station where the remains of the rod on the crank axle penetrated the boiler with disastrous consequences.

As an aside, the 1200HP River Don Steam Engine which is preserved as an operating exhibit at Kelham Island Industrial Museum in Sheffield also has Joy Valve gear but the designers Davy Brothers got round the weakness in the connecting rods by forging trunnions at the mid point of each connecting rod thereby eliminating the weakness round the drilled hole. This design enables the engine in full steam to be able to reverse from full ahead to full astern without taking the power off in two seconds. A sight well worth witnessing!

http://www.simt.co.uk/kelham-island-museum/ask@simt.co.uk%20

HACKWORTH VALVE GEAR

Timothy Hackworth was an engineer on the Stockton and Darlington Railway and was well known for a series of locomotives where the wheels were attached directly to the underside of the boiler a long way from the vertical cylinders and valves on the very top of the boiler and he needed a valve gear that could operate from a single axle mounted eccentric and be reversed by the driver on top of the boiler. He arranged a series of levers that brought the motion up to the operating platform



Hackworth valve gear is one of the simplest forms of valve gear available and rather in the same way that Joy valve gear derives its motion from the 90 degree out of phase vertical movement of the connecting rod, the Hackworth gear derives its motion from the out of phase horizontal component of a return crank driven link sliding up ad down in an angled slide. The slide can be set to point forwards or backwards to reverse the engine.

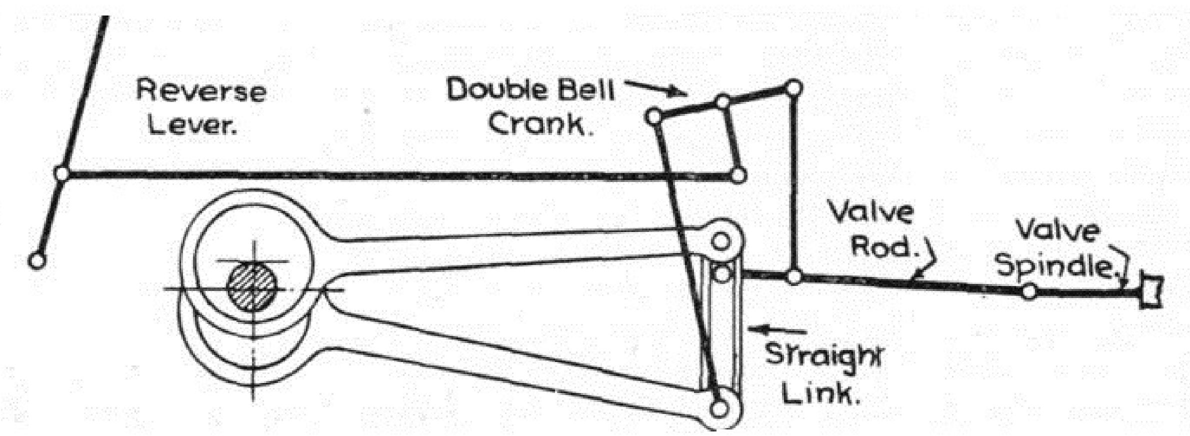
Hackworth gear is commonly found on narrow gauge industrial tank engine where rugged simplicity is more important than delicate finely controlled valve events

One big issue with Hackworth gear is that any vertical movement of the crank axle has a big impact on the valve events, so bad track or sloppy suspension can greatly affect the working of the valves. It is popular with Model Engineers, where rear axle deflections can be minimised by substituting rubber blocks for actual springs.

Another drawback to Hackworth gear is that a really vital and important working element of the locomotive is placed at the locomotive's widest and lowest points where obstructions near the track can easily cause damage to the rotating parts.

ALLAN STRAIGHT LINK VALVE GEAR

Alexander Allan was an Engineer who worked at Crewe Works and was responsible for the design of the so-called Crewe-Type of outside cylindered locomotive.



The Allan straight link valve gear (invented by Alexander Allan in 1855) combined the features of the Stephenson and Gooch gears. The reversing and cut-off functions were achieved by simultaneously raising the radius rod and lowering the link or vice versa. As with the Gooch gear, this saved space but the Allan gear gave performance closer to that of the Stephenson. Moreover, the straight expansion link simplified manufacture. Once again, the Allan gear was not often used in the UK but fairly common on the Continent. Notable UK examples are the GWR 1361 and 1366 classes, and narrow gauge locomotives produced by George England (e.g. "Prince" & "Palmerston" in preservation on the Ffestiniog Railway) and Fletcher-Jennings (No 1 "Tallyllyn" & No 2 "Dolgoch" in preservation on the Talyllyn Railway).

Note the comment about the use of Allan Straight link on the Continent. This takes us back to the accident at Gare de Montparnasse image with the outside eccentrics driving the straight reversing link we saw at the end of the section on Stephenson Link Motion

OTHER FORMS OF VALVE GEAR

The student should be encouraged to study the available data and investigate the different sorts of valve gear. This module cannot be expected to be an inexhaustible reference but a curiosity about how valves are worked should be encouraged in all students who seek to work with steam locomotives.

A good exercise would be to find a valve gear not described here and to create an explanation of how it achieves its objectives

VALVE SETTING

Finding dead centres accurately.

A prerequisite of setting valves with either of the two principle types discussed previously, is to determine the exact point of front and back dead centres and a method is included to determine this. However it might seem un necessarily picky to determine the exact point of dead centre when you can see through observation when the piston and crosshead stops moving at the end of the stroke. But the need to determine this accurately is much more important than a cursory glance might show.

We need the accurate position of direction change because it is at this point that the valve is travelling fastest in its cycle and a very small error in dead centre position corresponds to a large error in valve movement, so getting this right is very important.

To set the valves it is generally necessary to ensure that the valve openings and even as near as possible that which the designer intended them to be. It is often necessary to alter the length of certain rods to achieve the desired result. This can be done by adjustment if available or shortening/ lengthening the rods as necessary.

The driving wheels are mounted on rollers as in the *General Repair* film. The rollers are driven by a hand ratchet or pneumatic drilling machine. However the same result can be obtained by using a pinch bar to move the locomotive along the lines.

There is a splendid you tube film which shows this process well and I commend it.

Students should follow this exercise and then carry out the dead centres exercise unassisted in the workshops.

Next the port openings must be measured. On full size engines the openings must be adjusted so that the front ports open 1/16” more than the back ports so that when everything is hot they will be equal.

https://www.youtube.com/watch?v=rRGGSr68miQ

Setting Walschaerts Piston Valves LMS General Repair film 14 mins in

We would commend students to be-friend someone with a miniature steam locomotive with slide valves as a first step in learning about valve setting. Perhaps the local Model Engineering society would be a good starting point. Ideally you need to start with a Stephenson valve geared engine where the chassis is free of the boiler and it is possible to see into the valve chests to watch the valves traversing the port face as the crank rotates.

Once the action of the valve at dead centres has been mastered in full forward and full reverse, then it is possible to observe the concept that the lead increases as the locomotive is notched up. Indeed the most revealing thing is to observe what happens in Mid Gear where the valve should uncover the port minimally at dead centres and then close again showing that a well set valve will enable the engine to run forwards OR backwards at speed in mid gear!

Once the student is confident with the set up and how to make adjustments, then the same exercise should be repeated with a Walschaerts valve geared locomotive model where the student will see that a completely different set of parameters are at play during notching up.

Now these two exercises should be done to obtain familiarity with valve timing before moving on to piston valves. Don Ashton makes the comment that it is not necessary to be able to see the valve uncovering the port to be able to set them accurately. He argues that measurement of valve travel is far more important than observation. However for the beginner to gain a true understanding there is no substitute for seeing the actual port being uncovered and to observe how rapidly the valve is moving at that moment.

Now some piston valve engine models have what are called timing ports on the outside of the piston valve chamber which enable the piston valve timing to be seen as it uncovers the steam port within the chamber.

In full size practice however, the Don Ashton rule holds good and the valve setters use extension fixtures fitted to the end of the piston valve, which bring a surrogate working valve face and port out into the open air at the front of the cylinder. This gear is shown briefly at 14 minutes in, on the film *General Repair* and it is worth watching this clip several times to that you can get the hang of exactly what is going on.

The big difference with both common types of valve gear described earlier between full size and model practice is that small adjustments to the length of critical rods like eccentric rods is done by sending the rod to the smithy where it is heated to red heat and dropped to shorten it or heated to red heat and hammered to lengthen it. In model engineering circles this is simply achieved with shims.

There is another very useful way of checking valve timing on a model, and that is to run plastic pipes from the drain cocks into jam jars half filled with water. A very low air pressure supply like a paint spray compressor is connected to the steam chests and air bubbles appear in the water as the valve uncovers the port. This is especially useful with locomotives where steam chests and slide valves are situated between the frames where observing the action of the valve is very tricky.

Another way of gaining the necessary knowledge so that students can be confident they fully understand valve gear setting and how it works is to get access to one of the Mutual Improvement Class models that were generally made within house at Railway Workshops to allow new recruits to learn the trade.

Many of these models survive and still have a useful life at preserved railways where the teaching continues. Typically they would be quarter full size and would allow the valve events on a specific design to be studied. (It is understood that BESTT has recently acquired one of these from the K&WVR, which is to be welcomed). This example shown below is of a Walschaerts Inside admission locomotive with screw reverse and makes an excellent learning resource.

STEAM LOCOMOTIVE MOTION

This is the name given to the parts of the locomotive that connect the wheels and drive from the cylinders together and allow reciprocating motion to be converted to rotary motion.

There are some very special engineering issues to be overcome within the design of the motion to allow the locomotive to function effectively at speed.

Materials for rods and bushes and pins see FIG 86

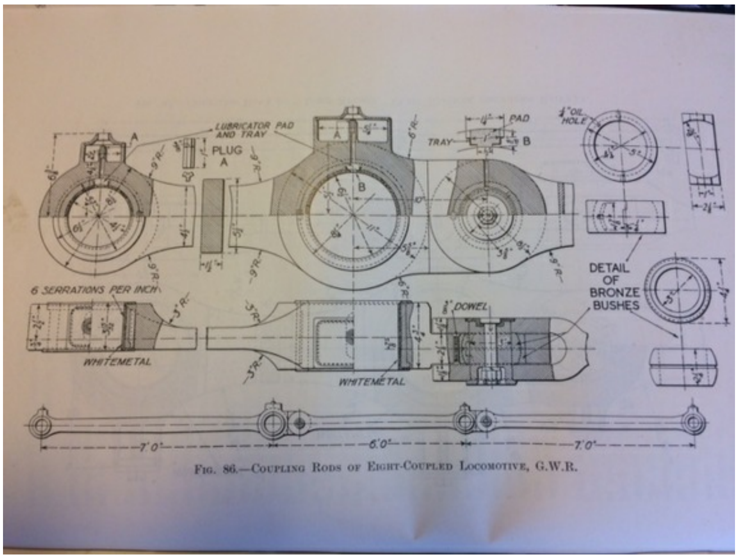


Fig 86

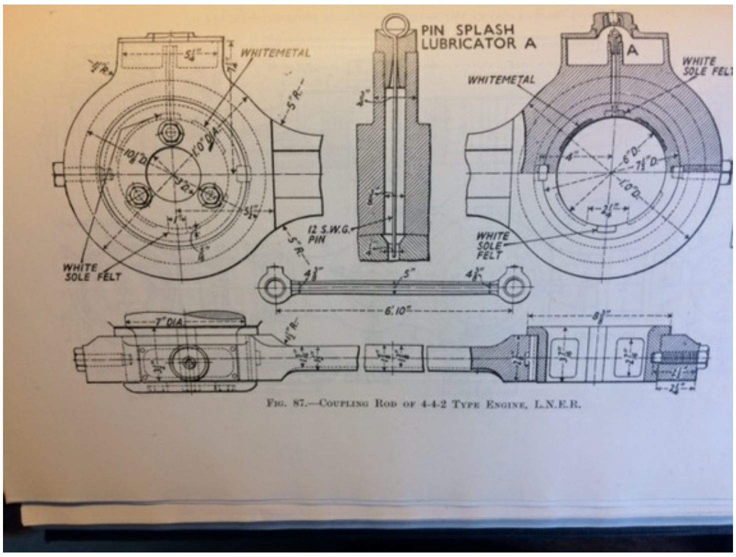


Fig 87

The coupling rods and connecting rods of a steam locomotive are such a vital and obvious feature of the appearance that the hidden purpose of what they achieve is often obscured.

Anyone who has ever driven a pedal car will know that for the drive to be really effective the driving thrusts must come at 90 degree intervals with a two cylindered locomotive. The wheels as we have previously seen in wheels and axles are fastened to the axle with keys and keyways set at 90 degrees. The wheels are constrained to stay in time by the coupling rods, yet the wheels and axles can move up and down over rough track because the springs and hornblocks allow independent vertical movement of the axleboxes.

In order to accommodate this the coupling rods have a pivoted joint, usually to the rear of the centre bearing. The joint is known as a *Gradient Pin* for obvious reasons as it allows the coupling rod to flex vertically.

If one wheelset moves vertically in relation to the others it is inevitable that the distance between the centres of the wheels will change and tighten as the coupling rod shortens. So clearances have to be introduced between the rod and crankpins to allow the rod to do this without locking up. MT276 encourages the creation of clearances at the extremities of the coupling road rather than in the middle where excessive clearance will introduce knocking.

The longer the coupling rod the more pronounced are the issues and there is one North Eastern Railway eight coupled heavy freight locomotive (I think it's the TA CHECK) where there is not only a gradient pin to allow differential vertical movement, but there is a vertically pinned joint on the rear section of the coupling rods to allow the coupling rods to have sideways freedom as the rear wheelset tries to move about sideways within the long rigid wheelbase to negotiate tight curves.

Now the rotating of the coupling rods brings us to the issue of out of balance forces and how a steam locomotive copes with these forces at high speed. The answer is that the classic steam locomotive copes badly with out of balance forces, and trying to find a balance compromise is difficult. One difficulty is that the wheels and axles are able to have vertical freedom within the hornblocks even though they are constrained fore and aft by the horn-cheeks. To try and minimise this effect the rods are often designed to be of "I" section, which is the strongest, section available for a given weight. Often in high-speed engines the coupling rods are made of high strength alloy steel, which means they can be made of lighter section, and still do the job. The coupled wheels themselves are not uniform discs because they have a boss for the crankpin as part of the wheel centre, so this introduces more out of balance forces. Most of this is compensated for by having cast or applied balance weights within the perimeter of the wheel and the idea of this is to try and minimise that is known as "Hammer Blow" which we have surely all experienced in cars when unbalanced wheels vibrate alarmingly up and down at certain speeds. The effect of this with a heavy steel wheel on a steel rail is to pound the surface of the rail and wheel with forces many times the static loading on the wheel rail interface. That is why the early railway civil engineers used to keep the mechanical engineers of the early railways on a tight rein for axle loading wherever they could as train speeds rose!

But that is not the end of the problem for balancing as the heavy connecting rod which joins the reciprocating crosshead to the rotating crankpin, is oscillating in a straight line at the crosshead end (little end) and rotating in a circle at the crankpin end (big end).

Trying to balance some or part of the strange motion sets the mechanical engineers a real problem and a compromise has to be reached where perhaps two thirds of the total weight of the connecting rod is compensated for by additional balance weights on the driving coupled wheels. So a useful exercise is to look at side on images of various steam locomotives and observe the varied and sometimes strange balance weight configurations. (Students to do a survey within their workshop)

The problem is made more complicated by locomotives with inside cylinders whose cranks might be set at 120 degrees for a three cylinder locomotive or 90 degrees for a four cylinder locomotive (*Lord Nelson*)

I have seen an aerial photograph of a Norfolk and Western “J” type locomotive taken with a fast film at high speed from a plane, and one of the sets of six coupled driving wheels is at least two inches clear of the track as the coupled unit bounced up and down on the track. No wonder the civil engineer was worried about the damage that fast powerful locomotives were doing to his tracks and bridges! It makes it easier to understand perhaps how William Stanier was very keen to experiment with steam turbine or diesel electric driven locomotives as a successor to the steam locomotive

LO1: Valve Gear - General

1. Types of Valve Gear
2. Eccentrics
3. Sheaves
4. Eccentric, Sheaves and rods
5. Throw
6. Expansion link
7. Die block

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO1 1	Types of Valve Gear	Name the three common types of valve gear you are likely to encounter.	Classroom	
LO1 2	Eccentrics	What is an eccentric? Draw a diagram. Why are they two per valve?	Classroom	
LO1 3	Sheaves	Draw a typical eccentric sleeve	Classroom	
LO1 4	Eccentrics, Sheaves and Rods	What is the purpose of an eccentric & sheave?	Classroom	
LO1 5	Throw	What is the throw of an eccentric?	Classroom	
LO1 6	Expansion link	Draw a typical expansion link	Classroom	
LO1 7	Die block	What is the purpose of a die block?	Classroom	

LO2: **Stephenson Valve Gear**

1. Eccentric Rods
2. Reverser
3. Notching Up
4. Admission valves
5. Valve arrangements
6. Suspension Links
7. Suspension methods
8. Disadvantages

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO2 1	Eccentric Rods	If the reverser lever is put in full forward gear referring to fig 1, which eccentric rod drives the valve?	Classroom	
LO2 2	Moving reverser	What affect does moving the reverser have on the eccentric rods	Classroom	
LO2 2	Notching up	What is meant by 'notching up'?	Classroom	
LO2 3	Cut off	What do you understand by the term 'cut off'?	Classroom	
LO2 4	Inside admission valves	What difference does inside admission valves make to the arrangements?	Classroom	
LO2 5	Stephenson valve arrangements	How many arrangements of Stephenson's gear are there?	Classroom	
LO2 6	Suspension links	Why is the method of suspension important?	Classroom	
LO2 7	Suspension links	Which is the preferred method for an express locomotive?	Classroom	
LO2 8	Disadvantages	What are the disadvantages of Stephenson's gear in terms of construction?	Classroom	

LO3: WALSCHAERTS VALVE GEAR

1. Advantages
2. Walschaerts valve gear Typical Pistons
3. Reversing
4. Lap & lead
5. Die block
6. Return Crank Bearing

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO3 1	Advantages	What are the advantages of Walschaerts valve gear over Stephenson's	Classroom	
LO3 2	Walschaerts valve gear	Draw as simplified diagram explain the operation	Classroom	
LO3 3	Reversing	How is reversing and variation of travel achieved?	Classroom	
LO3 4	Lap & Lead	Where is the Lap & Lead motion derived from?	Classroom	
LO3 5	Die block	Why is it preferred that the die block is at the lower end of the expansion link in forward gear?	Classroom	
LO3 6	Return Crank Bearing	What type of bearing is used in this position and why does it need to be spherical?	Classroom	

LO4: OTHER VALVE GEAR

1. Gresley Conjugated Valve Gear
2. Bulleid-Walschaerts Valve Gear
3. Baker Valve Gear
4. Joy Valve Gear
5. Hackworth Valve Gear
6. Allan Straight Link Valve Gear

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO4 1	Gresley Conjugated Valve Gear	Describe with the aid of diagrams Gresley's conjugated valve gear	Classroom	
LO4 2	Bulleid-walschaerts valve gear	Describe with the aid of diagrams Bulleid-Walschaerts Valve Gear	Classroom	
LO4 3	Baker Valve Gear	Describe with the aid of diagrams Baker Valve Gear	Classroom	
LO4 4	Joy Valve Gear	Describe with the aid of diagrams Joy Valve Gear	Classroom	
LO4 5	Hackworth Valve Gear	Describe with the aid of diagrams Hackworth Valve Gear	Classroom	
LO4 6	Allan Straight Link Valve Gear	Describe with the aid of diagrams Allan Straight Link Valve Gear	Classroom	

LO5: VALVE SETTING

1. Dead centre position
2. Determine the Dead centre position
3. Setting Piston Valves
4. Setting Piston Valves
5. Setting Length of rods
6. Models of Valve Gear

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO5 1	Dead centre position	Why is it important to determine accurately the dead centre position?	Classroom	
LO5 2	Determine the Dead centre position	Carry out in the workshops the exercise to determine the dead centres.	Workshop	
LO5 3	Setting Piston Valves	Set the valve travel for a locomotive with Stephensons Valve gear	Workshop	
LO5 4	Setting Piston Valves	Set the valve travel for a locomotive with Walschaerts Valve gear	Workshop	
LO5 5	Setting lengths of rods	How could the length of critical rods be modified?	Classroom	
LO5 6	Models of Valve gear	Visit a mutual Improvement classroom or other places such as the NRM and study the various models used to explain valve operation	Classroom	

LO6: **Routine Examination for Valve Gear**

Refer to MT 276 for limits of wear

1. Steam Leaks
2. Motion
3. Cylinder drain cocks
4. Fastenings
5. Distortion of Piston Rods
6. Lubrication
7. Cross arms
8. Radius Rod
9. Rocking shafts and levers
10. MT 276 2.03

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO6 1	Wear on reverser	Check for wear on the screw thread of the reverser lever	Workshop	
LO6 2	Reversing Shaft	Check for any excessive wear in the shafts and bushes	Workshop	
LO6 3	Hanging links	Check for wear and security	Workshop	
LO6 4	Eccentric straps and sheaves	Check for cracking, excessive side play or lift	Workshop	
LO6 5	Sheaves	Check for any movement on the axle and ensure the keys are tight	Workshop	
LO6 6	Eccentric rod	Check end nuts, fork end pins, nuts and spit pins for security	Workshop	
LO6 7	Die block	Check for wear or damage	Workshop	
LO6 8	Radius Rod	Check for security and wear	Workshop	
LO6 9	Rocking shafts and levers	Check for wear and security and also check anchor bolts for security	Workshop	
LO6 10	MT 276 2.03	Carry out checks as described in MT276 section 2.03	Workshop	

LO7: Locomotive Motion

1. Motion
2. Coupling rods
3. Clearances
4. Section of Rods Lubrication
5. Balance
6. Balance

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO7 1	Motion	What is meant by the term ‘Motion’ in the terms of a steam locomotive?	Classroom	
LO7 2	Coupling rods	How are the coupling rods arranged to allow independent movement of the wheels?	Classroom	
LO7 3	Clearances	What clearances does MT276 suggest for the ends of coupling rods?	Classroom	
LO7 4	Section of Rods	What cross section is often used for rods and why?	Classroom	
LO7 5	Balance	How is the motion balanced?	Classroom	
LO7 6	Balance	Study images of different types of locomotive and comment on the methods of balancing.	Classroom	

LO8: **Locomotive Motion Inspection**

Refer to MT 276 for limits of wear

1. Coupling rods/connecting rods
2. Pins and washers Section of Rods
3. Coupling rod joint pins
4. Gudgeon pins
5. Crosshead
6. Motion bars
7. Big ends

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO8 1	Coupling rods/connecting rods	Examine for any signs of wear or damage, lack of lubrication and excessive play	Workshop	
LO8 2	Pins and washers	Check all washers, safety bolts and spit pins/taper pins for security	Workshop	
LO8 3	Coupling rod joint pins	Check for excessive play and for discolouration which could indicate overheating	Workshop	
LO8 4	Gudgeon pins	Check gudgeon pins for tightness and spit pins etc. are correctly fitted and secure	Workshop	
LO8 5	Crosshead	Examine crosshead arms for security and cracking around holes	Workshop	
LO8 6	Motion bars	Check for excessive clearance between crosshead and motion bars	Workshop	
LO8 7	Big ends	Check big ends for excessive side clearance or lift. Examine Keep, glut and any cotter and spit pins for security	Workshop	

On completion of the module the trainee should be able to use correctly and safely the following equipment:

- Measuring instruments
- Hand Tools

Assessment

Learners could demonstrate competence in this unit by:

- Documental evidence
- Photographic evidence
- Witness statements e.g. written or verbal statement from a competent person stating that they have completed tasks satisfactorily.
- Underpinning knowledge questions e.g. written questions, multi choice answer sheets, on-line tests, and assignments.
- Practical training tasks

BESTT Locomotive repair and overhaul - Module LM5 – Valve Gear and Motion

Assessment Record for: **Training Centre:** **Year:**

LO1	**1**	**2**	**3**	**4**	**5**	**6**	**7**			
Supervisor Initials and date										
LO2	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
Supervisor Initials and date										
LO3	**1**	**2**	**3**	**4**	**5**	6				
Supervisor Initials and date										
LO4	1	2	3	4	5	6				
Supervisor Initials and date										
LO5	1	2	3	4	5	6				
Supervisor Initials and date										
LO6	1	2	3	4	5	6	7	8	9	10
Supervisor Initials and date										
LO7	1	2	3	4	5	6				
Supervisor Initials and date										

LO8	1	2	3	4	5	6	7			
Supervisor Initials and date										

Witness Statement: The trainee has completed the Learning outcomes to a satisfactory standard

Supervisor signature: **Print Name:** **Date:**

Verified by BESTT Assessor **Name:** **Assess**