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## Steam Locomotive Repair and Overhaul

## Module LM4

# Steam Locomotive Cylinders, Pistons and Valves

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**October 2017 – version 1.1**

**Module BESTT LM4**

**Steam Locomotive Cylinders, Pistons and Valves**

## Aim

This unit will give learners an understanding of how Locomotive Cylinders, Pistons and valves are arranged, constructed and operate.

The learner will consider: -

Cylinders

Different types of valves

Pistons

Inspection

Materials

**Learning Outcomes**

LO1 Cylinders

LO2 Valves

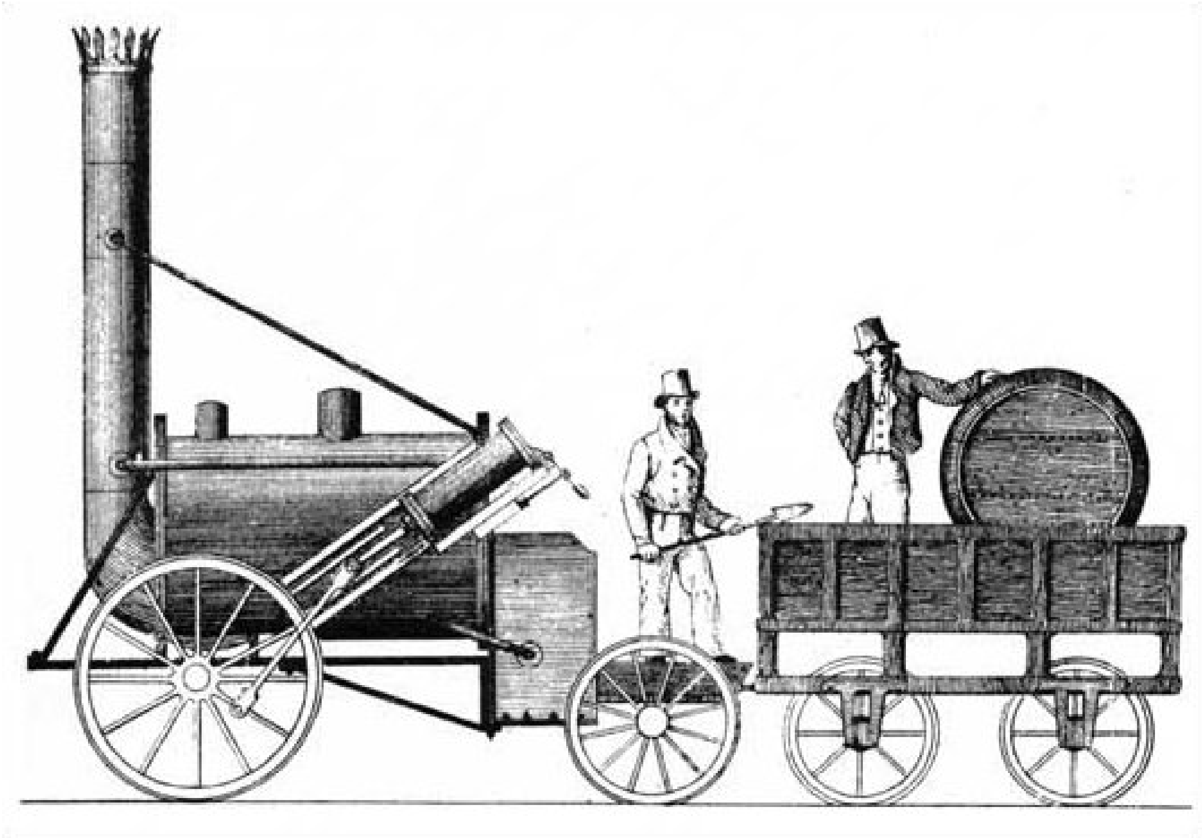
LO3 Pistons

LO4 Routine examination

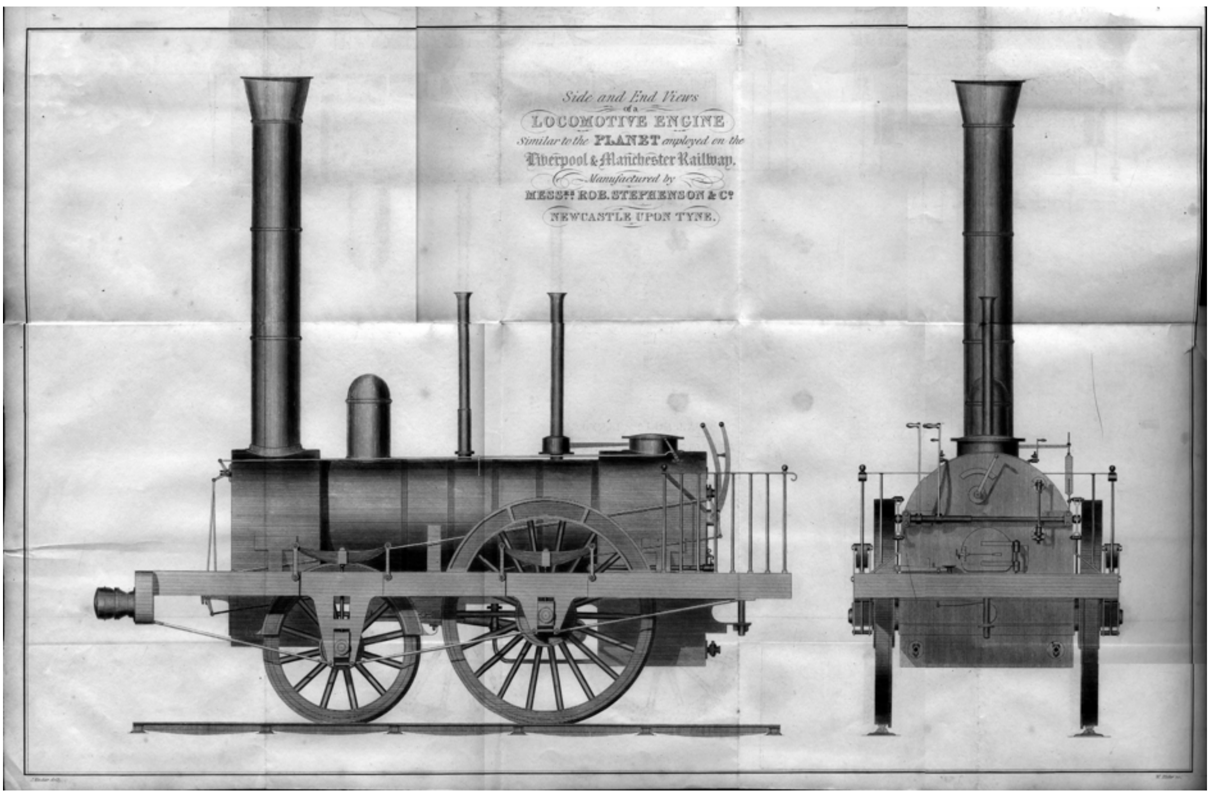
LO5 Inspection – locomotive stripped

**INTRODUCTION**

The cylinders of standard gauge locomotives in the UK can be found either outside or inside the frames or indeed both in the case of 3 cylinder locomotives. (See module LM3) The cylinders house pistons, which are pushed backwards and forwards by steam to provide the forces at the wheels to power the locomotive and train along the track. Like the cranks on a bicycle or pedal car the forces are generally arranged within the cylinders at 90 degrees so that one cylinder is providing the full available force whist the piston in the other cylinder is changing direction.

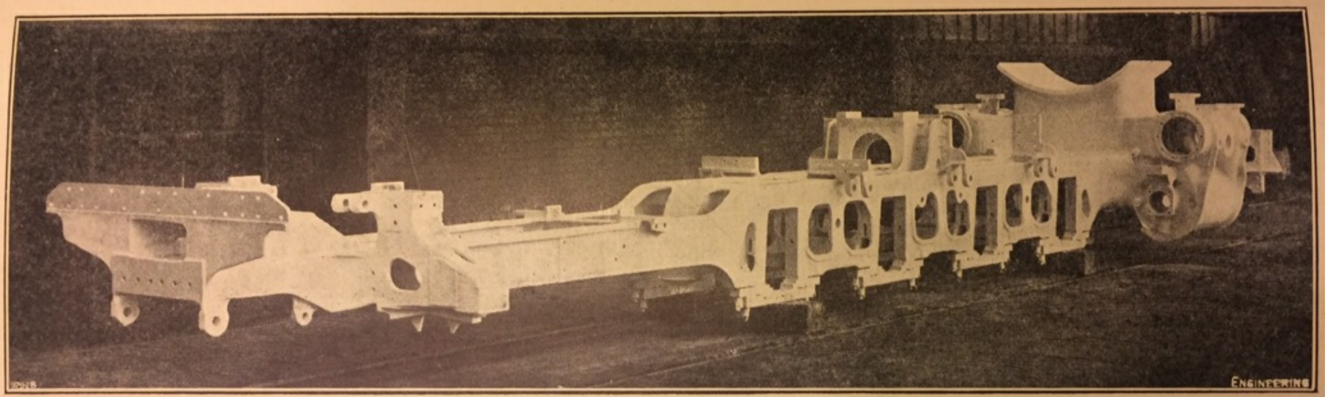


Early locomotives like Stephenson’s Rocket had outside cylinders firmly fastened to the frames to resist the propelling forces but very rapidly the early engineers realised that there were advantages from bringing the cylinders round to the front and putting them between the frames. The principle effect of this was to make the force to the axle nearly horizontal which prevented the rocking motion to which Rocket was liable. This change got all the forces aligned more advantageously.



Although this involved the construction of a technically challenging crankshaft for the driving axle it had advantages in terms of the overall width of the locomotive and there were thermal advantages to be derived from having the cylinders snugly tucked away under the smokebox keeping them warm and free of condensation.

It is interesting to digress here for a moment to look at practice in the USA and on the Continent and South Africa where often Bar Frames were the norm as the steam locomotive developed and became more powerful and because of their greater frame width there was insufficient room left between the inside faces of the frames to allow two full size cylinders side by side between the frames. Almost without exception bar framed locomotives had their cylinders placed on the outside.  Indeed the cylinders were often cast in one unit with the frames, which created a hugely rigid structure suitable for resisting the "Racking" forces so strongly felt in a locomotive frame.



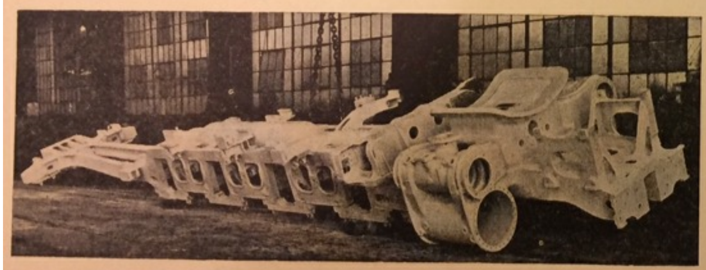



*Fig. 8.* Cast-steel Locomotive Beds.
*Above.* South African Railways 2-8-4 Locomotive.
*Left.* New York Central 4-8-4 Locomotive.

But for the purposes of this module we need primarily to concern ourselves with plate framed locomotives with inside or outside cylinders (or even both inside and outside in some cases).

The cylinder is generally a separate casting which is bolted to the frame of the locomotive with fitted or "driven" bolts thus able to resist the forces described above

The cylinder contains a close-fitting piston which is attached firmly to a piston rod which projects through the rear face of the cylinder and is guided by a crosshead to move in a straight line back and forth.

Although one end of the cylinder is generally sealed, it is necessary to have some sort of sealing arrangement where the piston rod passes through the rear cover of the cylinder in order to ensure steam-tightness. This is called a gland or stuffing box and will be covered later in the module.

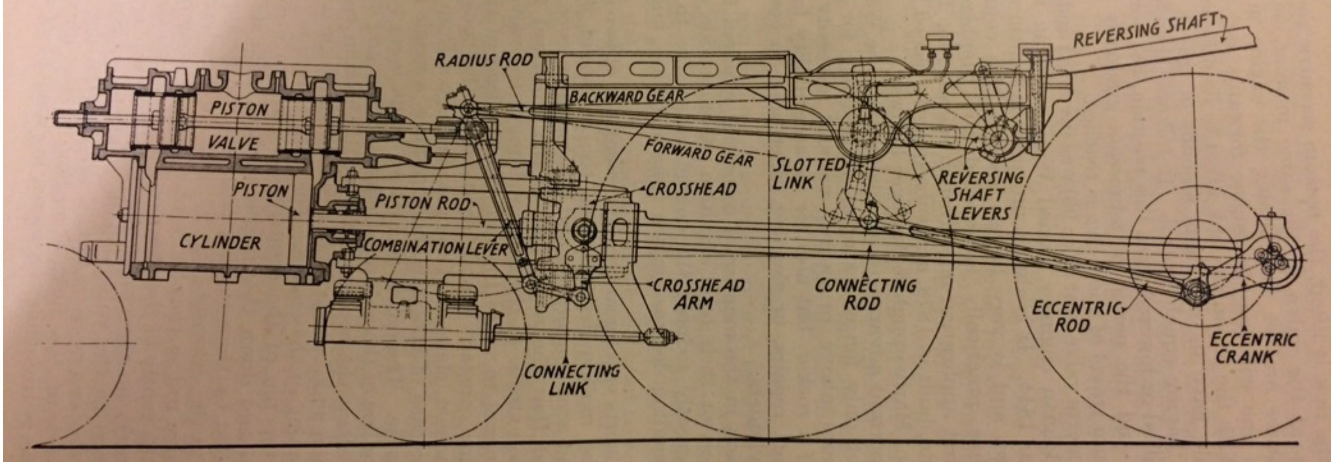


FIG. 93.—THE WALSCHAERTS VALVE MOTION APPLIED TO OUTSIDE CYLINDERS OF A MODERN EXPRESS LOCOMOTIVE.

Cylinders and pistons are generally made from cast iron. This material is ideal because the free graphite in the cast iron will ensure that the surfaces slide easily together. However, this sliding must be accompanied by lubrication in order to be really effective, and the topic of steam cylinder lubrication will be covered later in this module.

The inside of the cylinder barrel is bored to receive the piston with its multiple piston rings. When the cylinder is new or after Works repairs the clearance on the diameter of 1.5 mm is allowed between the piston and bore, the steam tight joint being made by the piston rings described later. The clearance may increase due to wear to as much as 8mm or more. The ends of the bored cylinder are bell-mouthed so that the piston and rings can be entered into the bore without damage during assembly

In some examples locomotive cylinders can be made of cast steel for added strength and in such cylinders a cast iron liner is inserted into the bored cylinder so that the satisfactory friction pairing of a cast iron piston in a cast iron bore is retained.

The way the steam from the boiler is led to the correct end of the cylinder to force the piston back and forth is achieved by means of valves. There are three different kinds of valve we need to concern ourselves with here.

The first very basic valve is called a Slide Valve and is that used on Stephenson's Rocket and many simple locomotives since.  The important feature to remember is that the steam pressure is pushing the slide valve hard against the flat valve face, which causes some frictional losses and wear.

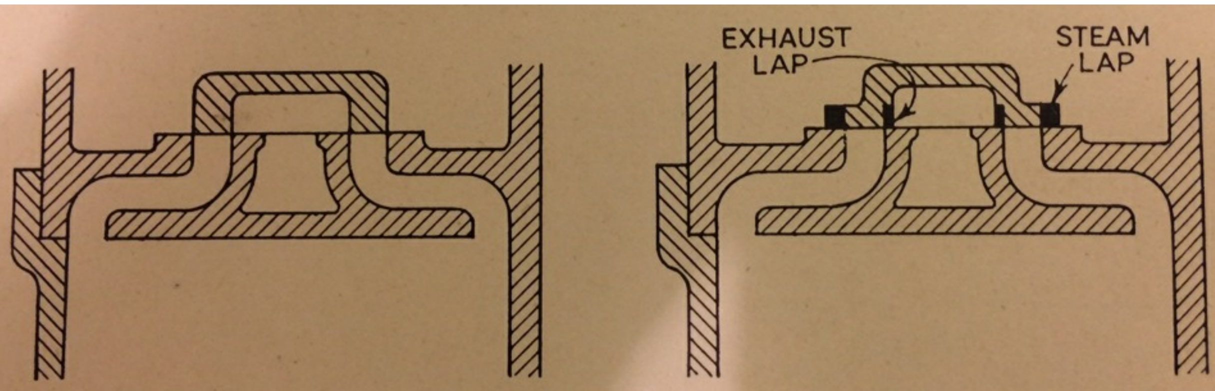


*Fig.* 1. Slide Valve. *Left* without Lap, *right* with Lap.

The second type of valve is called a piston valve and although it is more complex than the slide valve it has great advantages and is more appropriate for the modern high-performance steam locomotive. The majority of passenger and many goods locomotives built during the twentieth century had piston valves. There is little frictional loss like there is with a slide valve.

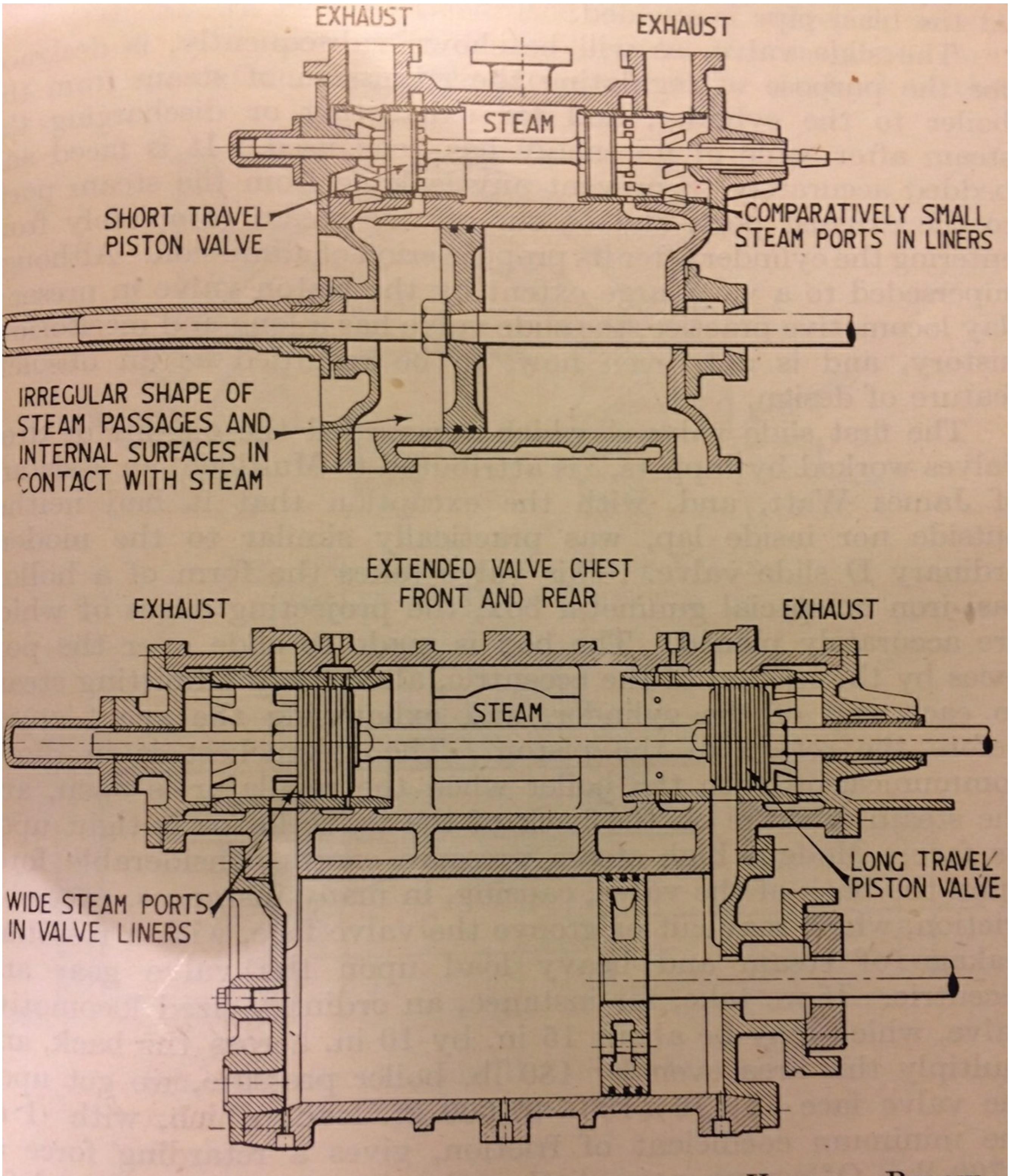



Fig. 99.—Above: Old Pattern Cylinder and Valve. Below: Cylinder Valve and Piston of New Standard Locomotives, L.M.S.R.

marked with a letter " D " on th

The third type of valve is known as a poppet valve and has many advantages over the piston valve but as it was used seldom in the UK its details are outside the scope of this module but much has been written and is available in the literature list with the module.

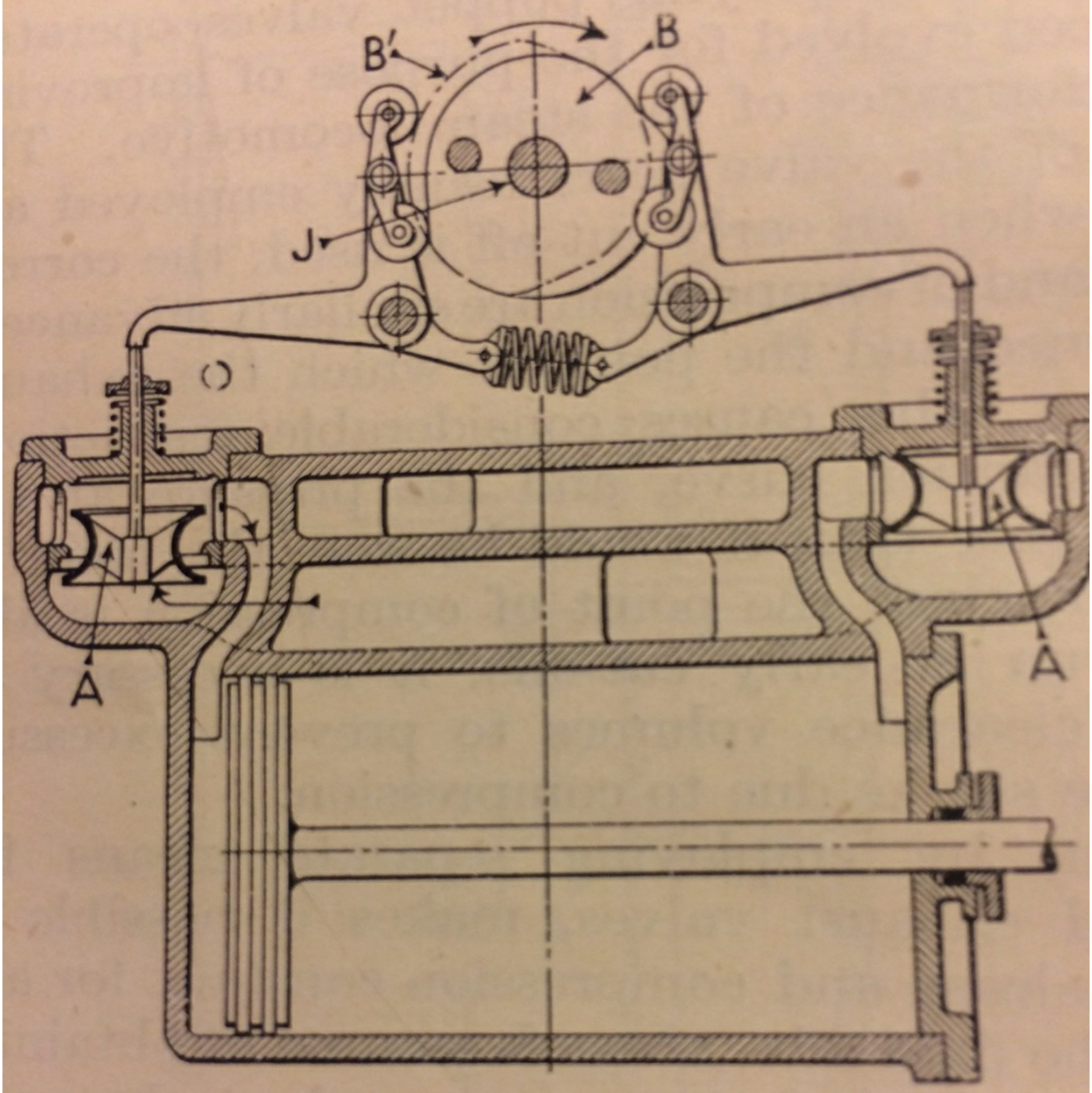



FIG. 107.—SECTION THROUGH CYLINDER AND INLET VALVES.

DESCRIPTION OF HOW A SLIDE VALVE WORKS

We start with the simple slide valve where the section through the cylinder shows that the valve is lying over three ports cut into the flat port face. The left hand one feeds the left end of the cylinder and the right hand one connects with the right end of the cylinder. There is a cavity under the valve which is broad enough to span any two of the three ports on the port face, but not all three. The centre port which is generally wider than the other two connects to the exhaust of steam from the cylinder. That is generally up the chimney via the blast pipe. It can be seen that as the slide valve is moved a small amount left or right, steam surrounding the valve in what is called the valve chest, is admitted to the slightly open port that feeds down to the piston and the steam pressure is able to push the piston within the cylinder bore. The cavity under the valve is in the meantime able to connect

the centre exhaust port to the steam port not directly in use at the time. This enables the used steam to escape from the cylinder unhampered.

Once the piston has completed its stroke under pressure the valve is moved (by valve gear) to the opposite position where steam is now admitted to the opposite end of the cylinder pushing the piston back, and now the exhaust from the first stroke is able to escape through the back of the valve again and through the centre port up the chimney, completing the cycle.

However, the simple slide valve can be made much more sophisticated than that, by the simple expedient of making it longer and increasing its available stroke.

*Image of slide valve with "lap"*

With this set up the valve with lap is longer than the simple valve. A longer valve has to travel a greater overall distance to do its job. It uncovers the relevant port to steam and whilst allowing the exhaust to stay open, after a predetermined period of staying open, the valve "cuts-off" the steam port it has just opened, and leaves the steam trapped inside the cylinder, continuing to push the piston as the trapped steam expands. Because the valve travels further in one cycle than it did with the simple set up described above, it follows that the valve is moving faster over the port face and gives a more rapid opening and closing action. This improves locomotive performance by making the valve action over the ports more lively.

A further improvement to the simple slide valve's performance can be made by allowing the valve to just crack open BEFORE the piston reaches dead centre. When this occurs the admitted steam gathers at the front or rear of the cylinder and cushions the oncoming motion of the piston as it reverses ready to begin the next stroke.

This cracking open of the valve before dead centre is called "lead "and again can improve the locomotive's overall performance considerably

The action of the valve gear which drives the valve to achieve these improvements is described more fully in the Valve gear and Motion module (LM5) but it is sufficient for now to understand that the valve controls the admission and exit of steam to and from the ends of the cylinders.

The friction of the flat valve on the valve face means that all the components of the valve gear need to be substantial to withstand the reciprocating forces involved. One of the ideas behind the invention of the piston valve is that because it does not get pressed against a port face by steam pressure, it merely fits snugly into the circular chamber above the cylinder, it generates almost no frictional forces but merely plugs the gap involved. In practice it is possible to move a piston valve of a large locomotive by hand when under full steam whereas it is really difficult to move a slide valve by hand.

There have been various attempts through locomotive history to reduce the friction under the face of a slide valve by balancing some of the pressure forces. Probably the most successful of these is the Richardson balanced slide valve, but it is complex and can only work with certain configurations of steam and exhaust porting

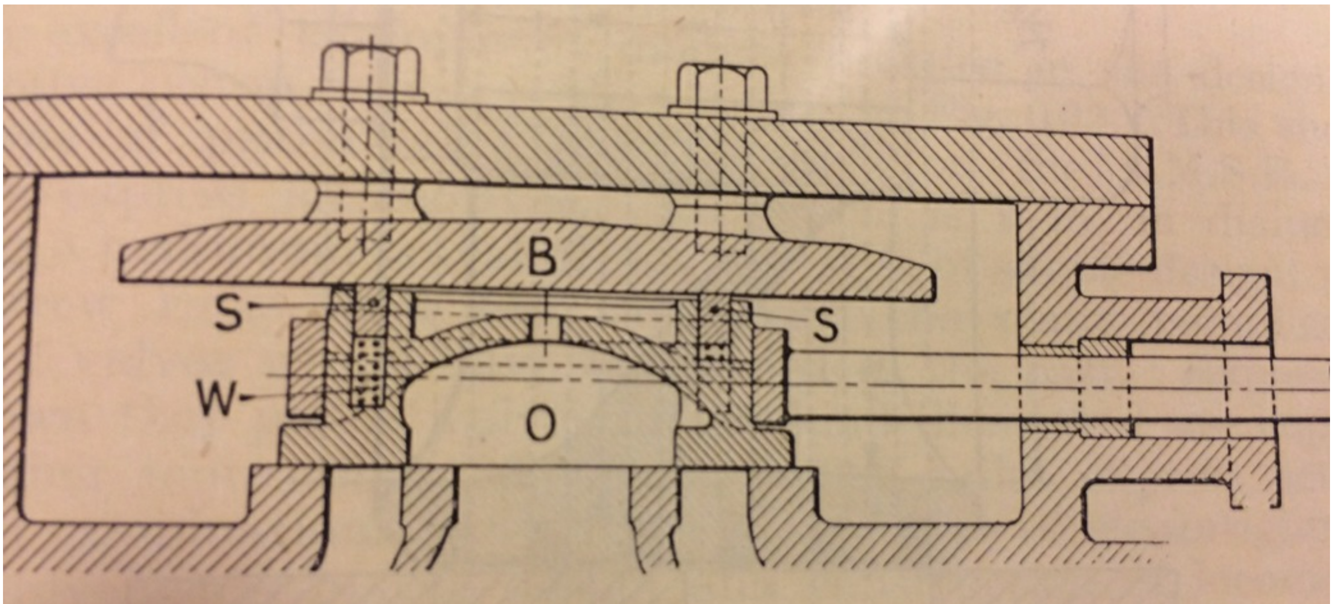



FIG. 101.—RICHARDSON BALANCED SLIDE VALVE FOR LOCOMOTIVES.

DESCRIPTION OF HOW A PISTON VALVE WORKS

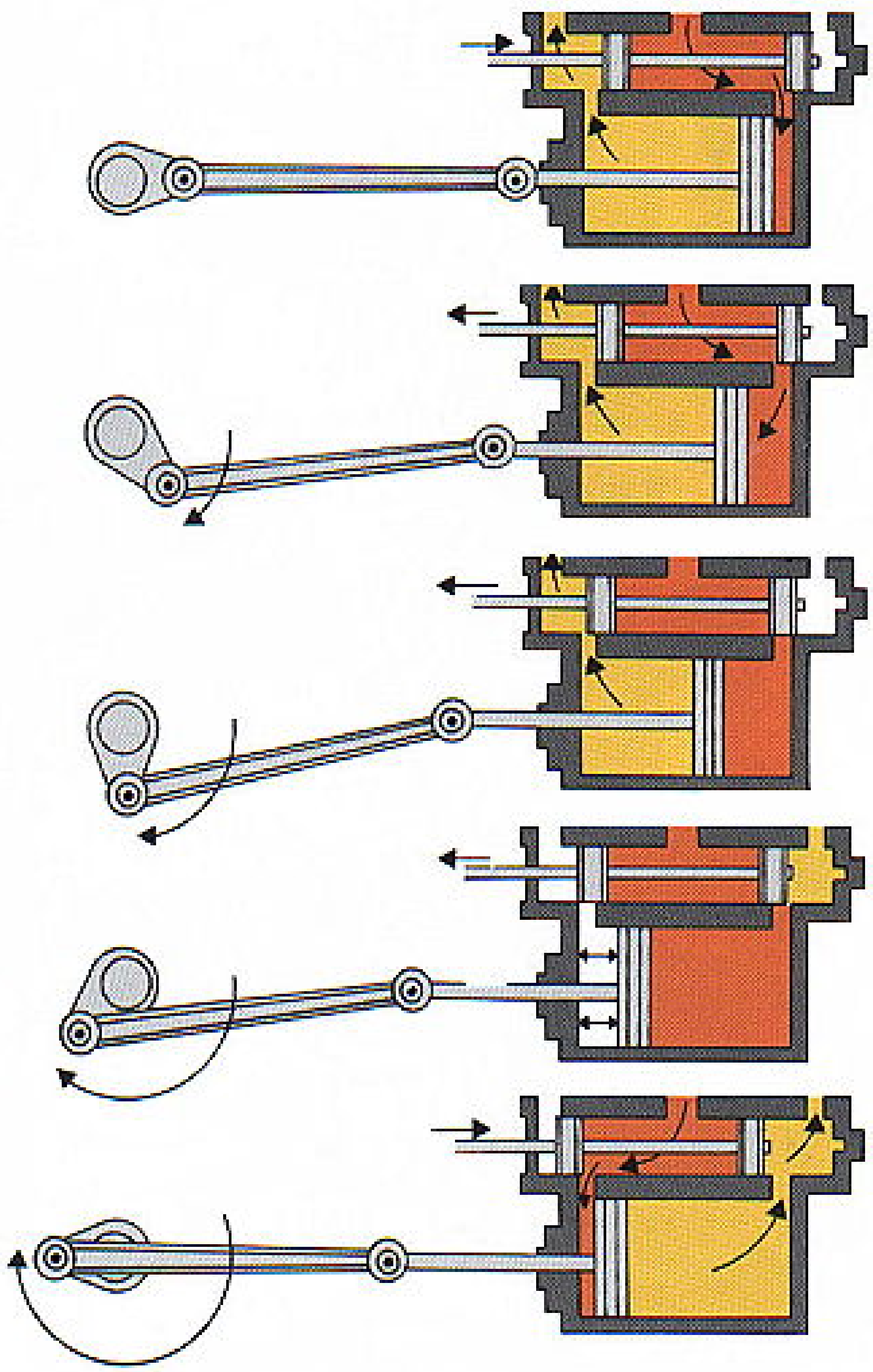
Just as the slide valve works back and forth within a steam chest, so the piston valve works within a smaller cylinder usually above the main piston which is longer than the main cylinder.

In the case of “inside admission” piston valves the steam from the boiler is admitted at a point half way along the length of the steam chest, either through a branch pipe integral with the cylinder or through a separate pipe connected by a flange joint.

The piston valve itself consists of a bobbin shaped component which is a perfect sliding fit into the steam chest. Each end of the bobbin has a valve head which is fitted to the valve spindle. The valve spindle passes through the cover of the steam chest and is driven by the valve gear. The valve heads reciprocate within the steam chest liner and are fitted usually with multiple piston rings, which fit the bore of the liner.

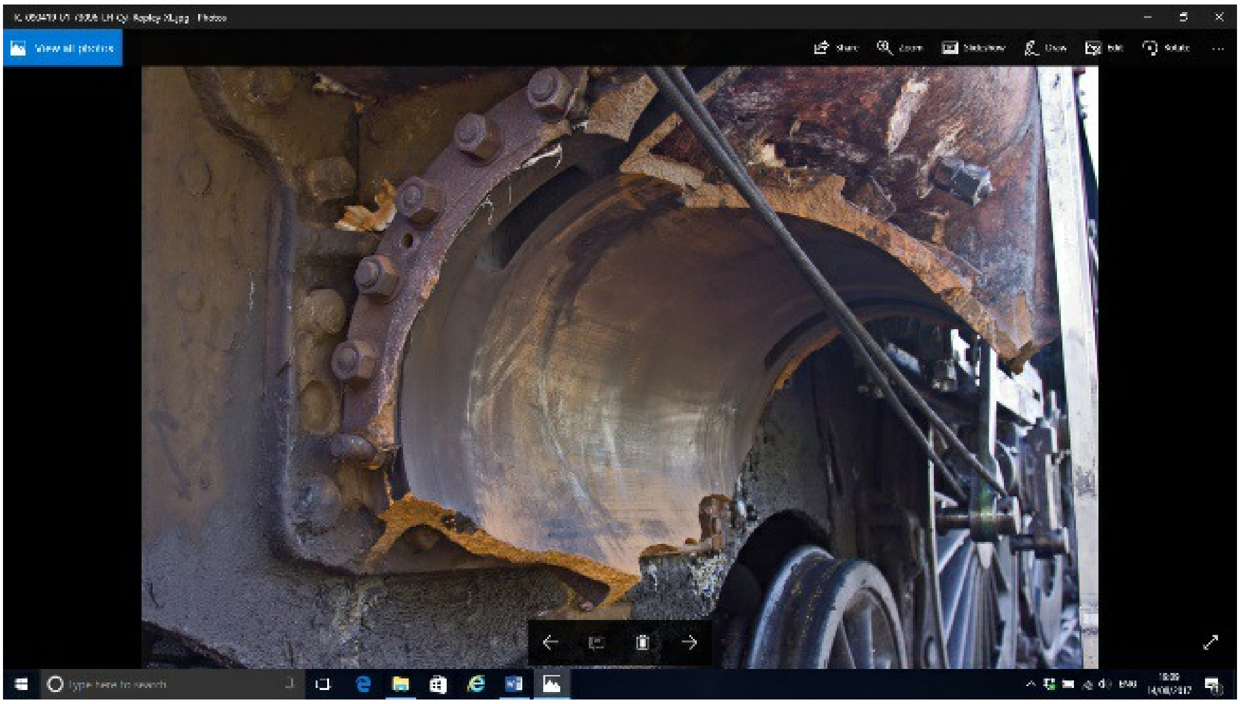
Piston valves may be inside or outside admission depending on where the steam is led to the steam chest bringing the steam to the bobbin either “inside” or “outside” the piston valve heads.

Inside admission is the more common type of piston valve so we will consider this first.



In the diagram above the pressurised steam is shown in red and the exhaust or spent steam is shown in brown. Something very interesting is occurring in the fourth diagram where steam is being admitted to cushion the piston and its attached hardware approaching the rear cover. This cushioning creates a smoother cycle and starts to build up the pressure ready to change the direction of the piston.

Although piston valves are virtually friction free in operation, and give a vastly improved area of steam porting there is one area where the piston valve is at a disadvantage to the humble slide valve. That is in how the two types of valve are able to deal with trapped water (condensed steam) in the cylinder. The slide valve simply gets pushed up off its face by the water pressure and the water is driven back into the steam chest. However the piston valve has no such escape route for trapped water and correctly set spring loaded relief valves (See later in this module) must be provided to allow for the compressed water to escape as the piston moves forward into the closed space. Even correctly set relief valves are sometimes not fast enough to cope with the hydraulic shock and there are many cases of the complete cylinder block being smashed in a moment of forgetfulness.  Great care must be taken with the early steps of a piston valve locomotive from cold to avoid a disaster like that shown below.



*NB No copyright obtained yet for photo! Mid Hants Rly*

This photo clearly shows the steam ports at each end of the cylinder and the effect of a hydraulic lock. Note that the remnants of the front cylinder cover are still in place.

The piston valve is shown in the diagram of the five positions as just a plain bobbin working in a smooth bore. That is fine in a diagram but the reality is that we need the bobbin to be a steam tight fit in the piston valve liner for many years of the locomotives life which means that piston valve rings need to be fitted to the bobbin to obtain a steam tight fit. Piston rings need to fit snugly into supporting grooves and it can be seen from the figure below that there can be confusion over which part of the bobbin is actually opening the port to steam.  The diagram makes clear how this can be avoided, but clearly special shapes are needed so that the moment of entry of the steam from one chamber to another is perfectly defined.

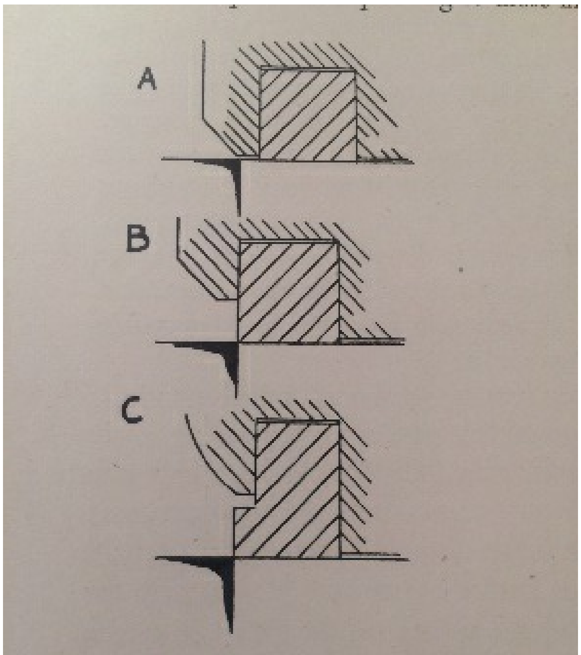


*Fig. 1.* Methods of fitting rings relative to valve heads. In each case

LONG TRAVEL VALVES

Long Travel valves should really be called Rapid Travel Valves because the basic valve (either slide or piston) which uncovers the steam and exhaust ports twice in each revolution as described above needs to travel in total only just over twice the width of the steam port to do its simple job. With that length of valve travel it is inevitable that the opening of any port is a relatively slow process during one revolution, so during starting when steam delivery needs to be at a maximum as soon as the piston sets off on its journey, normal valves are hampered by slow opening characteristics.  It was George Jackson Churchward, Chief Mechanical Engineer of the Great Western Railway in the UK who having looked at what the French and the USA at the turn of the nineteenth century were doing, realised that extending the both the length and travel of the valve over the ports, meant that as the valve starts to uncover the port, it is travelling much faster than in the simple case above. This means the uncovering process happens much more swiftly than in the case described above. This ensures that the steam and exhaust distribution capability is greatly enhanced and engine’s performance is markedly improved. Churchward’s magnificent designs for his various classes of locomotives all exploited the spectacular advantages of long travel valves. However the “not invented here” syndrome was deeply rooted in other railway companies and the Midland Railway at Derby together with its successor the LMS went on perpetuating short travel valves in their designs long after the lessons of redesign were well established. There is a charming tale that when the LMS Garratts were being designed to be built by locomotive contractor Beyer Peacock in Manchester, the firm proposed that they should be built with long travel valves, learning the lesson that Churchward had championed all those years previously , but the Derby HQ insisted on their own standard short travel valve proportions producing a relatively lack lustre performance from their locomotives which were first introduced in 1927 to avoid expensive double heading of heavy London bound coal trains from Midland Railway territory .

There is a synergy between long travel valves on steam locomotives and high lift cams or double valves) on an internal combustion engine. The idea is to get the powering medium in and out of the cylinder as rapidly as possible.

Photo of LMS Garratt


It was only when Sir William Stanier who was a Swindon trained man (under Churchward) through and through came to the LMS as their Chief Mechanical Engineer that the revelations of long travel valves really became appreciated and culminated in designs of steam locomotives like the Black Five, 8F, Princess Coronation and Duchess locomotives which really owed their ancestry and performance to Swindon understanding.

PISTONS AND PISTON RODS

Steam pressure acting on one side of the piston transmits the driving force through the piston rod, connecting rod and crankpin to the wheels. Simultaneously while the piston is travelling along the cylinder, its other side is exhausting the steam used in the previous working stroke. The piston head is usually, but not always, separate from the piston rod (The LNER forged their pistons and piston rods from one billet of steel thus avoiding the nightmare of piston and rod becoming detached!). Likewise the piston rod is usually but not always separate from the crosshead. The head has to be strong enough to withstand the pressures and forces yet light enough to minimise the partly unbalanced effect of reciprocating masses.

The head is generally made of cast iron because this is a metal which wears well, is inexpensive and readily cast, but cast steel and forged steel can also be used. The distance between the front and rear cylinder covers, the thickness of the piston head and the stroke are chosen so that there is a slight clearance between the head and the covers (about 3\8”). This is necessary for obvious mechanical reasons. A steam tight joint between the head and the cylinder bore is made by piston rings and between the rod and the rear cylinder cover by some sort of gland packing which is discussed later.

The most commonly used form of piston head is a solid cast iron disc embodying a boss in the centre and a wide rim to accommodate the piston rings. The shape of the cylinder covers will be made to accommodate the piston shape.

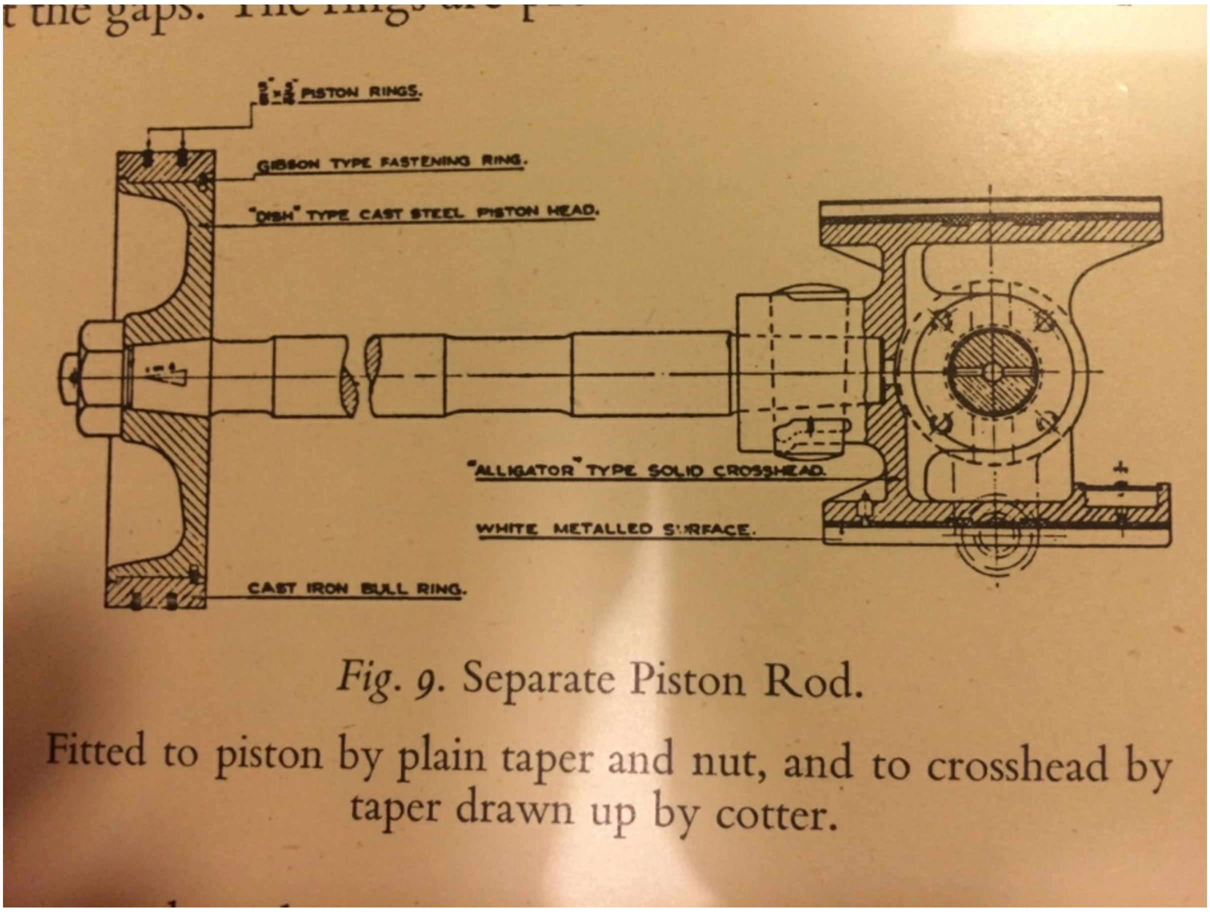



*Fig. 9.* Separate Piston Rod.

Fitted to piston by plain taper and nut, and to crosshead by taper drawn up by cotter.

TAIL RODS AND UNEQUAL SWEPT VOLUMES

It must be appreciated that such a piston as described will have considerable weight and there is a tendency for the piston to press unequally on the lower parts of the cylinder bore causing the bore to wear preferentially at the bottom  In Victorian times some locomotives (Like the LSWR T3) were fitted with Tail rods as an extension to the piston and piston rod passing through the front cylinder cover which provided additional support for the piston, rather in the same way that Textile Mill Engines often had tail rods to support the piston centrally in the bore. Tail rods pleased the theoretical brigade amongst steam enthusiasts because it meant that both ends of the swept volume of the cylinder were identical in volume whereas without tail rods the piston rod reduced the amount of steam in the rear half of the cylinder!

Without tail rods some designers like Stanier inserted a spring loaded bronze slipper in the lower part of the piston between the two sets of rings. This tended to keep the piston floating clear of the bore wall, but of course effective cylinder lubrication was paramount.

Piston rods as already noted are sometimes forged solid with the piston head or alternatively with the crosshead but normally, particularly in Britain they are separate. Steel which may be hardened is used. The major part of the length of the rod i.e. that part, which reciprocates in the gland, is ground truly cylindrical. A clearance hole is provided in the rear cylinder cover since no contact must be made at this point.  The rod may be fixed to the head either by means of a plain taper with a nut fitted on the screwed end of the rod, or by a screwed fit which may be parallel, with a nut at the front end, or slightly tapered to ensure a tight connection. Where a plain taper is used the nut, when tightened up, draws the rod into the corresponding tapered hole in the head and it is locked by means of a cotter or a pin which passed through a diametral hole in the nut and rod and is rivetted over at the end.

In cases where a taper screw arrangement is used considerable force is used to tighten the rod in the head. At the crosshead end the connection is almost invariably made by means of a tapered fit, except in a few cases where the rod is integral with the crosshead. A large carefully fitted cotter is driven through a slotted hole in the crosshead and piston rod, and is locked in position by a small cotter or pin. Sometimes a hole in the body of a crosshead enables the end of the rod to be seen when it has been forced into position, enabling a feeler gauge to be inserted between the end of the rod and the bottom of the tapered hole, so as to check that the fit is sound. In an alternative design the crosshead is split vertically and is formed with annular grooves and ridges which embrace corresponding grooves and ridges on the rod. The two halves are bolted together.

PISTON ROD PACKINGS

The seal between the piston rod and the rear cylinder cover used to be just a traditional stuffing box filled with strands of graphited yarn with an adjustable pressure collar as you might find on a domestic water tap.

However as temperatures and pressures of steam increased and the duties expected of the gland became more arduous something better was called for and the mechanical or metallic packing was introduced which far outlasts graphited yarn and is infinitely superior in performance. At first it is hard to understand how it works but it is cleverly self -adjusting for wear to both components involved in the sliding action. The type shown in the figure is common on British locomotives. The packing blocks, which are of cast iron, are arranged in two rings with the joints of one ring spaced at right angles to the joints of the second ring kept in place by pegs in the rings. Each ring consists of two pieces which

204 LOCOMOTIVE MANAGEMENT

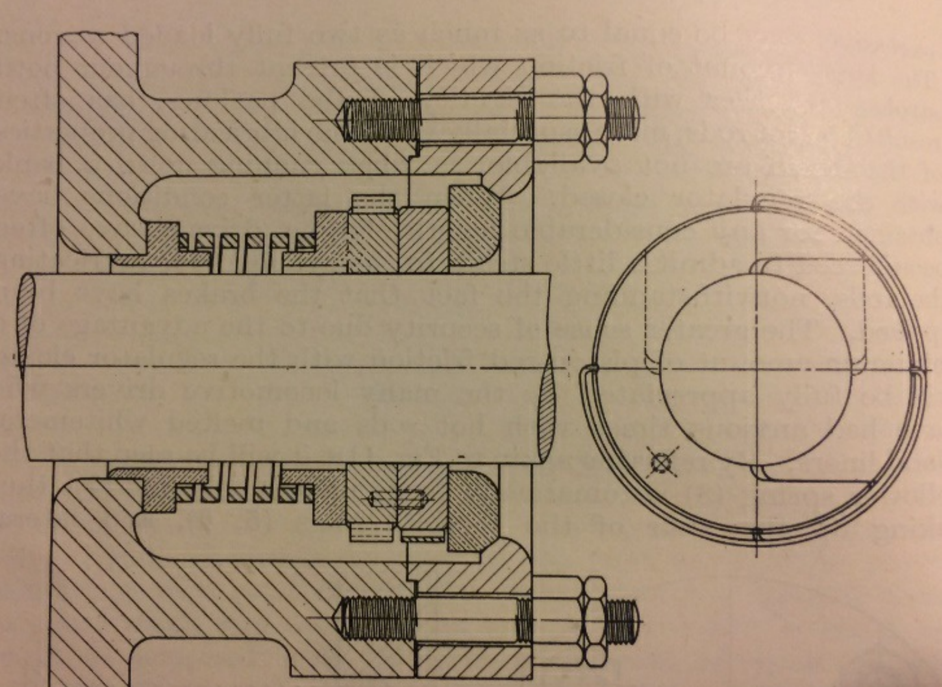


Fig. 122.—Packing with Cast-iron Rings. (United States Metallic Packing Co. Ltd.)

are held together and kept in contact with the rod by clip springs and as the packing and the rod slowly wear so the clip spring forces the smaller of the two pieces of each ring, closer to the rod thus compensating for wear. When the gaps shown north and south of the centreline in the right-hand diagram have been taken up it is time to overhaul /replace the cast iron rings. There are other sorts of metallic packing but they all work on the same principle (Further reading in Locomotive Management book 9th edition pages 203/204/205)

CROSSHEAD & SLIDE BARS

The job of the crosshead is to guide the outer end of the piston rod so that is travels in a straight line consistent with the centreline of the cylinder bore. In order to achieve that the crosshead has bearing surfaces which slide on the flat surfaces of the guide bars. These guide bars are generally supported on the rear cylinder cover at their inner end and by the so called “motion bracket” at the outer end. Now we have already talked about Swindon’s optical alignments system, which is a great help in setting these slide, bars up so the piston rod outer end is guided in a straight line.

The crosshead connects the reciprocating outer end of the piston rod to the connecting rod which drives the locomotive wheels around by pushing and pulling on the crankpin fastened into the wheel. The connecting rod is pulling and pushing on the crosshead at a variable angle as the wheels rotate and so the crosshead is asked to resist these forces by sliding only in a straight line. The really interesting fact about the crosshead is that instinct tells you that the forces on the crosshead will alternate as the piston travels back and forth but that is not the case. In the forward direction the forces on the crosshead are always UPWARD. Let us say the piston is at the forward end of the cylinder about to push the locomotive wheels forward. The connecting rod and crankpin is in the lower quadrant of the wheel as it moves off so the resultant force of the crosshead onto the slide bar is upward. When the piston reaches the end of its outward stroke and reverses to start coming back into the cylinder, the crankpin and connecting rod will be in the upper quadrant and so the resultant force on the crosshead as the steam drives the train along forwards for the second half of the revolution is STILL UPWARDS on the slide bars. This is initially counter-intuitive.

There are various ways of arranging the slide bars and their supports and the reader would do well to look at photographs of steam locomotives to see that various ways this issue was tackled. Also for further information study locomotive Management pp 205,206 207

The LNER and SR favoured three slide bars in a cluster above the piston rod whereas the GWR, LMS and LNWR favoured a bar above and a bar below the sliding crosshead. The beauty of the former is that access to the little end was unrestricted, whereas the great plus point for the latter system is that the connecting rod was retained safely by upper and lower slide bars should the gudgeon pin fracture to leave the connecting rod flailing around.

Slide bars are made of hardened steel and the sliding surfaces of the crosshead are generally bronze lined with white metal.

The outer support for slide bars is generally through what is known as a MOTION BRACKET which is usually a steel casting attached to the frames and carries the vertical forces imparted to the slide bars by the crosshead, induced by the angularity of the connecting rod. Students wishing to study this further should look at various types of motion brackets and ask themselves why they are shaped the way they are.

One important feature of the crosshead slide bar relationship is that there should be a relieved portion at the end of the sliding surface so that the crosshead slipper runs just off the end of the guide bar working surface. The purpose of this is to prevent the creation of a wear ridge at the end of the rubbing path of the two components.

## CYLINDER DRAIN COCKS

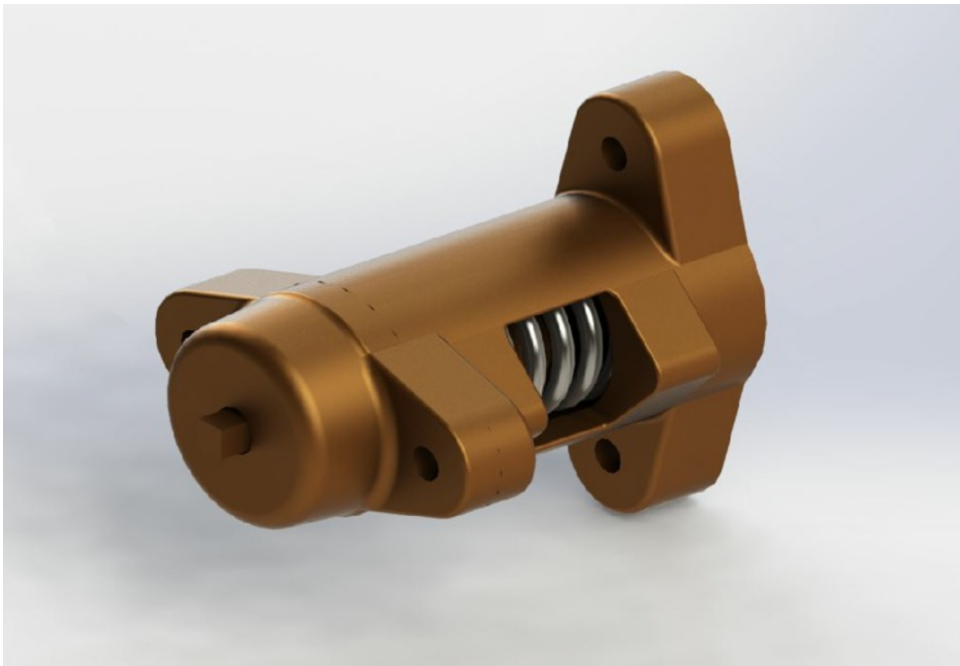
Those of used to working with steam locomotives are familiar with the use of cylinder drain cocks, which allow the steam and condensate to escape from cold cylinders as they warm through. The importance of getting rid of the condensate in piston valve engines has already been discussed. This is achieved with valves set at the lowest point of the locomotive cylinders sometimes referred to as “taps”. They take many forms, some are taper plug cocks some are spring loaded poppet valves but they all serve the same function to prevent disasters in the early stages of cold locomotive movement. The cocks are generally under the control of the fireman who must use judgement as to when they are to be closed. The situation with piston valved locomotives is much more serious as the condensate has nowhere to go if the cocks are closed. With most piston valve engines there is an additional cock on the same control mechanism which drains the live steam areas of the steam chest containing the piston valve itself.

Cylinder drain cocks have the additional advantage that they can be opened if a locomotive inadvertently starts to “prime” or carry boiler water over through running with too high boiler water level. Under these conditions opening the cocks can reduce the harshness felt within the locomotive as water droplets replace the free flow of steam into the cylinders

When the cylinder drain cocks are open the locomotive will not have the same thrust as when it is warm and operating at full pressure. Excessive use of the taps can wash away the lubricant from the cylinder walls.

(Cylinder drain cocks can be useful for scaring away stray sheep or cattle which have found themselves on the line)


CYLINDER PRESSURE RELIEF VALVES



These relief valves are mounted on a steam locomotives cylinder covers and their purpose is to relieve excessive pressure from possible hydraulic locking. The valves are set at about 10% above full boiler pressure and they should be checked for satisfactory operation at overhaul as they can well save a catastrophe. They cannot unfortunately respond instantly but they are an essential piece of piston valve cylinder equipment.

We have covered the various types of piston and valve combinations but we have not discussed the care of pistons valves and cylinders in service.

The removal of pistons and valves purely to look for wear might seem to be an unnecessarily hard task to take a locomotive out of service to perform an examination when nothing is apparently wrong but it is essential that this is done. MT276 lays down the mileages in between exams but the important thing to understand is that the consequences of not examining can be catastrophic.

The piston and valve rings on an express passenger Locomotive are working very near to the top temperature limit of the lubricant and if lubrication should be at all borderline, problems come thick and fast as rings seize and break up, being spat out in chunks through the cylinder drain cocks. Also the combination of worn piston, worn bore and worn rings can allow any free end of ring to completely escape the ring groove and break off in the combined gap into the bore to then be crushed at the end of the bore between the piston and cylinder head.

So regular piston and valve exams are essential.

All readers of this should watch the BTC film "General Repair" showing an LMS Jubilee going through the repair belt at Crewe Works and watch the process of examination that goes on before full repairs are carried out to as new condition. *(Available on YouTube)*

There is a way of checking piston valve rings and piston rings without stripping and this should be part of a fitness to run examination for main line steam locomotive.

The locomotive must be stood on level track with the handbrake and steam brake hard on with the reverser in mid gear and the drain cocks shut. Then the regulator is partially opened and the smokebox door is opened to listen and observe what is happening at the blast pipe. Worn or broken rings will allow escape of steam up the blast pipe. It is possible by parking the locomotive in different rotational positions to take this test much further and read much more into diagnosing valve piston and bore condition.

**LO1: Cylinders**

1. Cylinder positions
2. Crank orientation
3. Fastenings
4. Crosshead
5. Cylinder Material
6. Cylinder bore
7. Drain Cocks
8. Pressure relief valves

| LO | Objectives | Assessment Criteria | Delivery | Date achieved and Supervisors signature |
|---|---|---|---|---|
| LO1 1 | Cylinder positions | Why are locomotive cylinders arranged approximately horizontal. Draw a diagram to show cylinders on a typical locomotive | Classroom | |
| LO1 2 | Crank orientation | Draw a diagram to show crank orientation on a 2 cylinder and 3 cylinder locomotive | Classroom | |
| LO1 3 | Driven Bolt | Explain what a 'driven' or 'dowel' bolt is, what is there purpose? Where they would be used in relation to locomotive cylinders | Classroom | |
| LO1 4 | Crosshead | Draw a diagram of a typical crosshead and what is its purpose? | Classroom | |
| LO1 5 | Cylinder material | Give 2 reasons why locomotive cylinders are made from cast iron. | Classroom | |
| LO1 6 | Cylinder bore | Draw a diagram to show how a cylinder is machined to aid the fitting of pistons with rings. | Classroom | |
| LO1 7 | Drain Cocks | What is the purpose of cylinder drain cocks? | Classroom | |
| LO1 8 | Relief Valves | Why are cylinder pressure relief valves fitted to cylinder covers? & At what pressure are they set to release at. | Classroom | |

**LO2**: **Valves**

1. Types of Valves
2. Valve Lap
3. Piston Valve Locomotive, operation from cold
4. ‘Long’ Travel valve

| LO | Objectives | Assessment Criteria | Delivery | Date achieved and Supervisors signature |
|---|---|---|---|---|
| LO2 1 | Valve Types | Name 3 types of valves that could be used on a locomotive and draw annotated of the 2 most common types to explain their operation | Classroom | |
| LO2 2 | Valve Lap | In relation to valves what is ‘Lap’? | Classroom | |
| LO2 2 | Valve Lap | Why is valve lap advantageous to the operation of a locomotive? | Classroom | |
| LO2 3 | Operation from Cold | Why should care be taken in the operation of a piston valve locomotive especially from cold? | Classroom | |
| LO2 4 | Long travel valve | What is a long travel valve and what purpose does it serve? | Classroom | |

**LO3: Pistons**

1. Construction
2. Clearance between pistons and covers
3. Typical Pistons
4. Locking devices
5. Sealing
6. Materials

| LO | Objectives | Assessment Criteria | Delivery | Date achieved and Supervisors signature |
|---|---|---|---|---|
| LO3 1 | Pistons & Rods | Draw a diagram showing 2 construction methods of piston & rod | Classroom | |
| LO3 2 | Piston Clearance | What clearance must be arranged between pistons & covers? | Classroom | |
| LO3 3 | Pistons | Draw an annotated diagram of a typical piston | Classroom | |
| LO3 4 | Locking Devices | What locking devices are used to secure pistons to the rod and the crosshead to the rod? | Classroom | |
| LO3 5 | Sealing | How is the cylinder sealed where the piston rod passes through the rear cover? Draw an annotated diagram to illustrate your answer. | Classroom | |
| LO3 6 | Materials | What are suitable materials for: Piston, piston rings and cylinder covers. | Classroom | |

**LO4**: **Routine Examination –** locomotive not stripped

1. Steam Leaks
2. Motion
3. Cylinder drain cocks
4. Fastenings
5. Distortion of Piston Rods
6. Lubrication
7. Cross arms
8. Cracking
9. Checking - Loco in steam

| LO | Objectives | Assessment Criteria | Delivery | Date achieved and Supervisors signature |
|---|---|---|---|---|
| LO4 1 | Leaks | Check for major steam leaks, blow past on glands | Workshop | |
| LO4 2 | Motion | Check for any excessive tightness in the motion | Workshop | |
| LO4 3 | Cylinder drain cocks | Check for correct operation | Workshop | |
| LO4 4 | Fastenings | Check the security of cotters, nuts and bolts and taper pins | Workshop | |
| LO4 5 | Piston Rods | Check piston rods for distortion or damage | Workshop | |
| LO4 6 | Lubrication | Check for dry bushes, this could indicate wear | Workshop | |
| LO4 7 | Cross arms | Check cross arms for wear or damage and security | Workshop | |
| LO4 8 | Cracking | Check for cracking around bolt holes and other fixings | Workshop | |
| LO4 9 | Checking pistons and valves with Locomotive in steam | Describe the procedure for checking the condition of pistons, rings and valves with the locomotive in steam. Under supervision carry out this check. | Classroom and workshop | |

**LO5: Examination –** locomotive stripped

1. Bore wear
2. Piston Head clearance
3. Oiling ports
4. Cylinder liners
5. Valve liners
6. Piston valve spindles
7. Loose piston heads and valve heads
8. Slide valve wear
9. Limits of wear see MT276 section 6

| LO | Objectives | Assessment Criteria | Delivery | Date achieved and Supervisors signature |
|---|---|---|---|---|
| LO5 1 | Bore wear | Examine cylinder bore for wear and ridges. Record your findings | Workshop | |
| LO5 2 | Piston Head clearance | Describe how you would check the piston head clearances and carry out a measurement | Classroom & Workshop | |
| LO5 3 | Oiling ports | Why must oiling ports be kept clean? Examine oiling ports on a loco | Classroom & Workshop | |
| LO5 4 | Cylinder & Piston valve liners | Check liners for evidence of cracking, Use NDT equipment if necessary | Workshop | |
| LO5 5 | Piston Valve liners | Examine piston valve bores for wear and ridges. Record your findings | Workshop | |
| LO5 6 | Piston Valve spindles | Check Piston valve spindles for wear | Workshop | |
| LO5 7 | Security of Piston and valve heads | Check the security of piston and valve heads and their locking devices | Workshop | |
| LO5 8 | Slide Valve wear | Check slide valve for wear, what is the maximum amount of wear that is allowed before re-facing is required? | Classroom & Workshop | |

| | | | | |
|---|---|---|---|---|
| LO5<br>9 | Limits of wear<br>Use MT 276 Section 6 | What is the maximum amount of ovality or taper allowed on piston bore? | Classroom | |
| LO5<br>9 | Limits of wear<br>Use MT 276 Section 6 | What is the minimum thickness of piston rings? | Classroom | |
| LO5<br>9 | Limits of wear<br>Use MT 276 Section 6 | What is the maximum ovality allowed on piston rods? | Classroom | |
| LO5<br>9 | Limits of wear<br>Use MT 276 Section 6 | What is the maximum clearance allowed of slide block in bars on<br>a) Loco with soft packing<br>b) Loco with metallic packing | Classroom | |
| LO5<br>9 | Limits of wear<br>Use MT 276 Section 6 | What is the total clearance allowed on pins and bushes with<br>a) Running fit<br>b) Push fit | Classroom | |

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 LM4 – Cylinders, Pistons & Valves**

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

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **LO1** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | 8 | | |
| ***Supervisor Initials and date*** | | | | | | | | | | |
| **LO2** | **1** | **2** | **3** | **4** | | | | | | |
| ***Supervisor Initials and date*** | | | | | | | | | | |
| **LO3** | **1** | **2** | **3** | **4** | **5** | 6 | | | | |
| ***Supervisor Initials and date*** | | | | | | | | | | |
| **LO4** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| ***Supervisor Initials and date*** | | | | | | | | | | |
| **LO5** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| ***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**