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Steam Locomotive Repair and Overhaul

Module LM7

Brakes

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November 2017 – version 1.0

Module BESTT LM7

Brakes

Aim

This unit will give learners an understanding of how Locomotive Springs and Bogies operate and how to examine for wear.

The learner will consider: -

- Different Braking Systems
- Different types of Bogies and trucks
- Different types Radial Axles and boxes
- Examination and reporting

Learning Outcomes

LO1: Brakes - General

LO2: Automatic Vacuum Brake

LO3: The Ejector

LO4: Direct Acting Valves

LO5: Steam Brakes

LO6: Brake Test Requirements

LO7: Air Brakes

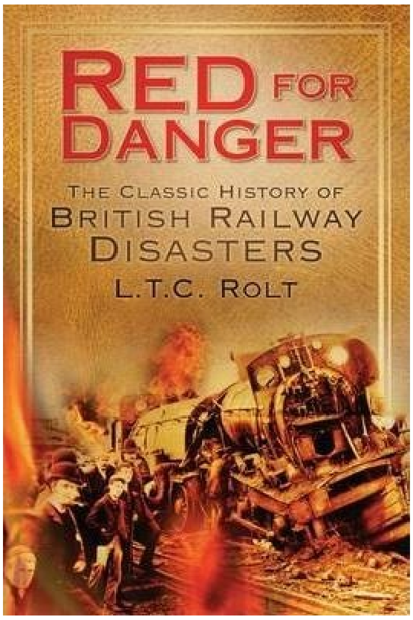
LO8: Examination

BESTT MECHANICAL MODULE LM7

STEAM LOCOMOTIVE BRAKES

INTRODUCTION

I believe that the first action that anyone wanting to learn about railway locomotive braking should take ought to be the compulsory reading of LTC Rolt's *Red for Danger.* Whilst it is not primarily about brakes it gives an inspirational insight into the importance of trains being able to stop in appropriate time and distance and travel safely and we cannot recommend it more highly.



The review says:

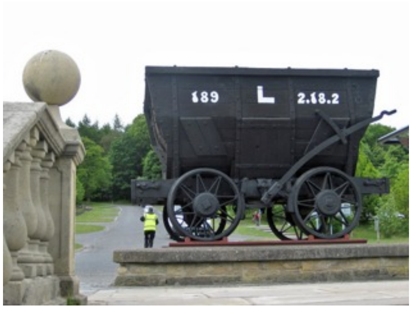
"Railway Disasters are almost always the result of human fallibility - a single mistake by an engine-driver, guard or signalman, or some lack of communication between them - and it is in the short distance between the trivial error and its terrible consequence that the drama of the railway accident lies. First published in 1955, and the result of Rolt's careful investigation and study of the verbatim reports and findings by H.M. "Inspectorate of Railways", this book was the first work to record the history of railway disasters, and it remains the classic account. It covers every major accident on British railways between 1840 and 1957 which resulted in a change in railway working practice, and reveals the evolution of safety devices and methods which came to make the British railway carriage one of the safest modes of transport in the world. This edition uses the last text produced by Rolt himself in 1966 and includes a new introduction by his friend and fellow railway historian Professor Jack Simmons."

It seems incredible to us now that the very early railways were built without brakes even though gradients and situations with the potential for disaster were commonplace. There is a significant parallel in that early cars and lorries were built with no front brakes because of the difficulty of applying a brake mechanism to an assembly that had to turn with the steering wheel.

In this module we cover the development of safe braking systems for railway vehicles and look at how the modern air brake superseded the vacuum brake and how Train Protection Warning Systems can be integrated successfully and safely with the traditional steam locomotive. Disc brakes generally replaced shoe brakes on modern vehicles.

Stopping or slowing of early railway vehicles like those on the horse-drawn Peak Forest Tramway in the Peak District was achieved by using “sprags” or metal bars which were thrust between the spokes of the vehicle by brave crew members to lock that particular wheel and slow the train, but brakes finally did come to the railway they were based on horse drawn cart brakes with a shoe of hard-wood (like oak or elm) rubbing against the rim of the cart wheel or railway wheel. The brake blocks were applied through an equalising mechanism, which ensured that the forces were shared out appropriately between all wheels

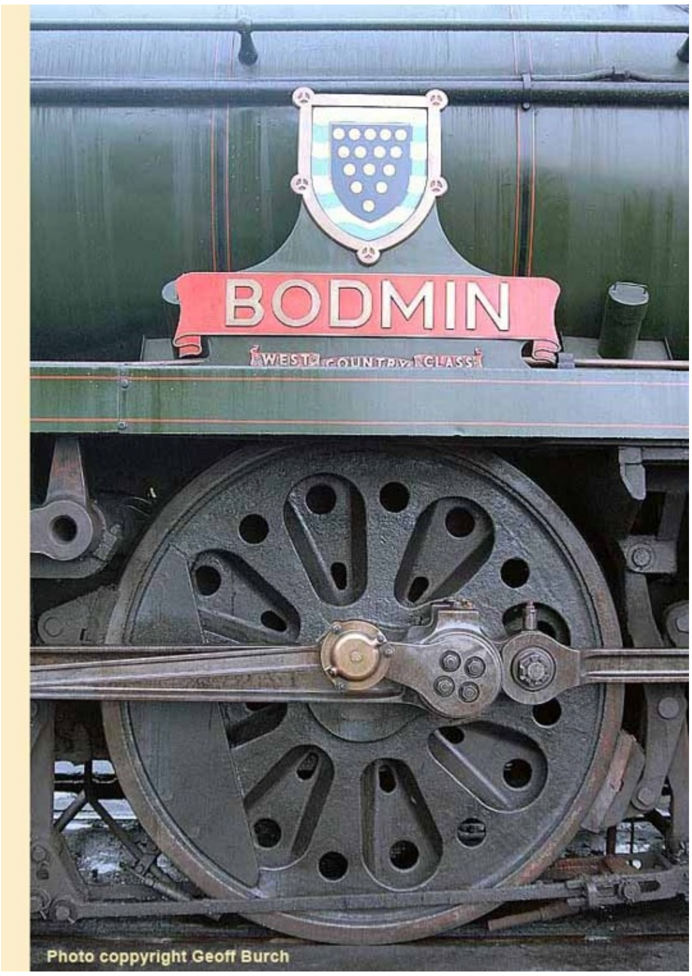
Horse Drawn Peak Forest Tramway Vehicle



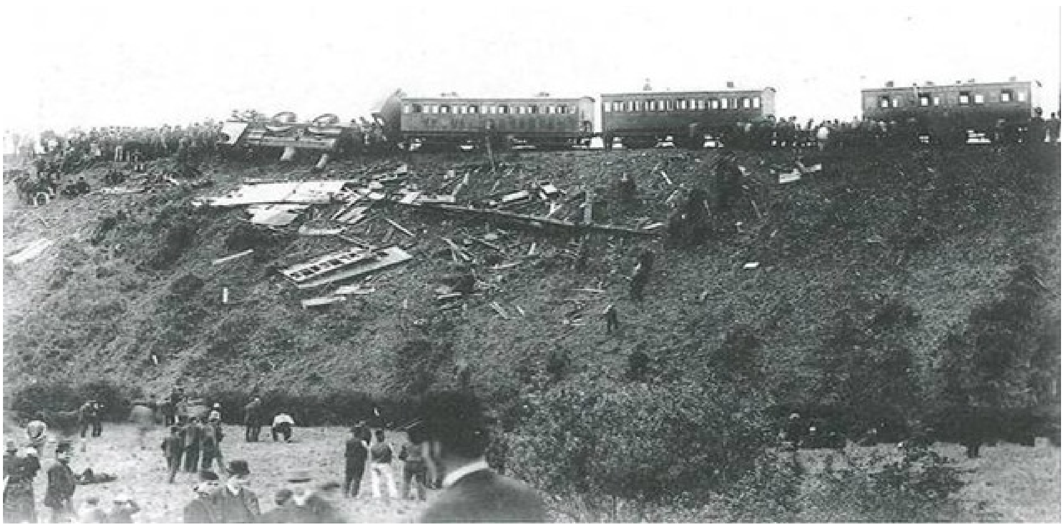
A Chauldron Waggon from early horse drawn and steam days with hand brake applied by a riding guard

Wood was superseded by cast iron which was pressed or pulled against the rim of the locomotive wheels but one thing that musty be remembered is that stopping by using the rim of the wheel concentrates the kinetic energy of the train into heat which is dissipated between the brake block and wheel rim. Braking from high speed with a cast iron brake blocked train can have two serious drawbacks. “Firebanding” can result from the brake as the brake block melts at the rubbing surface. In addition all that heat going into the tyre can under certain circumstances expand the tyre to the extent that the shrink fit between the wheel centre and tyre can be lost and the tyre becomes loose.

Learners will no doubt have seen white lines painted on the wheel and tyre of steam and diesel locomotives (or photos of same) so that checks can be made to see if the tyre has ever moved on its shrink fit.



The equalised cast iron brake blocks on the wheel of a “West Country“ Bulleid Pacific Locomotive



The tragic accident at Armagh was to change everything in attitude towards railway braking.

Those who are familiar with a modern air braked system on a laden train hauled by a diesel or electric locomotive may be forgiven for pondering why the UK Railways, when forced to go for automatic braking system chose mainly to go for the vacuum system where the reservoirs and the actuating cylinders are nearly twice the size of those required for an air braked system.

To understand why vacuum won the day over compressed air in UK as the power behind the chosen brake, we need to put ourselves in the shoes of engineers in the latter part of the nineteenth century, when steam was the predominant motive power. It was easy to use the locomotive's steam to create a vacuum by ejecting steam through a Venturi nozzle without having any moving parts in the device. Certainly that is not the case for steam locomotives running on the main line rail network where a steam driven air compressor has to be used to power the air brakes as vacuum operated brakes are not compatible with the modern railway.

Parking brakes were fitted to coaches in the days of Stephenson's Rocket and the Liverpool and Manchester Railway in 1830 but it took the dreadful Sunday school outing accident at Armagh in 1889 to really focus people's minds on the idea that brakes must be fail safe and able to be applied throughout the train in the event of an emergency by both driver and guard.

Elaborate experiments carried out by Sir Douglas Galton and George Westinghouse established that the retarding power of a brake is greatly diminished when the wheels begin to skid on the rails. The adhesion of the wheels and the speed of the train are the principal factors in determining the total retarding power that may be exerted by the brakes of a train. As the total braking power that could be applied with early brakes was proportional to the weight of the locomotive and the brake vans only, it was considerably less than that obtained by using the friction of every vehicle as with a continuous brake. Sanding the rails improved the adhesive capabilities of the wheels thus increasing the effectiveness of the brake by reducing the tendency to skid.

At higher speeds this liability to skid decreases, so that the effective brake power applied may be greater than at lower speeds. When stopping a train quickly the maximum brake power should be applied swiftly and carefully and then reduced as the speed approaches zero. The expression "*Stopping on a rising pipe*" derives from the correct use of this technique to come to rest smoothly. The friction levels of a cast iron brake block rubbing against a steel wheel rim are such that the value of the coefficient of friction trebles as zero speed is approached

Various types of powered brakes were tried in the early days of experimenting with continuous braking for obtaining the necessary brake forces such as chains actuated by friction pulleys on the axles, steam pressure, air pressure and vacuum all of which in the earlier stages were non-automatic so that if a breakaway occurred or the parts became disconnected the brake was rendered practically useless.

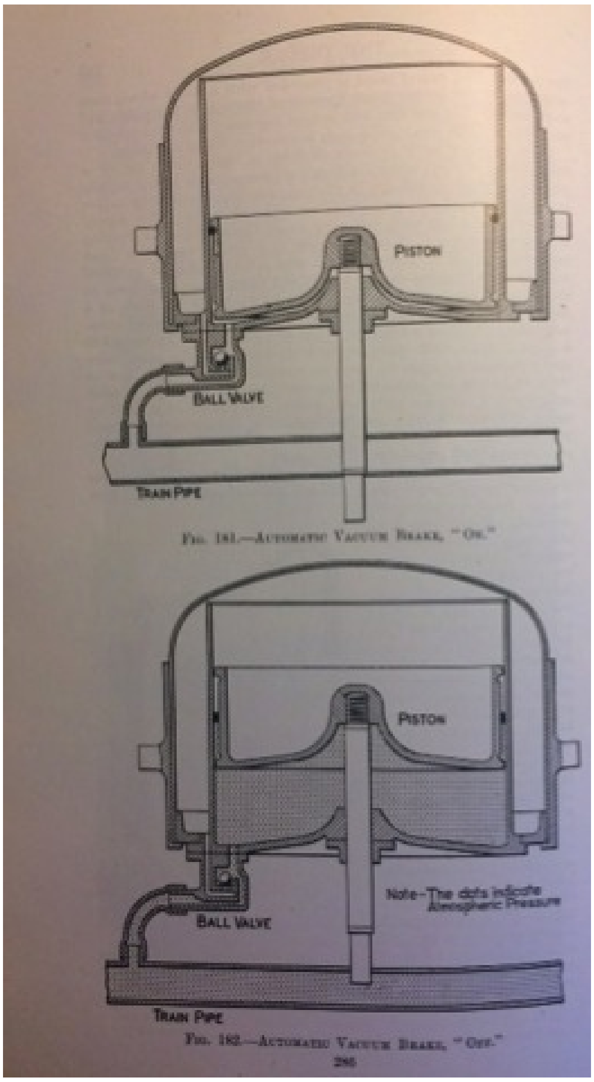
Compressed air and vacuum brakes as the most successful trials showed, were developed and improved so that when certain conditions were demanded by Act of Parliament in 1899, the Westinghouse Air Brake and Gresham & Craven Automatic Vacuum brakes were already so far perfected as to comply with the conditions. This ensured the survival of the two systems alongside each other for many years into the future.

Eventually the superior speed of application and convenience led the air brake to be the chosen as the way forward for modern railways but on heritage lines the traditional vacuum brake is still generally the preferred way of stopping trains, so this module will concentrate on understanding of the vacuum system. Steam Locomotives equipped to run on the main line with modern air braked stock are equipped with both systems and there are various ways that interaction between the two systems can be achieved.

THE AUTOMATIC VACUUM BRAKE

(Based on extracts from Locomotive Management Handbook 9th Edition)

In the automatic vacuum brake the power exerted by the brake blocks upon the wheels is obtained from the atmospheric pressure on a piston working with the least possible friction in a cylinder, and transmitted by levers and brake rigging. The manner in which the pressure of the atmosphere is utilised and made to exert the necessary force for retarding and arresting the momentum acquired by the train is best explained by reference to diagrams (fig 181 &182.) showing the pneumatic action of the vacuum brake in principle, whatever type of cylinder is employed. The illustration (fig 184) is of the "C" type having an external combined ball and release valve.



Figs 181 &182 Brake

OFF top & ON bottom

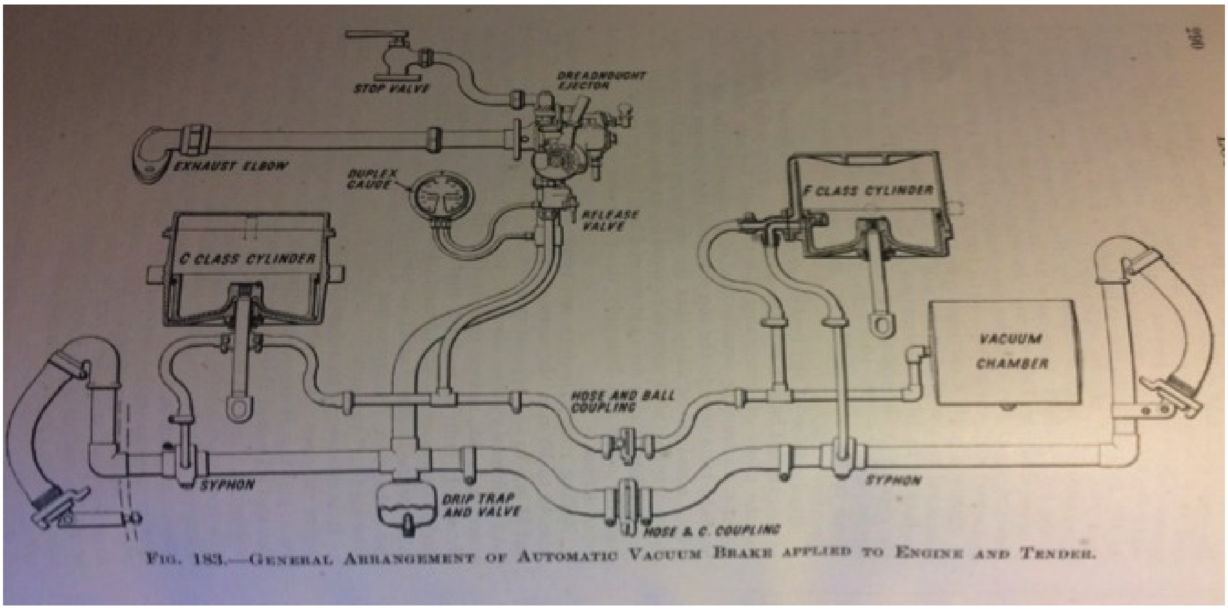


FIG. 183.—GENERAL ARRANGEMENT OF AUTOMATIC VACUUM BRAKE APPLIED TO ENGINE AND TENDER.

Figure 183

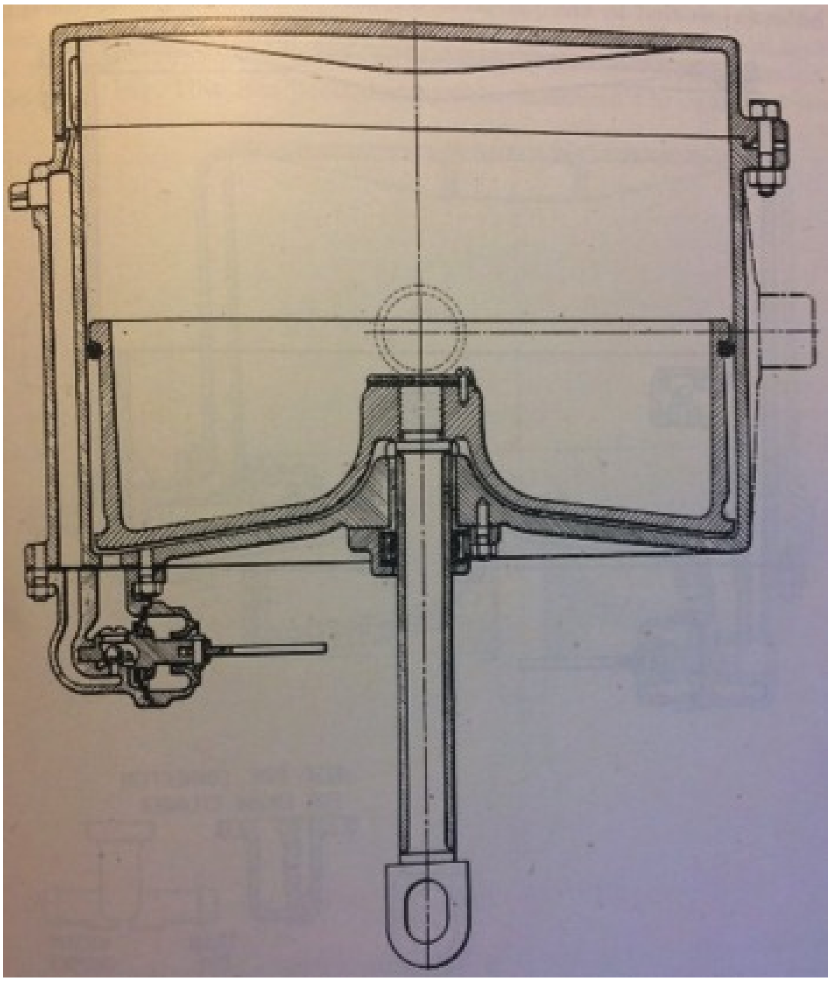


Figure 184

The piston is an easy-fit in the bore of the cylinder and is kept airtight by means of a round flexible rubber ring known as a “rolling ring” which rolls between the piston and the cylinder walls without friction when the piston moves, lying undistorted in the “relieving groove” provided in the piston when in the “brake off” position. The piston rod attached to the piston is made of brass coated steel, stainless steel or other suitable material, and is maintained airtight by passing through a packing housed in the lower cover, known as the gland packing ring. This has the characteristic of being firmly held to the rod by atmospheric pressure outside when there is a state of vacuum inside the cylinder. This pressure is relieved when air is admitted to the cylinder thus reducing the friction when movement is required. Air is extracted from the whole of the vacuum brake cylinder assembly through the train pipe via the hose pipe connection and valve, when both the top and bottom sides of the piston are in a state of partial vacuum. When air is admitted to the train pipe by the driver or guard, it flows through the connecting hose to the underside of the piston, but is prevented, by means to be explained later depending on the type of cylinder, from reaching the top or “chamber side” of the cylinder.

The dark shading in Fig 182 indicates the air in the train pipe and cylinder, while the “top side” or chamber, is still in a state of vacuum, so that the resulting difference in pressure forces the piston up against the weight of the piston and rod.

Hand release of the brakes on carriages is achieved by means of the external ball or release valve, which when pulled manually has the effect of connecting the top and bottom sides of the cylinder so causing equalisation of pressure by the air flowing from the train pipe to the top side until the pressure is equal. It will be noted that the air comes from the train pipe and not from the atmosphere outside, so that any failure of a ball or release valve does not mean a leak into the general system from the outer air but only the particular cylinder concerned, being out of action.

Rolling ring cylinders are made in standard sizes ranging from 10 to 30 inches diameter. In any type of cylinder, the topside of the piston must have sufficient volume above it to ensure that the stroke of the piston does not reduce unduly the effective vacuum above the piston. Starting with a vacuum of 21 inches of mercury, and then reducing this volume, (or compressing the rarefied air) will result in reducing the available vacuum, and therefore the effectiveness of the brake.

It is necessary therefore to give sufficient “top-side” chamber volume to compensate for the stroke losses, and this is arranged either by a chamber casing embodied with and all round the cylinder as in Figs 181 &182, or by a separate chamber connected by a hose pipe to the top side of the piston. In separate type cylinders the valve requires an additional branch to make this connection, and in the case of engine or tender cylinders, which have connections to the auxiliary pipe from the ejector, no manual release valve is necessary. The connections to train pipe and auxiliary pipe therefore are double branch hose although ball or release valves still may be used, and the drivers release valve on the ejector is available for independent release of the cylinders.

Fig 183 shows the general arrangement of connections on an engine and tender. The driver’s DUPLEX vacuum gauge (two independent needles) connects to the train pipe and the auxiliary pipe to the chambers respectively. The amount of vacuum destruction recorded in the train pipe by the admission of air through the driver’s valve is a direct indication of the degree of force that the brake can apply. In the “FULL BRAKE ON” position the porting of the driver’s valve gives a direct connection from the small ejector to the auxiliary pipe and chambers, so that the full working vacuum is created and maintained on these cylinders, and any loss from piston movement up into the chamber is eliminated. This is a very important feature and enhances locomotive braking over carriage braking during stopping.

DUPLEX locomotive vacuum gauge showing the measurement of the amount of vacuum available in “inches of mercury” in the two parts of the system.

Fig 184 shows a type “C “ cylinder, the original rolling ring cylinder that was in use throughout the world. The function of this type of cylinder is performed with an external ball valve through which the chamber or topside is exhausted. On admission of air to the train pipe, the ball seats and seals all connections to the chamber side, so isolating it. Hand release by means of a cord or string attached to the lever (lower left in Fig 184) displaces the ball from its seat allows the heavy piston to fall off. The ball valve is fitted with a diaphragm, and re creation of vacuum in the train pipe automatically draws in the spindle allowing the ball to return to its seat and function as before. The cords or strings are accessible from outside the vehicle and are marked by a white star painted on the sole bar.

There are variations on the type “C” cylinder with “E” and “F” types but essentially they work on the same principle with minor variations. Learners need to familiarise themselves with what type of vacuum chambers are in use on their locomotives and stock and know how to examine and overhaul them.

Both cylinders and brake shafts move in their bearings when an application is made, a fact frequently ignored. A great deal of trouble and brake defects can be avoided if these moving parts are given a chance and oiled or greased occasionally.

Confusion and difficulty often occurs when locomotives and rolling stock from the GWR are mixed with those from other regions as the ex GWR always insisted on running their vacuum systems with a more powerful level of vacuum than the other regions. Normally this is not a problem, as GWR locomotives and stock run at 25” of mercury vacuum reading and the remainder run at 21” of vacuum but it can become a serious issue if locomotives from non GWR sources try and double-head with ex GWR locomotives or if a locomotive change is performed part way through a journey. Under those conditions it is necessary to “Pull the strings” to equalise the two sides of the cylinder and restart the process of evacuating the chambers.

The vacuum brake is virtually instantaneous and is capable of being applied by the guard or the driver. The brake is also self-applying which means that the breakage of the train pipe, as by a vehicle becoming detached, will admit air to the train pipe and apply the brakes.

The brake train pipe is now the most approved means of providing passenger communication, and by the alarm cord in the carriages, any passenger can admit sufficient air into the train pipe to attract the attention of the driver or guard. When communication is made in this manner, the brake is not applied fully, so that if the alarm is given in a tunnel or other such inconvenient place, the driver by opening the large ejector is able to bring the train to the end of the tunnel or other convenient stopping place.

THE EJECTOR

Although we have already claimed that the manner by which vacuum is created on a steam locomotive has no moving parts, although this is true generally, there is a further complication concerning GWR locomotives. Ejectors for using live steam to create a vacuum were generally made by specialist companies such as Gresham & Craven or Davies & Metcalfe. Each type has their strengths but they both take steam from the top of the boiler inside the cab and feed it through special nozzles in the ejector, which then exhaust through the smokebox up the chimney. The guiding principle is that there is a large ejector to raise vacuum swiftly and effectively as the locomotive prepared the train for departure. Once the train is on the move with released brakes it is possible to maintain the vacuum using the small ejector, which uses a lot less steam than the large one. The GWR however made the decision to use mechanical power from the pistons and cylinders to power a vacuum pump situated under one of the sets of slide-bars and driven from the crosshead. The idea was that once the train was on the move the maintain of vacuum was all done mechanically without the need for small or large ejector. It is an arguable point as to whether this saved energy, certainly during coasting downhill the vacuum was being maintained for "free" so to speak and any power being consumed was helping to brake the train with no loss of steam…. but the vacuum pump was running all the time both up and downhill, with the familiar tick-tick-tick on every stroke that all GWR locomotives make.

The manner in which the small ejector can often be made to do all the work required should appeal to all drivers who wish to keep down coal consumption.

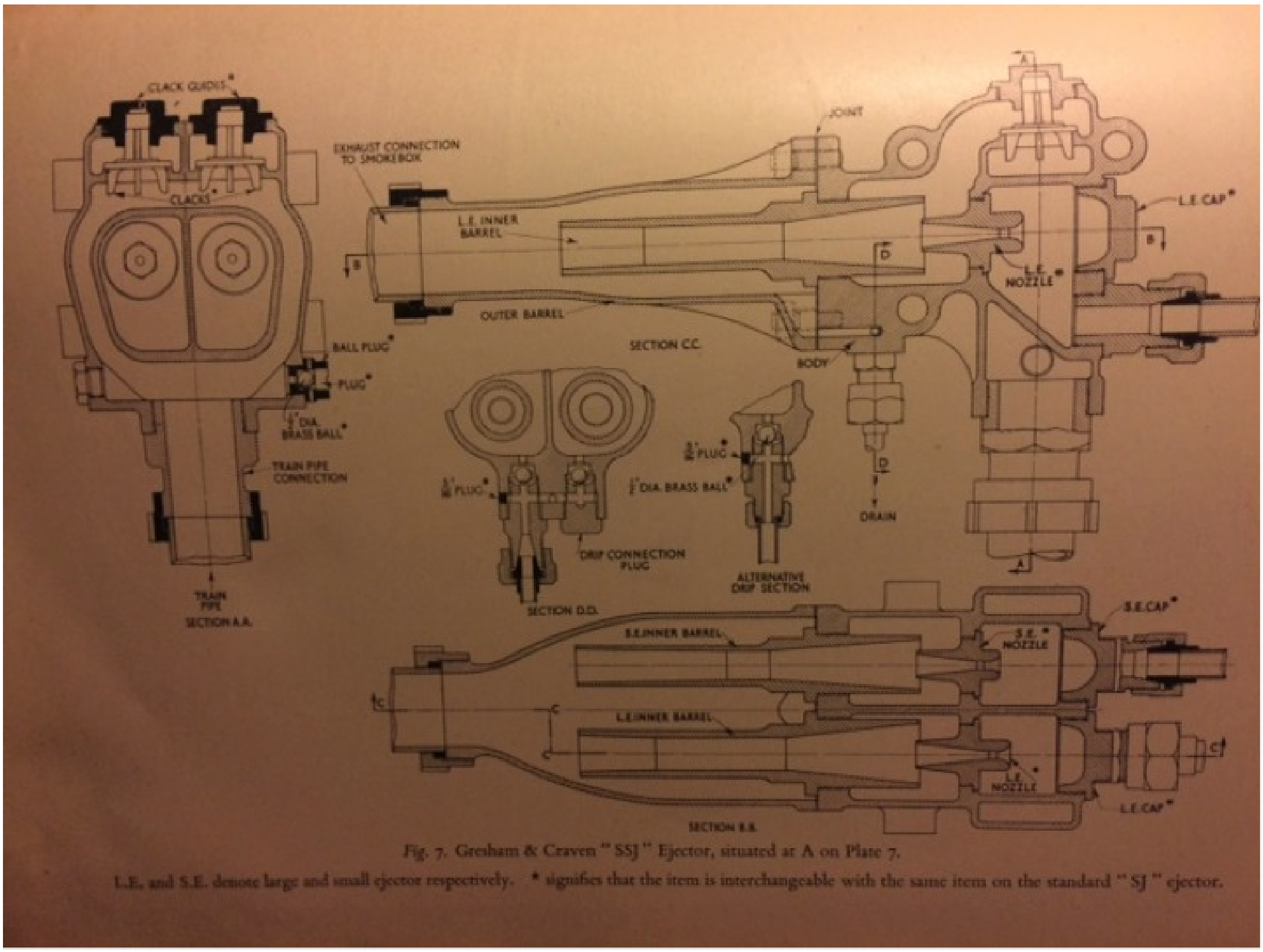
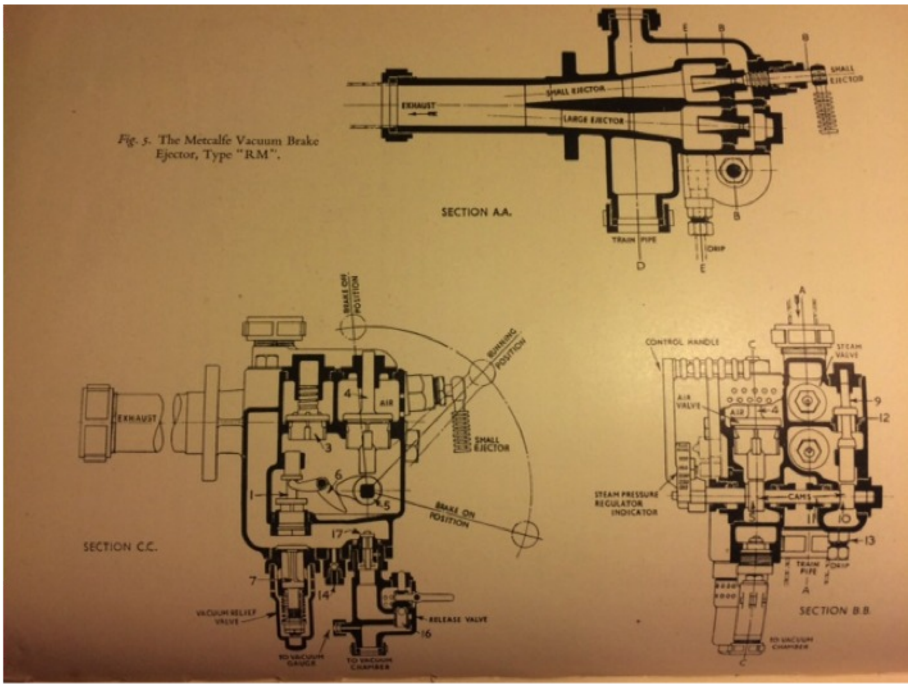


Fig. 7. Gresham & Craven "SSJ" Ejector, situated at A on Plate 7.
L.E. and S.E. denote large and small ejector respectively. * signifies that the item is interchangeable with the same item on the standard "SJ" ejector.

Gresham & Craven Vacuum Ejector



Davies & Metcalfe Vacuum Ejector

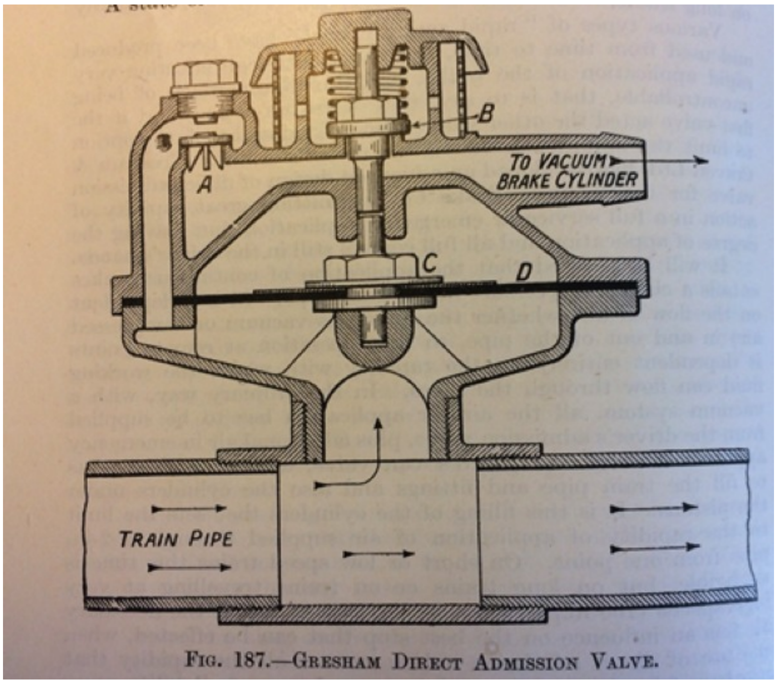
Learners are encouraged to get hold of the literature that applies to their own location and study the workings of the various components. Steam Locomotive Mutual Improvement Classes often had sectioned versions of these parts, which greatly aid understanding of their function. Learners should ask for help at their local Heritage site.

The NRM's warehouse displays are filled with such items and a visit with camera and notebook is highly recommended to gain a full understanding

Some Heritage sites have been faced with the non-availability of the ejectors described above (which are complex and very difficult to manufacture from scratch) and they have been extremely resourceful in creating their own design of exhaust ejector that has been without the sophistication and cost of the items described above. The Embsay and Bolton Abbey Steam Railway has been in the vanguard of this initiative and their products are effective and relatively easy to make.

DIRECT ACTING VALVES

It must be appreciated that if a steam hauled train of many coaches is travelling at speed and a brake application is made then atmospheric air enters the train pipe through the driver's control valve. But the amount of air that is required to destroy the vacuum in a long train pipe can be very large and getting that air to the very far end of the train to bring the train under control can be quite tricky. Engineers developed what is known as the Direct Acting (DA) Valve to eliminate this problem and make each individual vehicle responsible for admitting atmospheric air to apply its own brakes. That way although there is an element of sequential acting in the brake application, the whole process is much more rapid. The learner might be forgiven for wondering why the braking engineers are so interested in rapid application times. But as with the stopping distances of a car, the early seconds of a high-speed stop make a huge difference to the overall distance to rest involved in stopping and it is distance to rest that really counts rather than just the stopping time. For example a one second's delay in application at sixty miles an hour means the train covers 88 feet (27 metres), which when considering stopping at signals or level crossings is significant.



The Direct Acting Vacuum Valve

The DA valve senses a slight reduction in train pipe pressure and opens wide to let the air into the system and apply the individual carriage's brakes. Although strictly the DA valve is part of the carriage equipment it is so allied to the vacuum ejector and vacuum brake application system that locomotive engineers and maintainers need to be fully conversant with their action. There are other variations on the DA valve described and Learners are urged to read up further so that they understand all the complexities and nuances relating to long vacuum braked trains. Pages 298 to 307 in *Locomotive Management Handbook* relate.

Further interesting reading on the Automatic Vacuum Brake is available at

http://lmsca.org.uk/wp-content/uploads/2012/07/LMSRAVB.pdf

STEAM BRAKES

We have discussed the need for continuity throughout the train to achieve a safe and effective braking system but a steam locomotive occasionally needs to be able to use an independent method of braking in order to be able to operate effectively. For example, when trying to uncouple itself from a stationary train the locomotive needs to reverse up against the buffers of the fully braked train to compress the buffers and put its own brakes on. Now there is generally a tender handbrake but in order to achieve this properly, most locomotives are fitted with a steam operated brake, which can be controlled independently of the vacuum system of in conjunction with the vacuum system.

It will be appreciated that a steam brake operates at near boiler pressure (typically 10 bar and above) rather than at the pressures available within a vacuum system (1 bar max) that means that the steam brake components can be much smaller in size to produce the same braking force.

Many engines and tenders are fitted with steam brakes, which can be worked in conjunction with the automatic brake upon the train, or used separately when the locomotive is running light or working a goods train with no vacuum braked vehicles. This type of brake is very simple: the power is obtained by admitting steam at boiler pressure behind a piston contained in a cylinder about 10 "diameter placed below the footplate. The piston rod is connected to the brake levers so that the whole force of the steam may be exerted through the brake blocks. It is possible to use a very powerful brake on the locomotive so that with steam at say 180 lb./sq. inch pressure, an approximate load of 6tons is available for braking at the brake levers.

Although the cylinder is smaller and more compact than the vacuum system allows, the steam brake suffers greatly in the early stages of use from the steam condensing in the brake cylinder and giving erratic poor performance until it is fully warmed up.

The steam brake also requires flexible pressure connections between locomotive and tender which can be problematic unless correct allowance is made for movement between vehicles.

However it has the great advantage that with the clever control valves devised by Gresham and Craven and others, it is capable of "Co-acting" with the vacuum brake so that the locomotive and train all act in concert during a stop as well as being able to act independently, as required above.

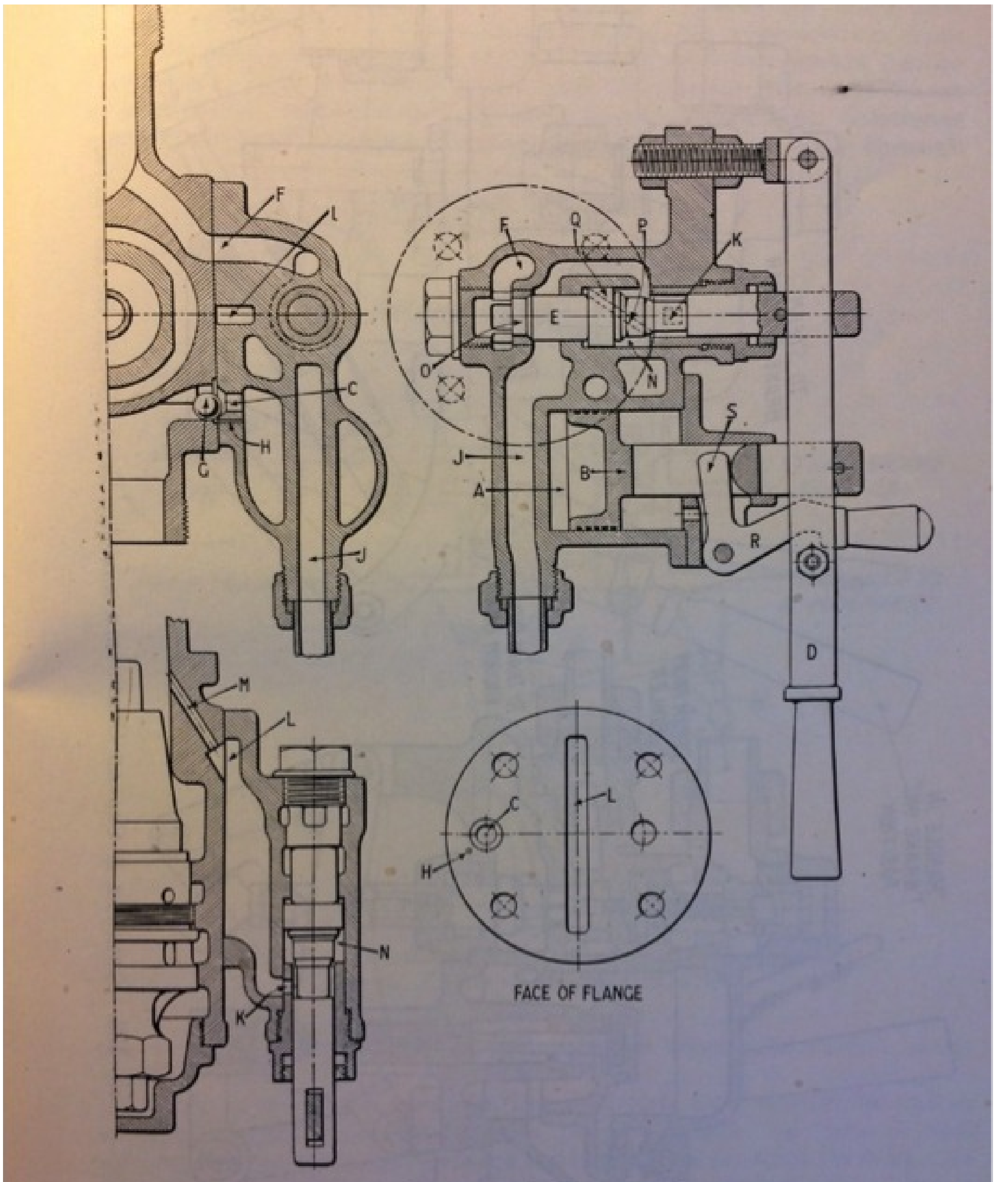


FIG. 195.—GRESHAM & CRAVEN AUTOMATIC STEAM BRAKE VALVE.

Co-Acting Steam Brake &Vacuum Brake Valve

NB

The learner needs to study the workings of this valve or similar versions of the co acting valve, (*Page 311 onwards to 315 as above*) They must be conversant with how the valve or similar equivalents, co-act to make the vacuum and steam brakes work together on a train and how they can also be separated to allow independent working when appropriate. The best possible lesson can be derived by experiencing and following the procedure whereby a vacuum fitted train pulled by a steam braked locomotive on a heritage branch line goes about detaching itself from the train safely and "running-round" the fully secured train at the end of the journey before coupling itself on the other end. The braking system is then re-established after coupling up and once a **Brake Safety test** has been carried out to establish the continuity of the newly coupled brake system the train is safe to continue on its journey. There are so many elements to the learning process in this procedure that it is an essential early experience and that understanding will be tested in the LEARNING OUTCOMES within this module.

KWVR Brake Test Requirements

Responsibilities of Guards

Guards are responsible for seeing that all the vehicles composing the train are properly coupled, including all brake and steam heat hoses when required.

Guards must be satisfied that the Fireman has coupled the locomotive to the train correctly, or, where no Fireman is provided, must couple the locomotive to the train themselves.

Guards must carry out a full brake test:
(a) before the train enters service; and
(b) after the train formation has been amended.

If a locomotive is attached to or detached from a train on which the full brake test has already been carried out, Guards must ensure that the automatic brake is still operative.

Regulations for the Working of Automatic Brakes

Vacuum brake test

When vacuum has been created the Guard must:

a) be satisfied that the required amount is registered on the gauge in the rearmost brake van of the train (minimum 18ins Hg);
b) open the brake application valve in that van and observe that as air is admitted to the train pipe the reading on the gauge falls to zero;
c) close the valve again and observe that the required vacuum is recreated.
d) inform the Driver that he intends to carry out a further brake test and ensure that the required vacuum has been recreated.
e) remove the hose at the trailing end of the rear vehicle from its dummy plug, check that the brakes are applied to the wheels on all vehicles in the train and ascertain that air is drawn into the train pipe through this hose for at least 10 seconds;
f) replace the rearmost hose on its dummy plug, ensure that the required vacuum is obtained and check with the Driver that the brake test was satisfactory.

When a full brake test is required, the Guard carries out steps (a) to (f). When a locomotive is attached or detached from a train on which a full brake test has already been carried out, the Guard carries out steps (a) to (c).

AIR BRAKES

(Information based on Wikipedia in italics)

Straight air brake

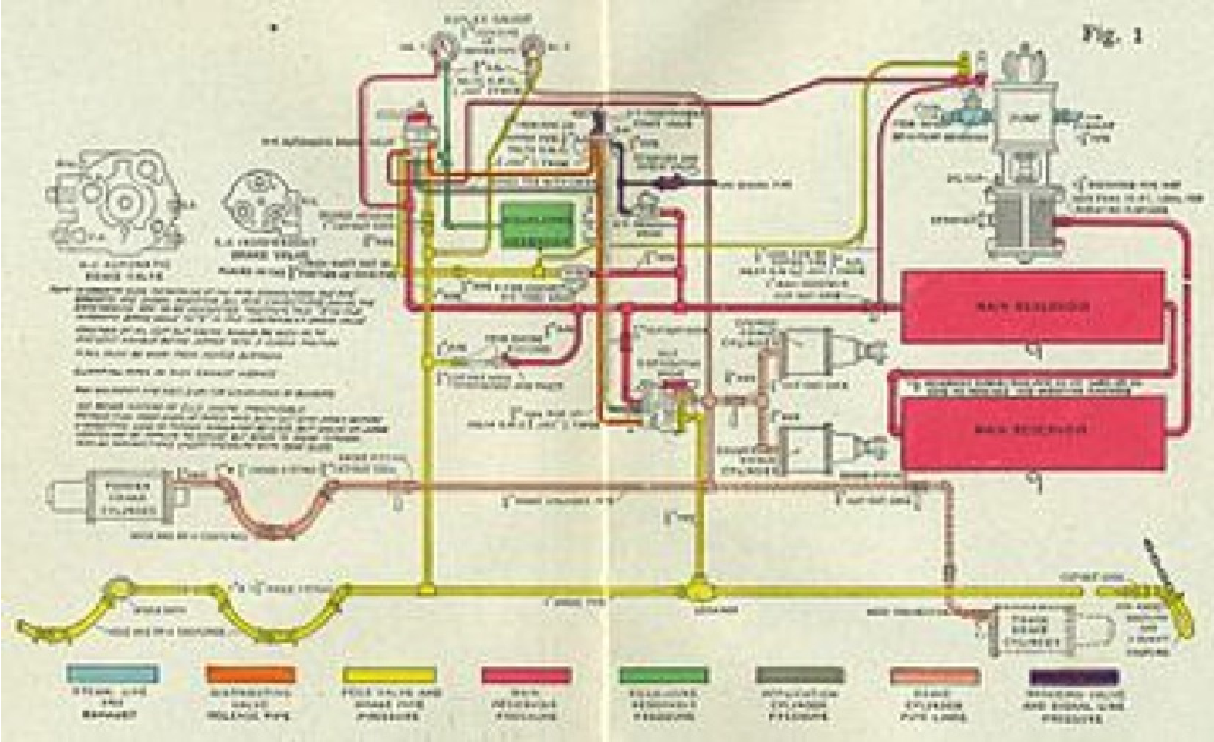
In the air brake's simplest form, called the straight air system, compressed air pushes on a piston in a cylinder. The piston is connected through mechanical linkage to brake shoes that can rub on the train wheels, using the resulting friction to slow the train. The mechanical linkage can become quite elaborate, as it evenly distributes force from one pressurized air cylinder to 8 or 12 wheels.

The pressurized air comes from an air compressor in the locomotive and is sent from car to car by a train line made up of pipes beneath each car and hoses between cars. The principal problem with the straight air braking system is that any separation between hoses and pipes causes loss of air pressure and hence the loss of the force applying the brakes. This could easily cause a runaway train. Straight air brakes are still used on locomotives, although as a dual circuit system, usually with each bogie having its own circuit.

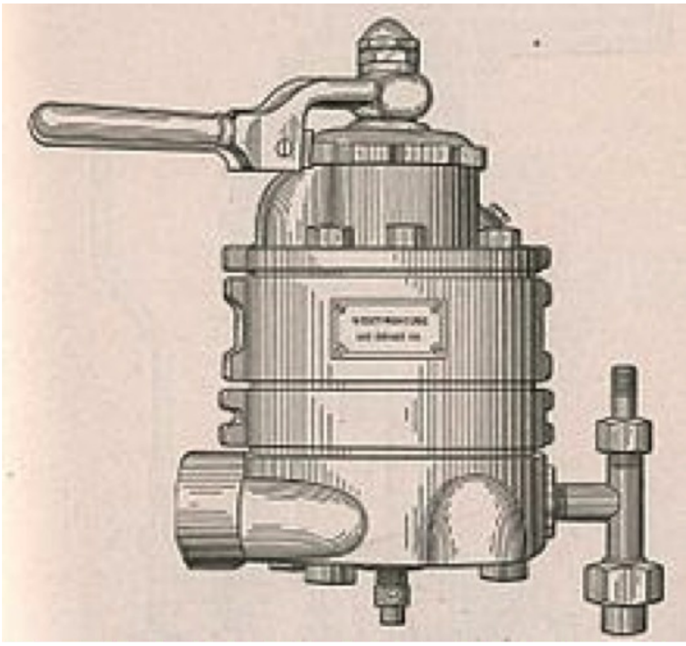
Westinghouse air brake

To design a system without the shortcomings of the straight air system, Westinghouse invented a system wherein each piece of rolling stock was equipped with an air reservoir and a triple valve.

Rotair Straight Air Brake Valve



Westinghouse 1909 locomotive schematic Air Brake system



Westinghouse Air Brake control

Unlike the straight air or vacuum system, the Westinghouse system uses a reduction in air pressure in the train line to apply the brakes.

The triple valve is described as being so named as it performs three functions: Charging air into an air tank ready to be used, applying the brakes, and releasing them. In so doing, it supports certain other actions (i.e. it 'holds' or maintains the application and it permits the exhaust of brake cylinder pressure and the recharging of the reservoir during the release). In his patent application, Westinghouse refers to his 'triple-valve device' because of the three component valvular parts comprising it: the diaphragm-operated poppet valve feeding reservoir air to the brake cylinder, the reservoir charging valve, and the brake cylinder release valve. When he soon improved the device by removing the poppet valve action, these three components became the piston valve, the slide valve, and the graduating valve.

- *If the pressure in the train line is lower than that of the reservoir, the brake cylinder exhaust portal is closed and air from the car's reservoir is fed into the brake cylinder. Pressure increases in the cylinder, applying the brakes, while decreasing in the reservoir. This action continues until equilibrium between the brake pipe pressure and reservoir pressure is achieved. At that point, the airflow from the reservoir to the brake cylinder is lapped off and the cylinder is maintained at a constant pressure.*
- *If the pressure in the train line is higher than that of the reservoir, the triple valve connects the train line to the reservoir feed, causing the air pressure in the reservoir to increase. The triple valve also causes the brake cylinder to be exhausted to the atmosphere, releasing the brakes.*
- *As the pressure in the train line and that of the reservoir equalize, the triple valve closes, causing the air in the reservoir to be sealed in, and the brake cylinder is not pressurized.*

When the engine operator applies the brake by operating the locomotive brake valve, the train line vents to atmosphere at a controlled rate, reducing the train line pressure and in turn triggering the triple valve on each car to feed air into its brake cylinder. When the engine operator releases the brake, the locomotive brake valve portal to atmosphere is closed, allowing the train line to be recharged by the compressor of the locomotive. The subsequent increase of train line pressure causes the triple valves on each car to discharge the contents of the brake cylinder to the atmosphere, releasing the brakes and recharging the reservoirs.

The Westinghouse system is thus fail safe (as with the vacuum system)—any failure in the train line, including a separation ("break-in-two") of the train, will cause a loss of train line pressure, causing the brakes to be applied and bringing the train to a stop, thus preventing a runaway train.

In the UK some railways adopted the Westinghouse system right from the introduction of legislation for automatic brakes, and the remainder after some resistance adopted the Automatic Vacuum Brake

Those air braked railways included London Brighton and South Coast Railway, Caledonian Railway, North British Railway, and Great Eastern Railway. As long as the locomotive and carriages from one Railway Company remained together than everything was fine, but as *through working* of carriages over different railway company’s networks became commonplace then confusion between incompatible braking systems broke out.

At the 1923 Grouping of the many railway Companies the “Big Four” companies standardised on Vacuum brakes for their system but eventually when British Railways was formed in 1947 they decided to adopt compressed air brakes for future new construction.

In general though, Heritage Lines in the UK are still running with Vacuum brakes but the situation where heritage locomotives are running on the Main line as well as on heritage sites (like “Tornado or “Flying Scotsman”) both air brake and vacuum brakes as well as the modern ERTMS systems must run alongside each other, and be fully compatible and co acting.

There is an interesting nuance with the air brake system with whether there are two pipes between locomotive and train or just one. In the UK we expect to see two pipes, one pipe with red end fittings known as the TRAIN Pipe and one pipe with yellow end fittings known as the RESERVOIR pipe, but it is possible to operate a competent air brake system with only one train pipe connection along the train as in the USA and in early UK air braked trains. This system has one major drawback.

The single pipe air brake system uses the one pipe to both act as the signal pipe to apply the brakes as well as to keep the auxiliary reservoirs on each vehicle fully topped up so as to be ready to make a full brake application. The system as described has one major drawback. When a brake application is made the triple valve permits rapid movement of air from the auxiliary reservoir to the brake cylinder. Similarly when the brakes are released the triple valve permits rapid release of air from the brake cylinder to atmosphere. However the recharging of the auxiliary reservoirs with air from the train pipe is not so rapid, so if a driver makes a quick succession of brake applications, it is possible that the auxiliary reservoirs will not have time to fully recharge with air, and the effectiveness of the brake will reduce. Releasing the brakes of a very long train can be very slow, especially if the locomotive only has a small main reservoir and there are a lot of auxiliary reservoirs to refill.

The problem of slow brake release is overcome by the two-pipe system. The red ended pipe is the Train Pipe. The system has the second pipe running the full length of the train and supplying air directly from the locomotives main air reservoir into the auxiliary reservoir of each vehicle It is therefore known as the Main Reservoir Pipe and is painted yellow at the ends where the shut off valves are fitted.

The yellow and red ends to the pipes are designed so that they cannot be inadvertently connected incorrectly.

LO1: Brakes - General

1. Material
1. Firebanding
2. Markers
3. Types of Brake Systems
4. Vacuum Systems
5. Coefficient of friction

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO1 1	Brake Block Material	What Material is used to manufacture brake blocks?	Classroom	
LO1 2	Firebanding	What is meant by the term ‘Firebanding’	Classroom	
LO1 3	Markers	Why are white lines painted across a wheel and tyre of a locomotive?	Classroom	
LO1 4	Brake Systems	Name the 2 systems you will likely find on a Heritage Railway	Classroom	
LO1 5	Vacuum Systems	Why did the Vacuum system become adopted in the UK for Steam Locomotive hauled trains?	Classroom	
LO1 6	Coefficient of friction	What happens to the coefficient of friction between a cast iron brake block and a steel wheel as the speed approaches zero?	Classroom	

LO2: **Automatic Vacuum Brake**

1. Vacuum Brake Cylinder
2. Vacuum brake system
3. Rolling Ring
4. Brakes Applied
5. Brakes Released
6. Duplex System
7. Pulling the String
8. Measuring Vacuum

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO2 1	Vacuum Brake Cylinder	Explain with diagrams the principle in which a vacuum cylinder operates	Classroom	
LO2 2	Vacuum brake system	Draw an annotated diagram of a typical vacuum brake system.	Classroom	
LO2 3	Rolling Ring	What is a ‘rolling ring’ and what purpose does it serve?	Classroom	
LO2 4	Brakes Applied	Show by means of a diagram the position of the piston and which parts are at atmospheric pressure and which are in vacuum with the brakes applied	Classroom	
LO2 5	Brakes Released	Show by means of a diagram the position of the piston and which parts are at atmospheric pressure and which are in vacuum with the brakes released	Classroom	
LO2 6	Duplex System	What is the advantage of a two pipe or Duplex system?		
LO2 7	Pulling the String	What does Pulling the String mean? And what effect does it have?		
LO2 8	Measuring Vacuum	How is Vacuum measured in systems on heritage railways? There are 2 different values used, what are they		

LO3: The Ejector

1. Large Ejector
2. Small Ejector
3. GWR method
4. Ejector principles

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO3 1	Large Ejector	What is the purpose of the Large Ejector?	Classroom	
LO3 2	Small Ejector	What is the purpose of the Small Ejector?	Classroom	
LO3 3	GWR method	What mechanism did GWR use to maintain vacuum?	Classroom	
LO3 4	Ejector	Draw an annotated cross section of an ejector and describe its action	Classroom	

LO4: Direct Acting Valves

1. Direct Acting Valve advantages
2. DA valve operation
3. DA valve construction

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO4 1	Direct acting valve	What advantage does a direct acting valve bring to the braking system?	Classroom	
LO4 2	Operation	Describe how a DA operates	Classroom	
LO4 3	Gresham DA valve	Draw an annotated section of a Gresham DA valve	Classroom	

LO5: **Steam Brakes**

1. Steam Brake
2. Pressure
3. Brake cylinder
4. Bogie side control springs

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO5 1	Steam Brake	Why are most locomotives fitted with a Steam brake?	Classroom	
LO5 2	Pressure	What pressure does a steam brake operate at?	Classroom	
LO5 3	Brake Cylinder	Compared to vacuum brakes what is the size of the brake cylinder?	Classroom	
LO5 4	Co-acting Valve	What is meant by the co-acting brakes?	Classroom	
LO5 6	Advantages & possible difficulties	What are Advantages & possible difficulties with a steam brake?	Classroom	

LO6: **Brake test requirements**

1. When a brake test needs to actioned
2. Minimum Vacuum
3. Application Valve
4. Dummy Plug
5. Vacuum Brake test

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO6 1	Brake test	When does a brake test need to be actioned?	Classroom	
LO6 2	Minimum vacuum	What is the minimum vacuum required?	Classroom	
LO6 3	Application valve	When the application valve is opened what should the gauge read? On closing the valve what should happen?	Classroom	
LO6 4	Dummy Plug	Remove the vacuum hose from the dummy plug at the trailing end of the train, what should happen?	Classroom	
LO6 5	Vacuum brake test	Carry out a brake test satisfactory under your mentors guidance	Workshop	

LO7: **Air Brakes**

1. Straight Air Brake
2. Westinghouse Air Brake
3. Comparison of the two systems
4. Single/Dual pipe systems
5. Pipe identification
6. Connection
7. Connecting 2 systems

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO7 1	Straight Air Brake	What is the disadvantage of a straight air brake?	Classroom	
LO7 2	Westinghouse Air Brake	Draw an annotated diagram of a typical Westinghouse air brake system.	Classroom	
LO7 3	Straight Air brake/Westinghouse system	What is the main difference between the 2 systems?	Classroom	
LO7 4	Single/dual pipe systems	What is the advantage of a 2 pipe system?	Classroom	
LO7 5	Pipe identification	Which pipe is coloured red and which yellow?	Classroom	
LO7 6	Connection	Try connecting a red pipe to a yellow cock, can it be done?	Workshop	
LO7 7	Connecting 2 systems	How would you couple a two pipe equipped locomotive to a one pipe equipped carriage or vice versa?	Classroom	

LO8: **Examination**

1. Hangers
2. Brake Blocks
3. Brake Pull Rods
4. Brake Shafts
5. Trunnions
6. Safety Chains
7. Handbrake Column
8. Vacuum Pump if fitted
9. Brake test loco under steam

LO	Objectives	Assessment Criteria	Delivery	Date achieved and Supervisors signature
LO8 1	Hangers	Examine all brake hangers for distortion, missing clips, loose bolts and missing split pins	Workshop	
LO8 2	Brake blocks	Examine all brake blocks for fractures and wear and the adjustment is correct	Workshop	
LO8 3	Brake Pull rods	Examine for wear and distortion, particularly the fork ends and check for security of all fastenings	Workshop	
LO8 4	Brake Shafts	Examine shafts for excessive clearance in bracket bushes and where they connect to the cylinder push rods	Workshop	
LO8 5	Trunnions	Check for missing bolts, loose fastenings and the cylinder is free to move	Workshop	
LO8 6	Safety chains	Check Chains for wear in links and securing bolts and frame hooks	Workshop	
LO8 7	Handbrake column	Check for security and wear on the thread and nut	Workshop	
LO8 8	Vacuum Pump if fitted	Check vacuum pump for security, check crosshead and glands.	Workshop	
LO8 9	Brake test, Loco in steam	Carry out all tests as detailed in MT276 2.18 in the presence of your mentor/supervisor	Workshop	

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 LM7 – Brakes

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

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

LO8	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**