Air brakes on the Golden Valley Light Railway

Issue 1
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1. Introduction

From the outset, it was recognised that the GVLR would need a system of continuous automatic brakes. (Continuous throughout the train and automatically applied in the event of the train dividing.) By the time the railway was mooted in 1986, it was known that HMRI would require it, and in any case, it was anticipated that the railway would include steep gradients and a significant difference in altitude between the two ends. Ultimately, it transpired that the altitude difference was about 15m over a length of about 1.3 km, although the gradients are by no means continuous or even, and the most meagre of risk assessments would dictate the implementation of a decent braking system for passenger trains in any case. Get it wrong and you're in the public bar doing 40 mph!

Compressed air was chosen as the energy source and control medium due to the ready availability of suitable equipment on commercial road vehicles at the time, and the engineer's experience of introducing the identical system on the late lamented Lincolnshire Coast Light Railway at Humberston from 1979 onwards. The ready alternative, vacuum, has no readily and cheaply available equipment, requires much larger actuators, and consumes more energy both on steam and Diesel traction. You also couldn't use a loco as a power source for spray painting a carriage! Electricity for use as a control medium is not available on every locomotive.

Compressed air railway brakes can operate by a number of different principals, of which the two which do not require an electricity supply are described as follows:

1. The system used by "big" railways, commonly referred to as "Westinghouse" after one of its originators. This can use a single pipe which is continuous throughout the train and in which the air pressure is raised to release the brakes and reduced to apply them. While the brakes are released and the pipe is pressurised, a reservoir on each vehicle is filled via a non-return valve. A valve known as a distributor or triple valve measures the pressure in the train pipe and admits air from the vehicle reservoir to the brake actuator if it senses the train pipe pressure falling, releasing it to exhaust when the train pipe pressure rises again. The train pipe is painted red at the couplings if the brakes are active on the vehicle in question, or if the vehicle is unbraked but through piped, it is painted white to serve as a rapid identification. Since the parting of the train will depressurise the train pipe and therefore fully apply the brakes, the system is referred to as "fail safe" and "automatic". Passengers or the guard of the train can fully apply the brakes by opening passenger communication valves which are provided on each carriage.

Where trains are long and rapid response rates are required, an extra pipe is provided for the purpose of feeding the reservoirs only, at a higher pressure than the train pipe. Such pipes are painted yellow at the ends. GVLR does not need the yellow reservoir pipe.

2. The mining system, which is really a copy of a basic articulated lorry system. 2 pipes are provided. One supplies air directly to the air brake cylinders on every vehicle, and this system is therefore "fail dangerous". In order to achieve the objective of achieving a brake application in the event of a train parting, the other pipe fills a reservoir on each vehicle and applies the brake via an emergency valve if its pressure falls. The driver has no control over the pressure in the emergency pipe, except the ability to vent it totally, and the emergency valves on the vehicles do not respond in a proportional manner as does a distributor or triple valve, but make a full application after only a small fall of pressure in the emergency pipe.

   This system possesses the minor advantage by comparison with system 1, that the air consumption is reduced slightly in return for the increased complexity.

The system adopted for the GVLR is system 1. However, some vehicles were already fitted with system 2 at the time of their arrival, and have needed to be converted. This is not an unduly onerous requirement, since all brake systems have been fully overhauled before being introduced into service, and the additional work is small.

2. Brake rigging design.

All vehicle fitted with air brakes require additionally some form of parking brake. The simplest form of parking brake is an air brake cylinder which includes a spring which is compressed when air is available. This is very much not preferred from a utility point of view, since an air supply is required to achieve release. Many locomotives and non-passenger vehicles on the GVLR are not air fitted and never will be, and a vehicle which can't be moved just because it has the wrong type of parking brake is an unmitigated nuisance. A far better arrangement is a screw brake or a lever ratchet arrangement. If necessary these can be padlocked in the on or off positions for security.

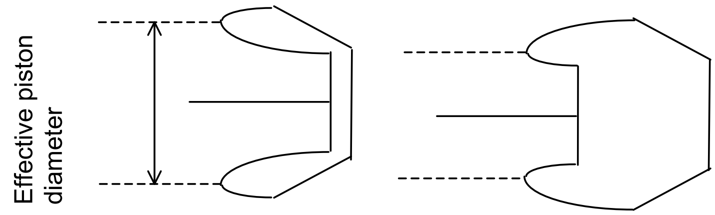
When designing a set of brake rigging, it should be the objective to achieve a brake block force on each wheel which is proportional to the vertical load on that wheel. This is less significant where the wheels are coupled as on a locomotive, but is considered vital on carriages, particularly where the wheels are loose on stationary axles. Carriages have the additional disadvantage that the axle load varies considerably with contents, a carriage of 2 ½ tonnes tare being capable of carrying approximately 2 tonnes of people (on a really good day!). It is possible to fit load variable compensation to vary the brake force in one of 3 ways, namely a manual empty / loaded changeover, an automatic empty / loaded changeover or a variable load / brake force system. All these add complexity, and the manual system is particularly prone to being forgotten and left in the loaded position, leading to wheel flats. We haven't bothered with this, and all our passenger carriages are braked so as to just lock their wheels on coming to a stand in the tare condition.

Brake rigging design is amenable to simple analysis by the laws of leverage. What is often forgotten, however, is that the length to be considered in levers is not the distance between pivots as actually measured, but the distance perpendicular to the line of force. Typically, the force at cast iron brake blocks should be designed to be of the order of 0.8 to 1.0 times the vertical load at the wheel. Fine tuning happens during commissioning.

Brake block friction surfaces can be of cast iron or composition material. Composition blocks usually last longer but have other disadvantages. For low speeds (<25 mph) cast iron is to be preferred, since its life is adequate, especially if the correct grade for non-gassy coal mine applications is used, and it does not suffer embedment from abrasive particles which can damage the wheel surface, as does composition. (In coal mines with flammable gas present, very soft cast iron is used for brake blocks, in order to eliminate spark generation. This leads to rapid wear, which is tolerated. For surface, non gassy, non explosive material environments, the odd spark doesn't matter.)

Disc brakes are sometimes found on more modern narrow gauge stock, and have both advantages and disadvantages. They are preferred on main line railways, since tread brakes contribute to wheel wear to a significant extent. This effect (brakes wearing wheel treads) can be turned to advantage where speeds are moderate, since at low speeds, temperature rise is minimal, and the blocks can be positioned close to the outer edge of the tread where they are not permitted for reasons of thermal cracking at high speeds, and where the resulting wear tends to help maintain the profile. Tread brakes have the advantage that they clean contamination from wheels when applied, which tends to reduce any tendency to wheelslide, and their friction varies automatically as the friction varies at the wheel / rail interface, again tending to minimise sliding. On locomotives, a light brake application can be used to increase adhesion in traction as well. None of this happens with disc brakes, and rusty discs don't half get through pads!

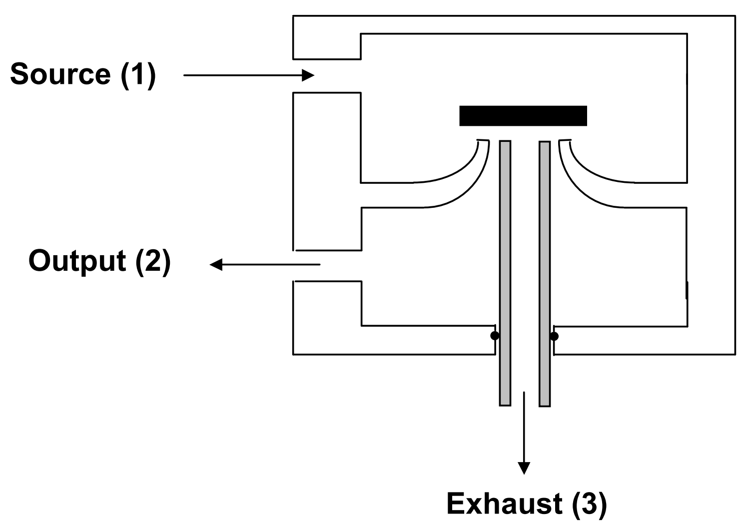
Once the first attempt at a linkage has been designed for force required from the brake cylinder, an assessment of brake cylinder travel must be made. Allowance must be made for clearance at the brake blocks in the context of available adjustment steps, wear at axle guides, and wear at pins and bushes, all of which will use up a large amount of brake cylinder stroke when high leverage is employed. Automatic slack adjusters are fitted on main line trains in order to limit the size of brake cylinder required. Brake cylinders must be sized for their ability to do work. Work done = force x stroke, and force = effective area x pressure. For a sliding piston seal, effective area = actual piston area, but beware of the reduction of effective area which occurs in diaphragm type cylinders as the stroke increases:

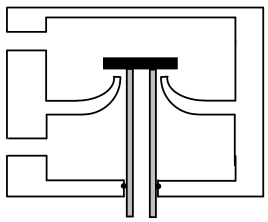


3. Method of operation

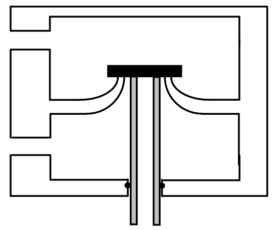
The chosen system results in a brake force which the driver can vary at will during both brake application and release. The air pressure in the train pipe is approximately proportional to the position of the handle of the driver's brake valve, and the pressure in the brake cylinders throughout the train is approximately proportional to the reduction in train pipe pressure from its starting value.

Extensive use is made of a device known as a 3 port valve, under the control of various actuating forces to govern whether it is admitting air from its source port to the delivery port, holding a fixed delivery pressure by closing all ports, or discharging air from its delivery port to its exhaust port. The whole effect is achieved simply by the position of the exhaust stem. In the following illustration, the ports are numbered, and the same sequence is used throughout the remainder of this document.

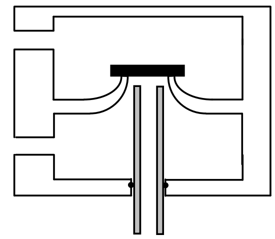




Output fed
from source,
exhaust sealed



All ports sealed,
"LAP"



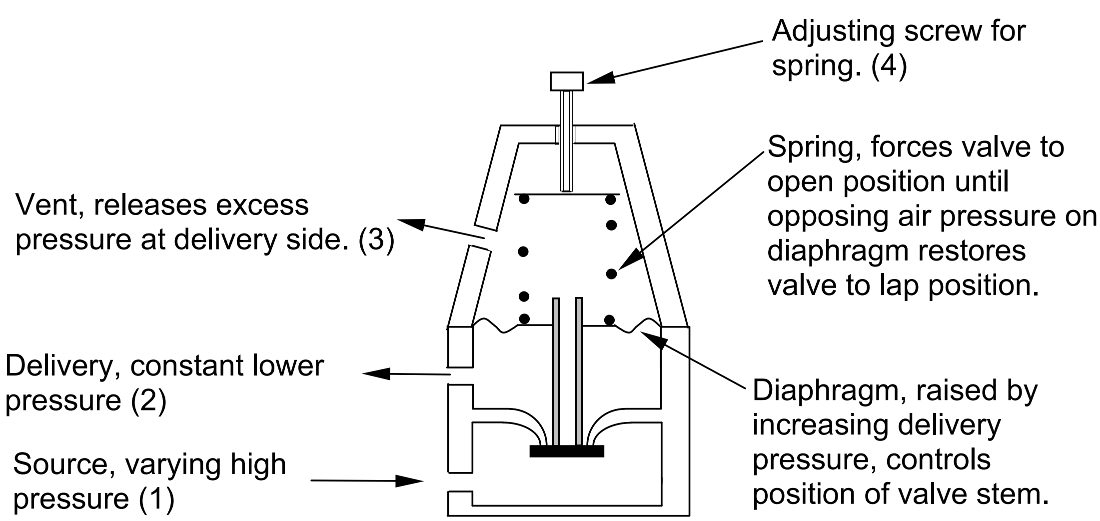
Output vented to
exhaust, source
sealed

The above illustrations show the 3 port valve in its 3 possible states. A light spring usually biases the admission valve to the closed position, so that a positive force can be created at both inlet and exhaust valve seats in order to achieve perfect sealing in the lap condition. The detailed layout may vary, but the concept is constant.

Typical applications of a 3 port valve are:

- A pressure regulator, used to provide a constant reduced output pressure from a source which has varying pressure,
- A driver's brake valve, used to control the pressure in the train pipe, or to provide a control air signal to a relay valve,
- A relay valve, used to vary the pressure of air in the train pipe with a higher volume flow than that available from the driver's valve,
- A compressor governor, used to switch an air compressor off load,
- A distributor, used to control the pressure of air in vehicle brake cylinders under the control of the pressure in the train pipe. This can be considered to be an inverting relay valve.

4. Pressure regulator



5. Driver's brake valve

A driver's brake valve is just a pressure regulator, but the adjusting screw has a coarse pitch, so that, e.g. a quarter turn of the handle covers the full range of adjustment. The valve body can include an extra valve which operates in only an emergency position, to vent the train pipe directly.

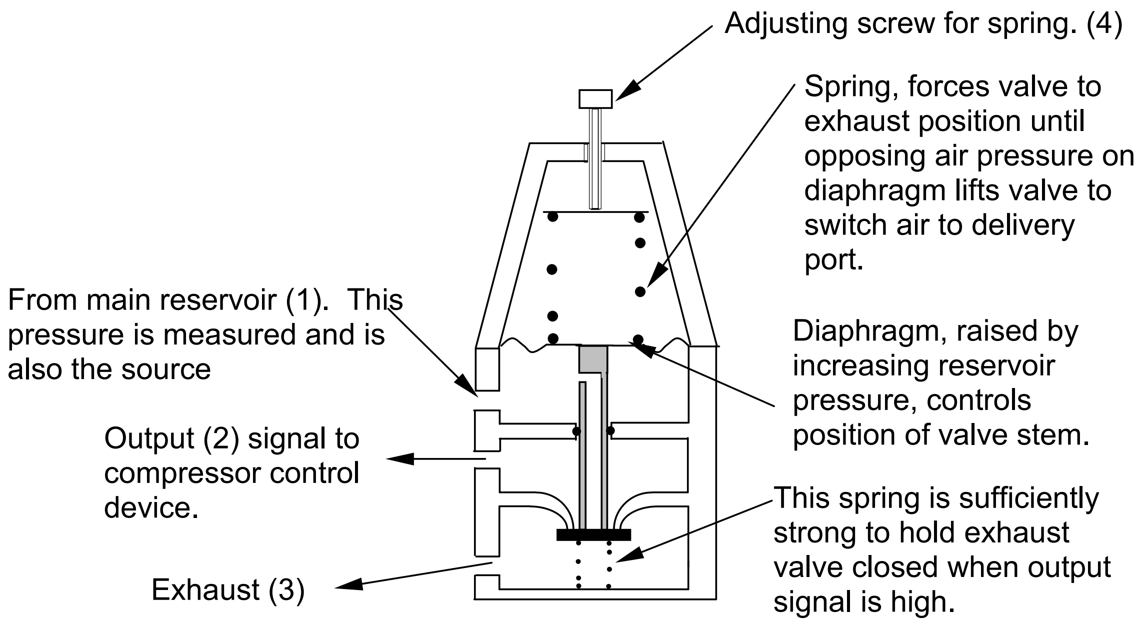
6. Relay valve

A relay valve is a modified form of pressure regulator. Instead of the regulating force being applied to the pressure measuring diaphragm by a spring, an air piston fulfils this role. The output pressure varies directly as the control pressure, up to the full source pressure. A relay valve is used where a small volume air supply is required to control a large volume air supply, e.g. where the original actuating force is limited.

7. Compressor governor

A compressor governor is used to switch off or unload a compressor for the purpose of saving energy and wear when the full working pressure is reached. When used to unload a compressor, the compressor stops pumping even though it may keep running. A safety valve could be used instead, but this would not save energy and wear. Where a governor is used to interrupt the supply of compressed air, a safety valve must in any case be fitted in case the governor fails.

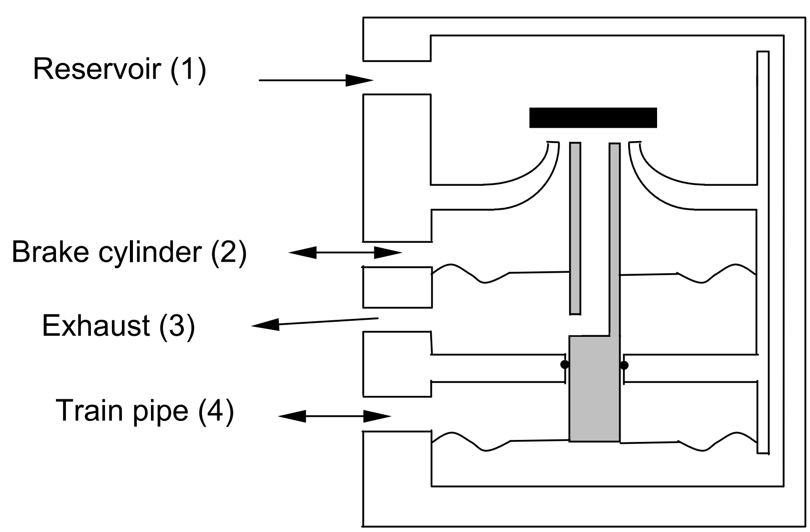
Between the compressor and main reservoir a non return valve is fitted. The governor measures the pressure downstream of the non return valve. When a pre-determined pressure is achieved, the governor switches a supply on to an external connection which can be used for a number of purposes. These could be any of switching off the steam supply to the compressor on a steam loco, opening a valve which vents the delivery of a continuously rotating compressor to atmosphere or operating small pistons to lift the valves in the cylinder head of the compressor. As the pressure in the main reservoir falls, the governor does not immediately switch the compressor back to the on state, but waits until a definite fall in pressure has occurred. This differential is created by causing the area on which the pressurised air acts within the governor to change at the point of switching, to increase it in the compressor unloaded condition. In the illustration below, the extra area consists of the area of the operating spindle which is only exposed to air pressure when in the raised position.



An identical device can be used as what is referred to as a main reservoir governor. This prevents brake release if the main air reservoir pressure is too low to satisfactorily achieve a full recharge of all the reservoirs in the train, and controls a relay valve in series with the drivers valve or its relay valve. Where such a device is fitted, it may be necessary to initially charge the reservoirs on a completely dead train in small stages in order to avoid it tripping.

8. Distributor

It is the function of the distributor to measure the pressure in the train pipe and as it decreases, to increase the air pressure in the brake cylinder on the vehicle. It also reduces the pressure in the brake cylinder as the train pipe pressure increases.



Note the internal connection from the top to the bottom chamber.

If the above diagram is considered, it will be seen that in order to maintain the inlet / exhaust valve in equilibrium, i.e. in the lap position, then the following balance of pressures must hold:

Reservoir + Exhaust = Train pipe + Brake cylinder

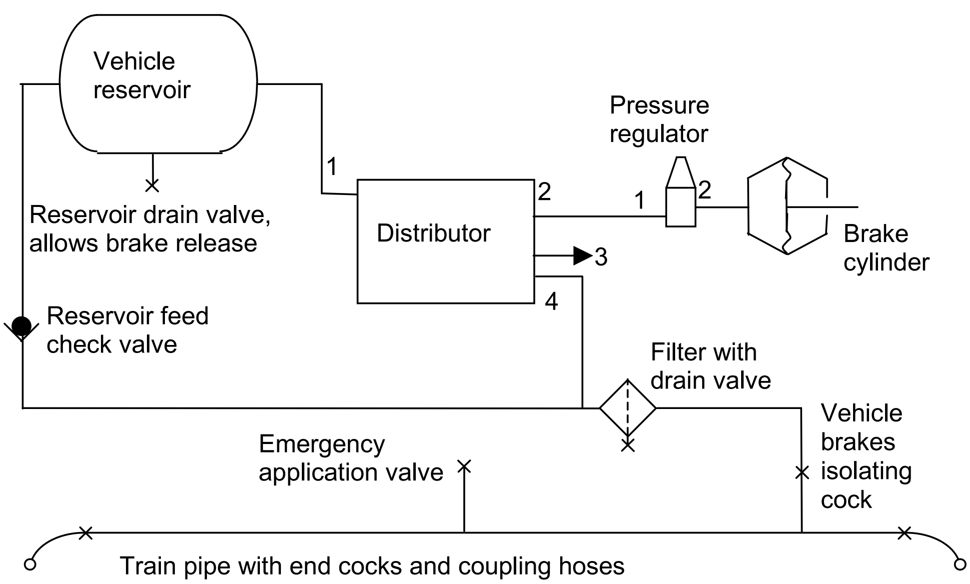
Therefore, it follows that if the reservoir pressure is constant and the exhaust pressure is constant (atmospheric) then as the train pipe pressure varies, the valve will adjust to vary the brake cylinder pressure, thereby restoring equilibrium.

The reservoir on each vehicle which applies the brakes is fed directly from the trainpipe via a non return valve which traps the air in the reservoir when the train pipe pressure reduces. Some distributors contain this non return valve, others need a separate one.

Photographs of 3 different types of valve which can be used as a distributor are in the Appendix, and if you have knowledge of the whereabouts of any of these which may be available, please contact the webmaster at www.gvlr.org.uk.

9. Schematic diagram of brakes on a vehicle

Every vehicle, including locomotives is fitted with the equipment shown below for the purpose of controlling its brakes as the train pipe pressure varies.



The above concludes the functional description of the equipment fitted on each trailer vehicle (carriage).

10. Characteristics and proportionality

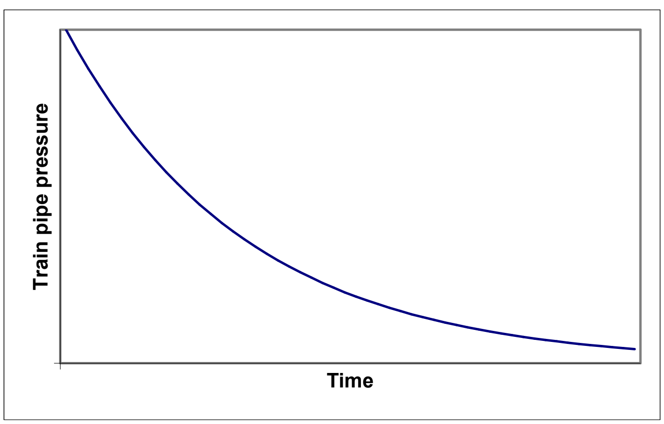
A number of features must be considered if a reliable and effective system is to be designed. These are:

1. Rate of venting air from the train pipe in an emergency, and therefore the rate at which the brakes apply throughout the train.
2. Avoidance of the locomotive overcoming an emergency application made by venting the train pipe elsewhere in the train.
3. Reliable release of the brakes throughout the train and the avoidance of dragging brakes when changing locomotives.

Each is considered in turn:

10.1 Rate of emergency application

As the pressure in the train pipe falls, so the rate at which air escapes through the train pipe and the passages in the driver's brake valve falls. This results in a pressure / time relationship of the form shown in the following graph:



Since the rise of brake cylinder pressure follows the fall of train pipe pressure, it will be seen that a significant delay could occur before the maximum retardation rate is achieved. Two modifications are used in order to ensure that the brake applies more quickly.

The first is to ensure that the train pipe is vented as rapidly as possible when demanded. Some driver's brake valves have only small passages, and while these could be used for direct train pipe control, the delay would be considerable. This can be overcome either by installing a relay valve to follow the pressure control signal generated by the driver's valve, or by having a separate large emergency valve, which may be integral to the driver's valve or entirely separate. Typically, on a steam loco, a separate valve would be fitted, accessible by the fireman as well as the driver.

The second is to arrange for maximum brake cylinder pressure to be achieved before the train pipe pressure drops fully to zero. The maximum brake cylinder pressure required is reduced by design of the mechanical linkage, and a pressure regulator is interposed between the distributor and brake cylinder to prevent this pressure from being exceeded.

10.2 Emergency brake application from the train.

Any person on the train can make an emergency brake application, simply by opening an emergency cock, of which there is at least one on every coach. Additionally, division of the train creates the same effect by parting the brake hoses. For this reason, the coupling heads on the hoses should be of the standard railway “gladhand” or “ palm coupling” type, which part without damage. Naturally, they must NOT be self sealing, as used on the reservoir supply (yellow) pipe or direct application pipe of a colliery 2 pipe system. Additionally, they must not stretch before parting, in order to avoid incidents of the type where a train parts, separates by a significant distance, and then suffers an impact as the two halves bang back together again.

If the locomotive carried a large reserve of air, which could be fed rapidly into the train, it is likely that this would hold off a full emergency application. The manner in which this is overcome is a restriction on the rate at which the locomotive can feed air to the train pipe. Typically, the train pipe is nominal ½” pipe (12 –13mm bore) and emergency valves have a 12mm clear through way. The locomotive’s train pipe feed has a restriction with a diameter of approximately 4mm, and this is considered to allow the train pipe pressure to fall rapidly almost to zero in the event of an emergency application. It does, however, have the disadvantage of increasing the brake release times. Drivers must be aware of this and allow adequate time for brake release in order to avoid dragging brake starts and early, jerky stops.

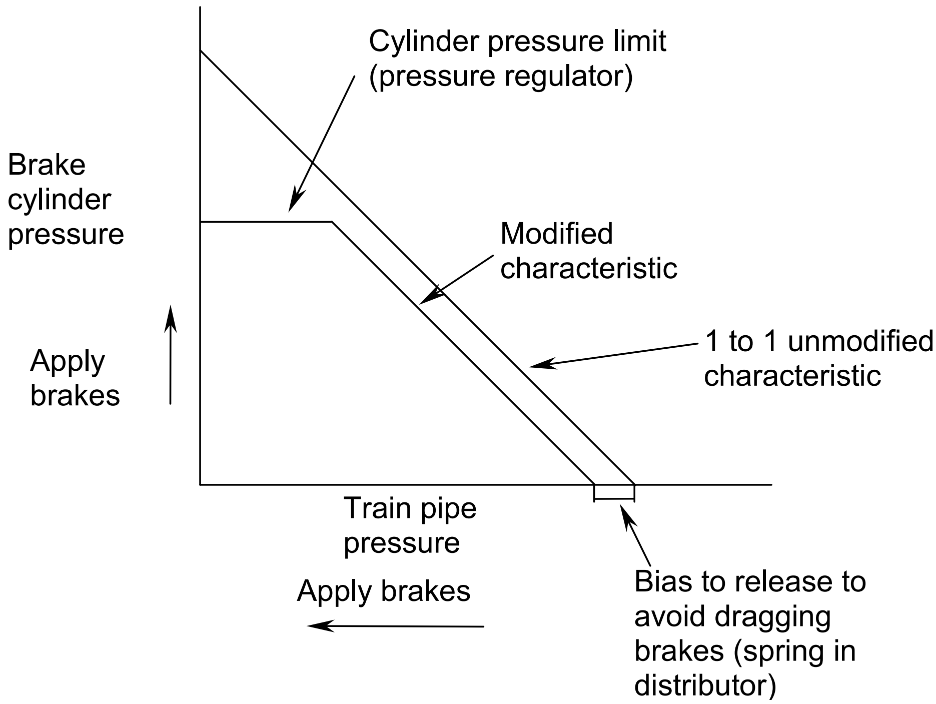
10.3 Reliable brake release

If the distributor were to actually be as drawn, then any slight fall in train pipe pressure below the reservoir pressure would result in some degree of brake application, on a one for one basis. Due to the restriction in the feed of air from the locomotive during release, complete brake release would take an eternity. When exchanging locomotives, no two of which have exactly the same air delivery pressure, dragging brakes could result.

Two measures help to avoid this. The first is that the vehicle reservoir actually contains a slightly lower pressure than the maximum train pipe pressure because it is fed by a non return valve, and these always close slightly before equilibrium is reached, although in some cases this differential is small. The second is that the distributor contains a spring which biases the whole moving assembly slightly to the exhaust direction.

The net result of all these refinements can be expressed on the following graph.

Additionally, it should be noted that there exist some types of valves which can be used as a distributor, which have different areas on different diaphragms, and so the slope of the line on the graph varies. It is desirable that each vehicle in the train should, more or less, provide its own braking requirements, so the intended characteristics need to be designed into the linkage and working pressure range for each design.



While we're on the subject, the term "distributor" refers to a device which provides both proportional application and release. A triple valve provides proportional application, but instantaneous release (any pressure rise in the train pipe provides total release). Triple valve systems have an overriding rule applied to them. Once you have started to make a brake release you must make a complete brake release and maintain it until the reservoirs all down the train have fully recharged before you apply the brake again. Can be a bit tricky! The emergency valves which respond to changes in pressure in the emergency pipe of the colliery 2 pipe system have instantaneous application, but release only on total restoration of the pressure in the emergency pipe (more or less). The GVLR single pipe system uses only distributors.

11. Air Compressor

Air compressors on other than steam locos are generally of the reciprocating piston type, with the piston powered by a crankshaft. There is no fundamental reason why a compressor of any rotary variety should not be fitted, and some standard gauge trains now use them, but in the small sizes required by the GVLR, they are not commonly available in an efficient form.

Compressor control could be arranged electrically, but an electrical supply is needed, and is not always available. This chapter concentrates on entirely pneumatic systems.

Typically, on a Diesel locomotive, a compressor of the type fitted to a lorry or bus is used, and this is driven by the engine. On an electric locomotive (the GVLR has a 50 HP 8 tonne battery locomotive in its stock, and this may one day be equipped with air brakes) a similar compressor is powered by an electric motor. These compressors are conventional single stage single acting piston pumps with a crankshaft and automatic inlet and delivery valves in their cylinder head. Usually they have 1 or 2 cylinders, but the 16 tonne 100 HP Hudswell Clarke mines type has a large 4 cylinder compressor to cope with the high air demands imposed by its air powered engine starting system and its ability to work very long and heavy trains.

On a steam locomotive, a special purpose compressor is used, with no rotating members. A steam locomotive may also be fitted with an axle driven compressor in order to save the steam consumption associated with a steam powered compressor. For a description of the workings of the steam powered compressor, the reader is referred to the separate chapter on this subject.

Control of the compressor when Diesel powered is by the signal from the governor either opening a large valve to atmosphere in the delivery line, with the main reservoir being protected by a non-return valve, known as in line unloading, or by the same signal operating small pistons which hold the compressor's inlet valves off their seats. In some cases, the governor and in line unloader is combined within one valve body.

For an electrically powered compressor, the motor is switched on & off automatically. There must be provision for unloading the compressor during starting so the motor does not start on load. It is best if the motor is controlled by a pressure switch which obtains its air signal from a governor rather than from the main reservoir pressure, & the governor then controls unloading.

In the case of the steam powered compressor, it is not usual for the governor to cut the steam supply entirely, but to reduce the supply considerably so that the compressor does not cool down unduly and emit a shower of water from its exhaust upon re-starting. Governor cut out is therefore accompanied by a sudden slowing of the compressor.

As air is compressed, its temperature rises. The more it is compressed, the higher the temperature. The higher the temperature, the greater the volume occupied by a given mass of air, and since the compressor does work according to the product of volume change and pressure, it is the case that the amount of work done in compressing a given mass of air from a starting pressure to a final pressure is less if the temperature can be reduced during compression. For this reason, and to limit the oxidation of the lubricating oil and protect other materials in the system, air can be compressed in more than one stage, with extraction of heat in an intercooler between stages. Small compressors have higher pressure capabilities per stage than large compressors, since their surface area to volume ratio is higher, and they therefore naturally lose more heat. The sizes of compressor that are needed for the GVLR are quite satisfactory as single stage machines up to 8 bar (120 psi), but standard gauge trains which store air at up to 10 bar (150 psi) commonly have 2 stage compressors. (Compressors for SCUBA equipment, which compress up to 200 bar are typically 4 stage.) Another efficiency gain with multiple stages arises from minimising the effect of the "dead volume" in each cylinder. Cylinder volume which remains when the piston is at the end of its stroke cannot be entirely eliminated, and limits the compression ratio per stage which can be physically achieved, and is economic to achieve.

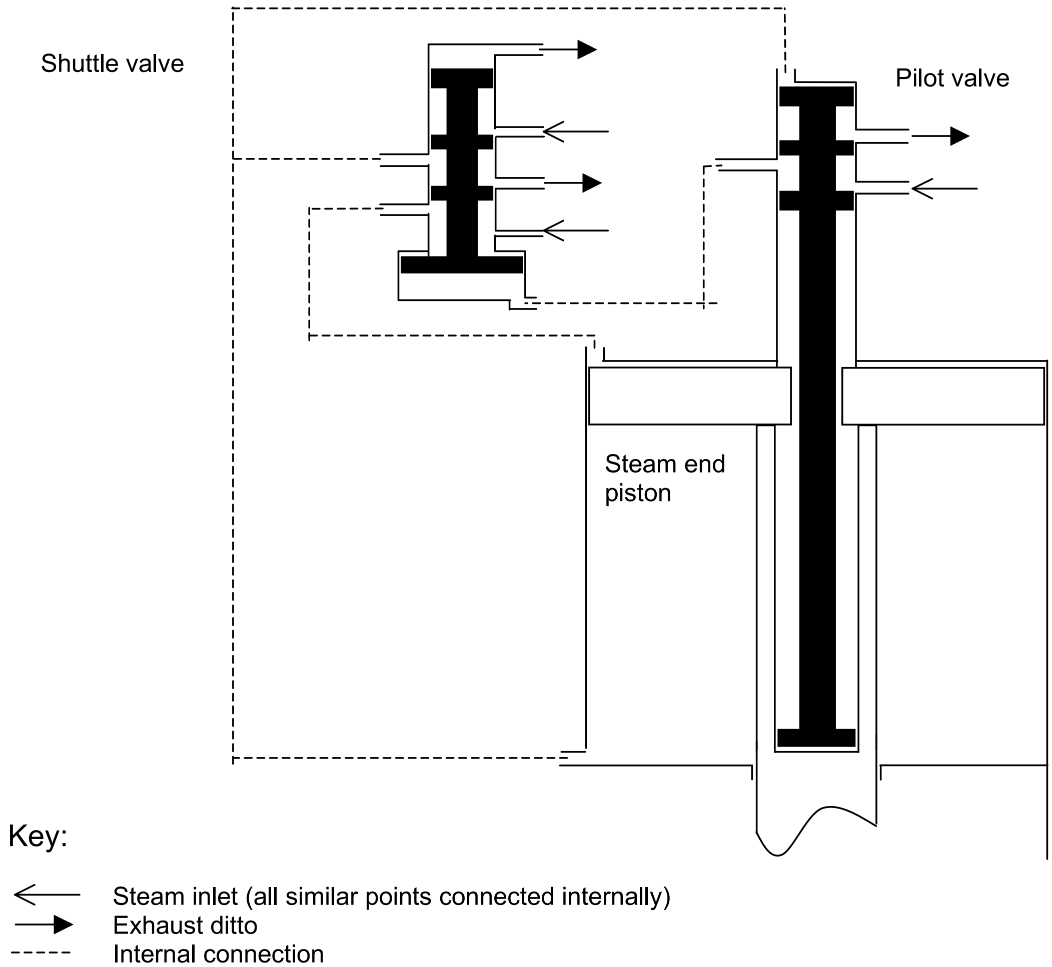
12. Steam powered compressor

The objective of the steam part of a steam driven air compressor is purely to drive the air piston of a conventional air compressor backwards and forwards. The compressor part is usually double acting, and may be 2 stage on larger machines than are needed by the GVLR. It is quite possible to drive a shaft driven compressor from a steam engine with a rotary output, but this arrangement occupies rather a large volume, although some small economy of steam can result from expansive working. This chapter will concentrate solely upon the method by which the steam piston of a non-rotative compressor is caused to reciprocate automatically.

Steam and exhaust connections require to be switched alternately from end to end of the steam cylinder.

In diagram 1 below, first consider the steam piston. To achieve the objective of forcing it up and down, live steam and exhaust must be applied above and below it alternately. The shuttle valve in the position shown is applying live steam above the piston and exhaust below it. The piston will therefore descend. To reverse this situation, the shuttle valve must be lowered.

The shuttle valve is caused to move up by admitting live steam to the large piston at its base, which then overcomes the force imposed by the exhaust pressure acting on the small piston at the top and the reduced area of the large piston on its top side. It is usual to make the area of the small piston approximately half that of the large piston so that the forces available in each direction are equal. To move the shuttle valve down, it is necessary only to connect the bottom of the large piston to exhaust, whereupon the steam pressure acting upon the reduced area at the top of the larger piston will cause it to descend.

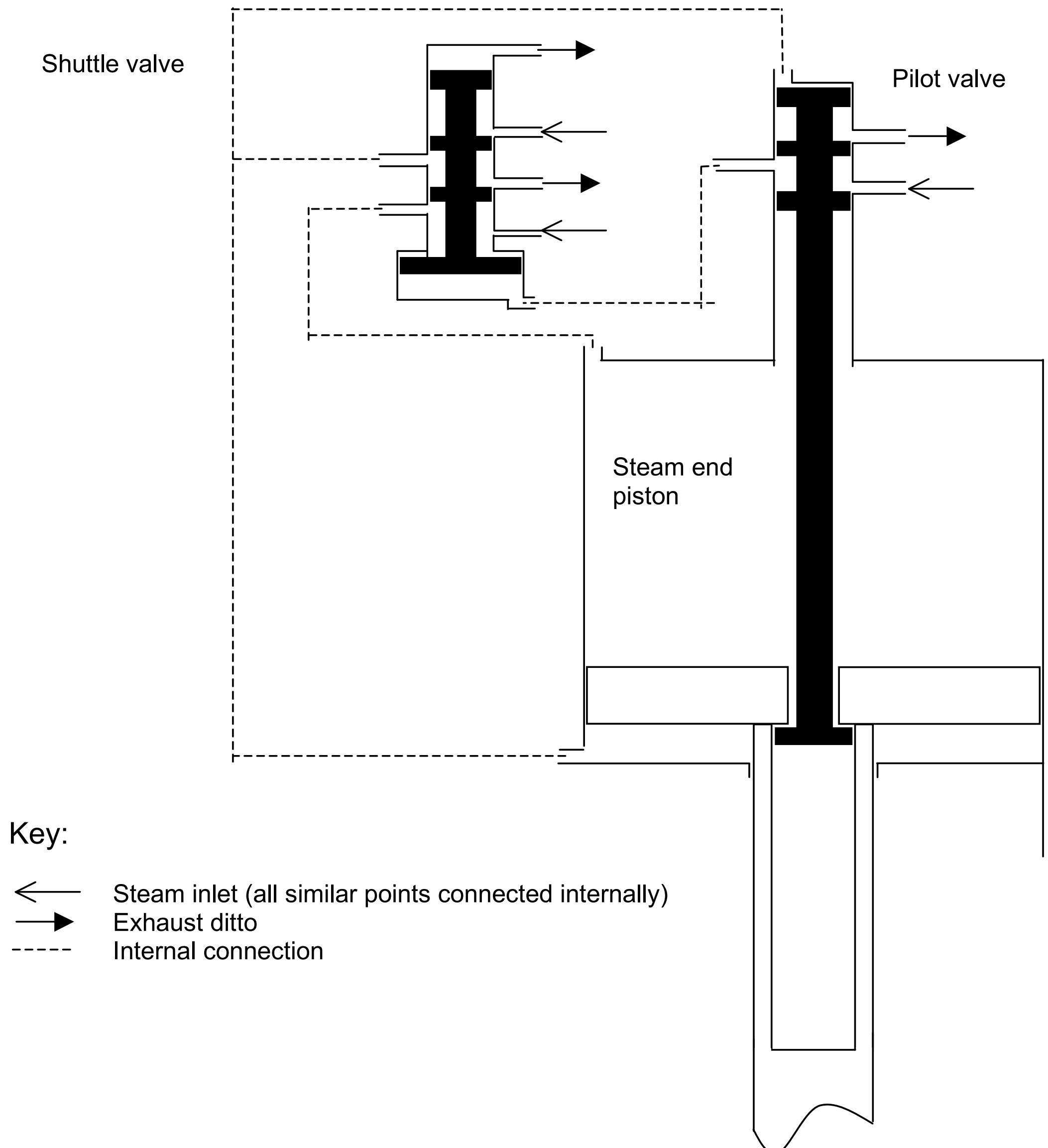


Steam compressor diagram 1

In order to achieve actuation of the shuttle valve as described, it therefore requires an alternating steam and exhaust connection to just one actuating piston. This is supplied by the pilot valve, which in the diagram above has just been pushed to its uppermost position by its actuating rod contacting the bottom of the drilling in the hollow main piston rod. Any incompleteness in its travel is prevented by the live steam pressure which is now applied to the top of the air pump main piston being applied also to the underside of the first (bottom) piston of the pilot valve by intentional leakage around the valve stem. Its top end is open to exhaust via an internal connection to the shuttle valve.

In diagram 2, the valves have not yet changed position, but the main piston has nearly arrived at the bottom of its stroke. As it travels beyond that position, the step at the top of the hollow piston rod pulls the pilot valve down with it. The output signal from the pilot valve switches over, reversing the shuttle valve. The output from the shuttle valve is therefore reversed, and the top of the main piston is therefore exposed to exhaust while its underside is exposed to live steam. Also, the top of the pilot valve is exposed to live steam and its underside to exhaust via the connections to the main cylinder.

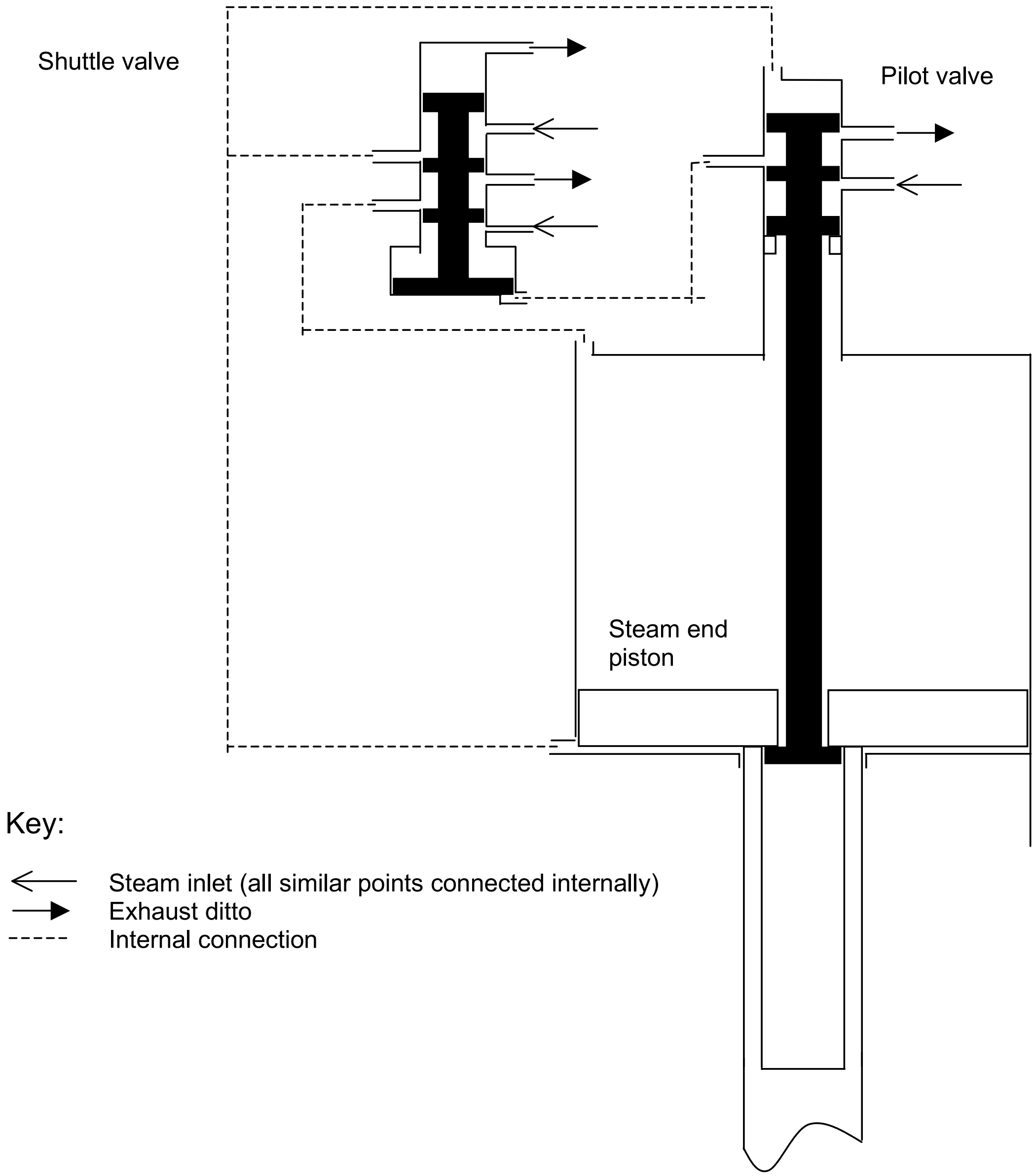
Even if the pilot valve’s stroke was not completed by it being pushed by the main piston rod, it is therefore now driven fully home by steam pressure. Diagram 3 shows this condition, with the main steam piston about to commence upward travel.



Steam compressor diagram 2

With live steam underneath and exhaust on top, the main piston is now propelled upwards until the bottom end of the pilot valve stem is pushed upwards by the bottom of the drilling in the hollow piston rod, and the entire cycle repeats.

If any reader knows how to animate these diagrams, please contact the webmaster.



Steam compressor diagram 3

The details shown above resemble those of the Westinghouse manufactured compressor, although that particular model has a horizontally disposed “D” slide valve for a shuttle valve. A significant number of Polish manufactured copies of the Knorr Bremse main line compressor have been imported for use on main line and larger narrow gauge locomotives. The arrangement on these is similar, but the pilot valve, instead of being pulled downwards mechanically, is actuated by a small steam piston at its top end. This receives its feed from a drilling in the side of the main cylinder, which is uncovered by the main piston at the bottom of its stroke. At the top of the main piston stroke, the pilot valve is pushed upwards in the manner described for the Westinghouse compressor.

Compressors manufactured by the now defunct Winson Engineering company use a steam valve arrangement based on that of the “Weir” type of boiler feed pump, but with a failed attempt to superimpose the valve above the main steam cylinder. This results in a continuous and significant waste of steam directly to exhaust during the upward stroke of the main piston, since there is no adequate seal between a chamber permanently filled with live steam and the top of the piston. In the original Weir pump arrangement, the steam valves were at the side of the cylinder and an adequate gland was provided at this position. The original Winson design should certainly NOT be copied.

When installing steam powered air compressors, a liquid separator should be provided in the exhaust pipe in order to minimise the hot oil and water thrown from the chimney, and the drain should be directed away from the rail head.

All steam powered air compressors require lubrication (separately) of both air and steam ends. A displacement lubricator feeding saturated type steam oil is adequate for the steam end in the smaller sizes, and a siphon wick should be arranged to feed a few drops of thinner oil to the air end every hour. Diesel engine oil should NOT be used, as this forms a sludgy emulsion with precipitated water.

An air intake filter should be fitted in order to keep cinders etc. out of the cylinder, since these will accelerate wear.

13. Compressed air quality

Atmospheric air, in addition to the gasses listed commonly as its primary constituents, contains a variable amount of water in gaseous form. The point at which a volume of air can dissolve no more gaseous water is known as 100% relative humidity (Rh), and marks the onset of condensation on cold surfaces, the appearance of fog etc. Half that concentration would be known as 50% relative humidity etc. It is the case, approximately, that a given volume of air can dissolve a given mass of water almost regardless of the pressure of the air, but with the amount varying strongly as the temperature. In fact the amount of water which a given volume of air can carry before becoming 100% saturated roughly doubles with every 10ºC rise of temperature.

This country of ours is a fairly soggy place, with relative humidities varying from about 20% up to close to 100% during rainfall or fog. If a volume of air at atmospheric pressure is compressed so that it occupies only half its volume at the same temperature, it is 100% saturated with only half the previous quantity of water in suspension, so if it started with a relative humidity of 50%, it now has 100%, and this is only with compression to 1 bar, 15 psi on the pressure gauge.

As air is compressed, its temperature rises, which as previously stated, increases its capacity for holding water. This effect in fact prevents the humidity from falling below 100% when air is compressed, until it is cooled. When it is cooled, however, much liquid water is precipitated. Arrangements must be made to drain this away.

Liquid water in railway braking systems is a nuisance, because it washes grease out of valves and cylinders, and in cold weather can freeze, seizing moving components, bursting pipes and blocking flow.

Since the air in the train away from the locomotive is at ambient temperature, it is necessary to get as much water as possible out of the compressed air before sending it there, and in order to do this, it needs to be cooled as much as possible.

The first stage of cooling occurs in the pipe from the compressor to the main reservoir. On installations with large flow rates, this can be extended, looped round etc. to form an identifiable aftercooler. The water precipitated in this pipe can either be allowed to pass into the main reservoir or drained off before it gets there. If there are either any low points between the compressor and the reservoir, or a possibility that the water will drain back to the compressor, then it must be drained anyway in order to avoid component damage due to either liquid water or frost. Further water collects in the main reservoir, and this must again be drained away. Even if all the liquid water possible is removed from an ambient temperature main reservoir, it is possible to remove further water downstream. Air is used at a lower pressure than that at which it is stored, and reducing the pressure through an orifice in a pressure regulator causes cooling, and further precipitation. By separating this water quickly and preventing it from re-evaporating, a reduction in humidity slightly below 100% can be achieved downstream, and at this point in the system a pressure regulator which includes a filter / separator is employed to achieve this. Large systems which produce large quantities of compressed air must be provided with automatic drain valves, but these are not essential for a GVLR type system , and manual drain valves are preferred. Manual drain valves must of course be accessible, or at least have an accessible actuation point such as a wire to pull.

If very dry air is required, a different approach must be adopted. The air from the compressor is made as cold as possible, then all free water is drained away. Next the air passes through an air dryer, which is usually of the type in which a chemical absorbs water from moist air before passing it to the reservoir. The chemical can only absorb so much water, and from time to time it must be regenerated by passing a modest quantity of its own very dry air back through it. The air for regeneration is usually stored in a separate reservoir. Cycling is automatic, regeneration either taking place when the compressor off loads, or if the flow is constant, a double dryer system takes it in turns to regenerate.

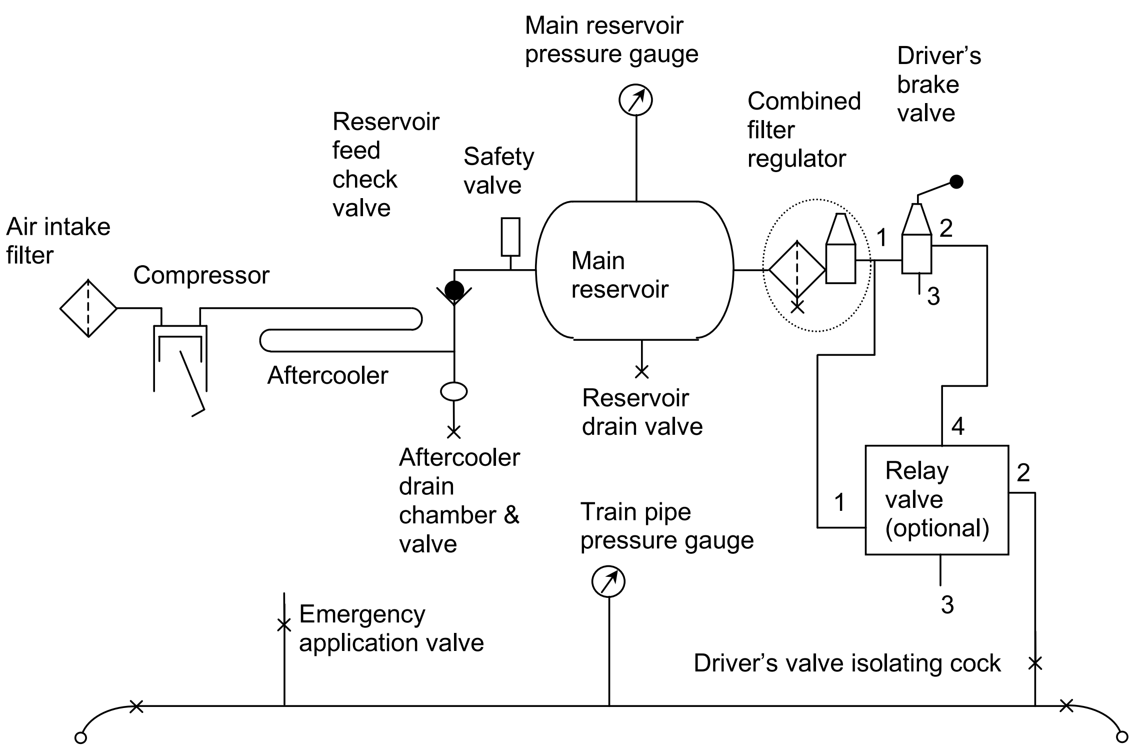
Oil mist in the compressed air (added by the compressor) will quickly foul the dessicant chemicals rendering them ineffective, so an oil coalescer is usually installed before the dryer. Systems without a dryer also benefit from this, as the oil carried over from compressors is often oxidised and acidic, and causes gumming of valves downstream.

Grit particles are drawn into the compressor with the intake air, and in the interests of compressor longevity, these are best filtered out before the compressor by an effective intake filter. Grit in the form of carbon particles from oxidised oil can also be generated if the compressor has to work very hard, and these are filtered out before they reach any valves etc.

Another fruitful source of grit and water is bare coupling ends on the train pipe, that at the front of a steam locomotive being particularly prone to filling with cinders during smoke box cleaning. As much as possible this should be excluded by good practice, it being preferable to leave coupling ends facing downwards if they may fill with rain or cinders. Ideally, dummy couplings are fitted to blank these off when not in use, although they should not be air tight, just in case the hose needs to be used to make an emergency application while coupled. It is considered to be highly desirable to have a filter between the train pipe and each set of vehicle equipment.

14. Locomotive schematic

In addition to the equipment fitted to a trailer vehicle, a locomotive also has to be capable of controlling the supply of air to and from the train pipe.



Train pipe with end cocks and coupling hoses

The Driver's brake valve isolating cock is also known as the double heading isolating cock

The driver's valve isolating cock is closed if the locomotive in question requires to become a vehicle from which the brakes are not controlled, e.g. if it is the second locomotive in a double headed or banked consist. As far as the brakes are concerned, it then behaves as a fitted wagon. A more complicated brake test is required when 2 locomotives are in use, in order to confirm that not only does the leading locomotive have control of the brakes throughout the train, but that other locomotives do not.

15. Standards

The only standards of which the author is aware refer to construction and maintenance of air reservoirs. It is strongly preferred that the reservoirs should be in accordance with the British or International standards for railway vehicle reservoirs, (BS EN 286 - 3, 1995 "Simple unfired pressure vessels designed to contain air or nitrogen part 3. Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock" which supersedes BS 3256, 1960) since these allow a reduced maintenance regime. Pressure vessels which are in accordance with obsolete standards may continue in use if still in a safe condition. Other types are much more lightly constructed (as a function of the contained pressure) and are commonly used on such applications as road transport vehicles and static installations. The pressure systems regulations set the requirements, and it will be found that the pressure x volume product as defined in those regulations, means that every vehicle reservoir of useful volume needs to be treated as "large". It is better to be caught by these regulations rather than to attempt to use "small" reservoirs and find that there is insufficient brake energy available. The total pipe system, if ½" steel tube is used, will be found to count as "small" and therefore require only to be designed, constructed and maintained in accordance with "sound engineering practice", regardless of the length of train within reasonable limits. Failures will occur as a result of repeated bending due to vibration or expansion etc, rather than as a result of the contained pressure, so the support requirements, including the requirements to accommodate vehicle distortion must be fully understood.

There does not appear to be a standard for the train pipe pressure on small systems, and the feed pressure on visiting locomotives needs to be set against the railway's own master gauge before they enter traffic.

Whilst there is no requirement for any periodic inspection of the air reservoirs on road vehicles (yes, really! If one is found leaking, the annual MoT test man might stop it, but that's all) if you apply one to a train, it should be inspected as though it was constructed as a static reservoir. Static reservoirs require (at the time of writing) a visual internal inspection every 2 years and a hydraulic test every 10 years.

Reservoirs constructed in accordance with the standard for railway vehicle reservoirs require only visual internal inspection every 10 years at the time of the hydraulic test. This is allowed simply because of the greater wall thickness of this type, which contains effectively 10 years worth of corrosion allowance (at the worst case). After internal inspection / hydraulic test, the interior should be thoroughly dried by gentle heating and ventilation, and then protected from corrosion with a thin coat of Waxoyl. External paint repairs should be made thoroughly, including cleaning rust patches to very bare metal, since more reservoirs fail due to external rather than internal corrosion. Areas particularly prone to suffer external corrosion are narrow gaps where water can sit for extended periods, such as under mounting straps and labels. The latest version of the design standard does not permit labels to be simply welded flat against the surface of the vessel for this reason.

The installation should protect the reservoir from rain and cleaning fluids, dirt and moisture splashed up from wheels, and from corrosive combustion products and by products such as smokebox char and ashes from the ashpan. The route taken by spilled battery acid should also be considered.

All reservoirs need identification, and if a plate is not attached, this should be painted on, since stamped identifications are illegible when painted over. Large contrasting painted letters in a consecutive series such as GVLR 1, 2 etc. will allow identification against previously recorded data. A register needs to be kept in order to control their maintenance and allocation to vehicles, since their numbers soon mount up. There are at least one per coach and two per locomotive. One of the GVLR's locomotives, the 100 HP 16 ton mines Hudswell Clarke, has no less than 4, serving the functions of Main, vehicle brakes, engine start, and sanders / horn.

The engine start reservoir needs to have high integrity against leakage, and therefore has an isolating cock immediately adjacent to it. Ideally, the pressure would be maintained indefinitely, but enough for an engine start after a fortnight is a reasonable target. This type of loco cannot be tow started due to the characteristics of its transmission, so once the start air has gone, the only option is to connect an external air supply. Even when fully charged, the air start system only contains enough energy for about 3 ordinary attempts, so thorough preparation and no mistakes are essential.

16. Maintenance

Aside from scheduled reservoir inspections and tests, the following are recommended at intervals which can only be determined by experience.

Continuity test. The driver releases the brake so that there is full pressure in the train pipe, the guard briefly opens the most remote end cock, and the driver hoots to acknowledge that he has seen the train pipe pressure gauge dip in response, thereby proving that the train pipe is continuous through the train. Every time the train pipe connections or end cocks are interfered with, e.g. during after running round, adding vehicles to or taking them from the train, and even if you just operated briefly an intermediate cock.

Brake functional test. Apply the air brakes, make sure all are on, then release them and make sure all are off. Daily at the start of running, and every time a different locomotive is used.

Blow water from aftercoolers, main reservoirs, and any filters provided expressly for the purpose of collecting water or oil. These are found only on locomotives, and it is generally found that vehicle reservoirs do not collect water. This needs to be done daily by the driver, as part of disposal duties.

Lubricate brake linkage. During assembly, surfaces should be coated with grease. Thereafter, all pivots and slides should be oiled lightly at an interval of 3 months (in traffic). Handbrake screws mostly benefit from oiling at the same time, so long as it has been previously established that oiling will not do more harm then good by allowing automatic unscrewing due to low friction. Simplex locomotives are particularly bad in this respect. At the same time, do yourself a favour for the future and oil all exposed areas of adjusting threads. No need to clean until required for adjustment, and a thick layer of oil soaked dirt will maintain the screws in good condition.

Check locomotive's set pressure of the train pipe with brakes released against a master gauge, adjust, investigate and rectify as required. On the GVLR this is annual, and on the arrival of new or visiting locomotives.

Check for retention of applied brake. The brakes must still be firmly applied 30 minutes after the train pipe pressure has been reduced quickly from full release to zero. Annual on every vehicle and after any repairs which involve breaking into the air system.

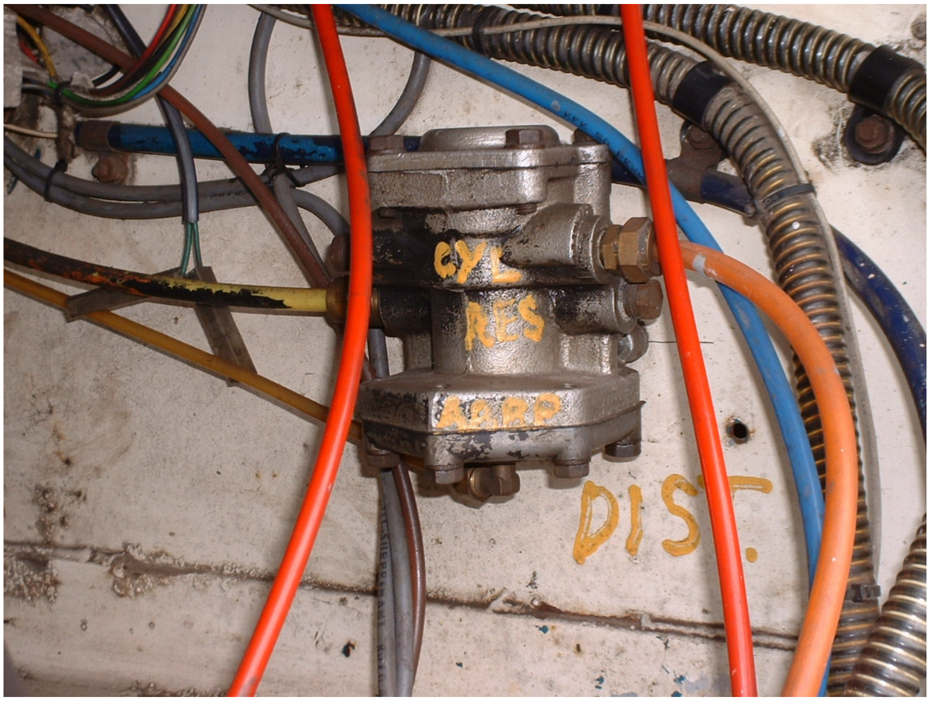
Check for rate of build up of air from dead and rectify as necessary. The rate for each locomotive or consist will vary, so should be known when in good condition as a baseline for comparison. It is usually sufficient to roster the engineer as driver occasionally!

Check for air leaks with the brakes released. As above.

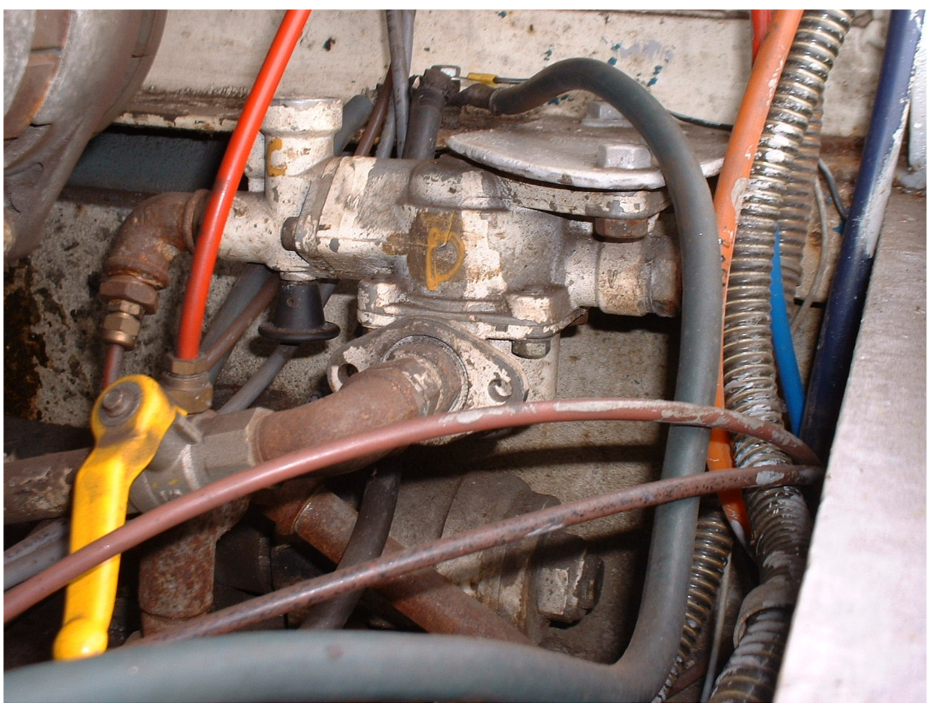
Check brake adjustment / adjust brakes. This depends entirely upon the ratio of brake block size to axle load, and the materials from which brake blocks are made. Generally hard cast iron lasts much longer than soft, but it will be found that vehicles from coal mines use soft cast iron to minimise spark generation. On the GVLR the interval varies from 10 years on one particular carriage, to about every 2 weeks for the mines Hudswell. Diesel traction reduces brake use downhill if engine braking is available.

Appendix

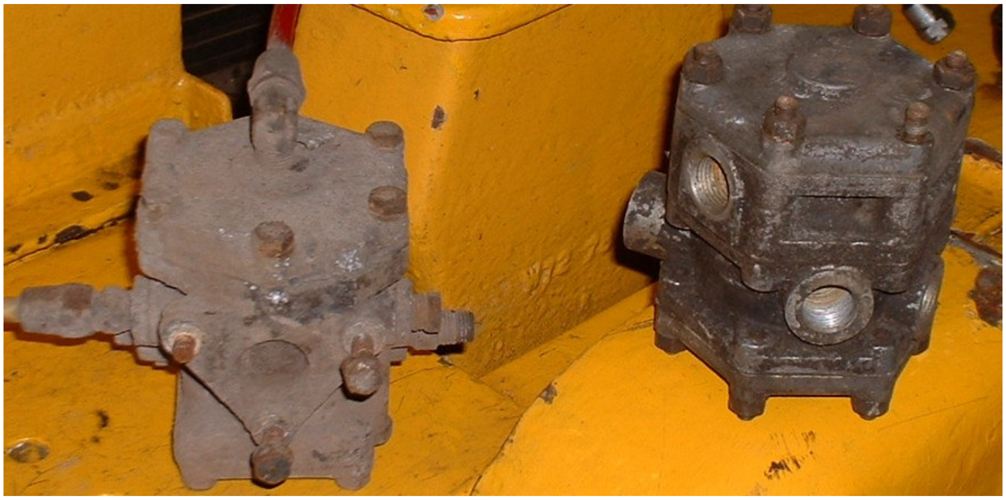
PHOTOGRAPHS



1. A valve which may be used as a distributor. The Clayton Dewandre “Anti Compounding” valve. In this case, installed on the Simplex T class locomotive.



2. A Westinghouse valve which can be used as a distributor, in this case inverting the signal from a direct acting driver’s valve on the T class Simplex.



3..Two distributors from stock. On the left is a Clayton Dewandre Anti Compounding Valve, showing the exhaust port between its mounting bolts, identical to photograph 1. On the right is a Clayton Dewandre Inverted line control valve.

4: The Talyllyn Railway manufactured compressor (the best currently available – enquire via their web site) installed on O&K 7529, just in front of the right hand cylinder.