

Air brakes

Introduction

Air brakes

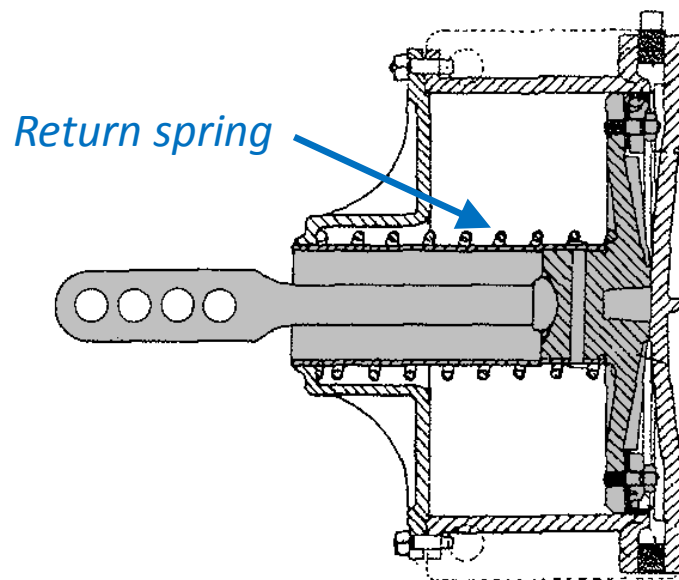
Discussion

As the Ffestiniog and Welsh Highland Railway (F&WHR) uses vacuum brakes, you may wonder why a section on air brakes is included in this presentation. There are two reasons.

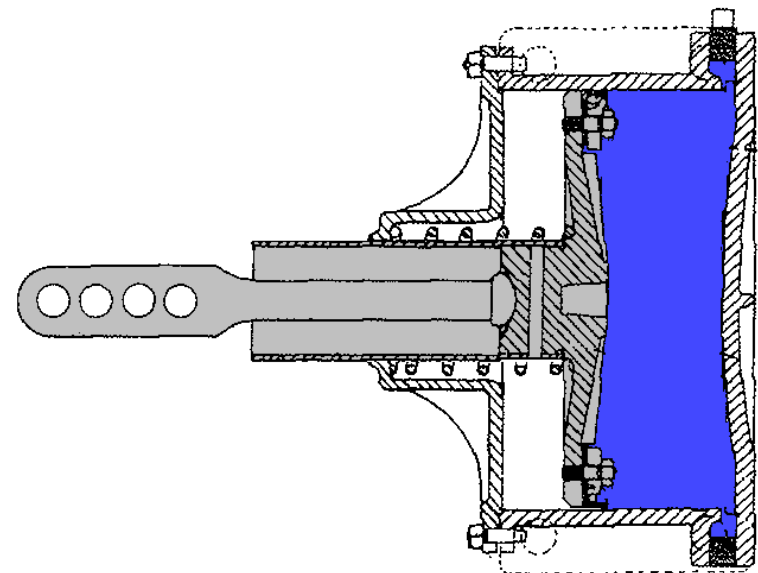
- (1) Air brakes are more efficient than vacuum brakes and could be adopted in future. It is important to understand that there are various air brake systems and they work in very different ways. Therefore, if there is to be any future debate on this subject, it is worth having the background knowledge of the available systems.*
- (2) Many F&WHR crews visit railways with air brakes, such as the nearby Vale of Rheidol and the Talyllyn. The following slides will hopefully give an appreciation of the operating characteristics inherent in the various types of air brake system.*

Air brakes

Air brake cylinders generally operate at up to 55psi gauge pressure. This means that the air brake system is 5 ½ times as powerful as the vacuum brake system, which has 10psi gauge pressure. However, this does not mean that you get more brake force. Instead, the same brake force can be achieved using smaller brake cylinders.



Brake released



Brake applied

Air brakes

Discussion

As the air brake cylinders are small, the piston head does not have enough weight to be arranged to move the blocks away from the wheels. The brake cylinders are fitted with a return spring for this purpose. This means that air brake cylinders can be mounted horizontally whereas vacuum brake cylinders have to be mounted vertically.

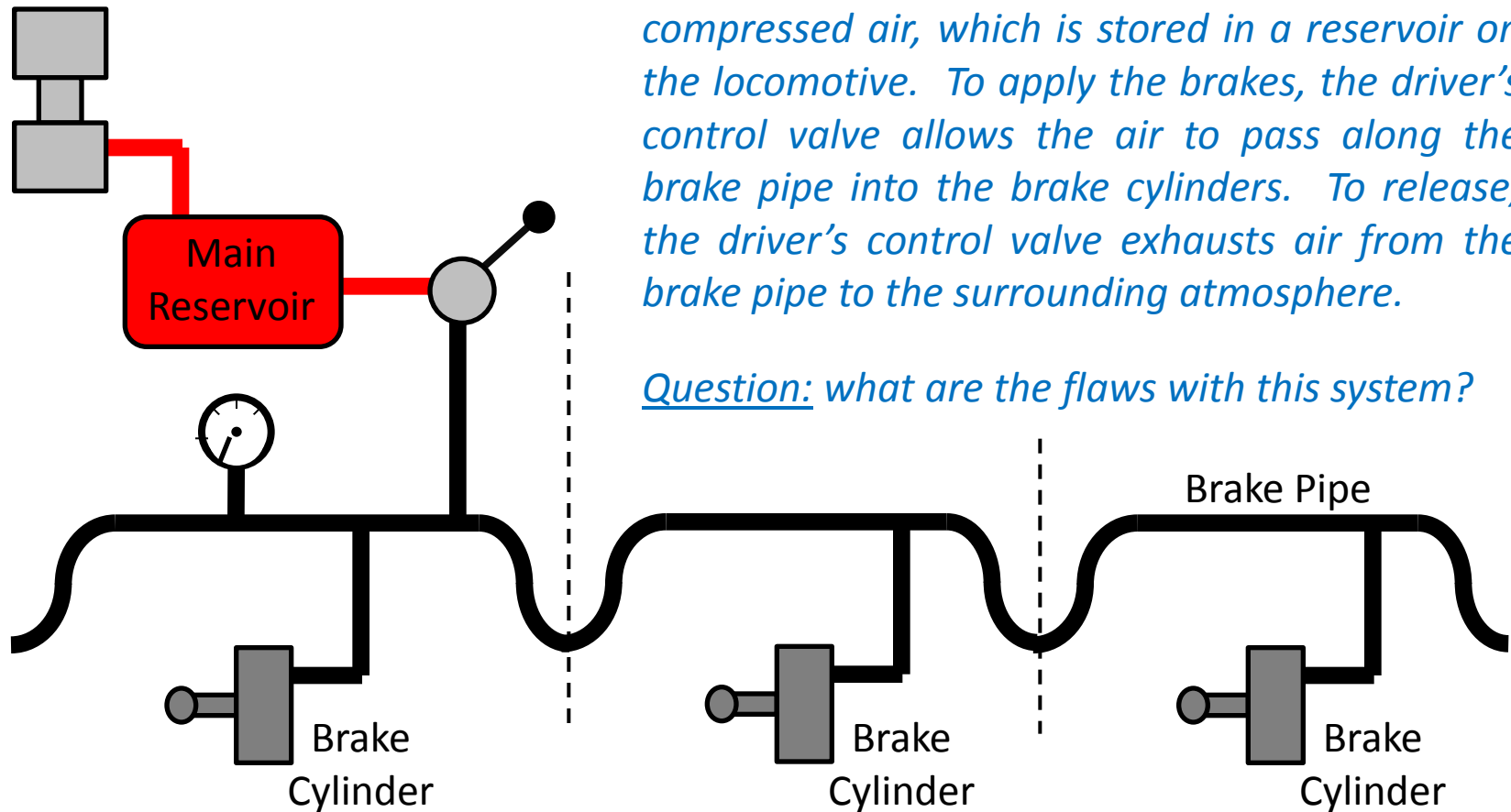
The higher pressure difference used in air brake systems gives them a much faster propagation rate. Thus, the response time of an air brake system is noticeably quicker than a vacuum brake system.

Alternatives

This diagram represents George Westinghouse's first air brake system.

A steam powered pump is used to generate compressed air, which is stored in a reservoir on the locomotive. To apply the brakes, the driver's control valve allows the air to pass along the brake pipe into the brake cylinders. To release, the driver's control valve exhausts air from the brake pipe to the surrounding atmosphere.

Question: *what are the flaws with this system?*



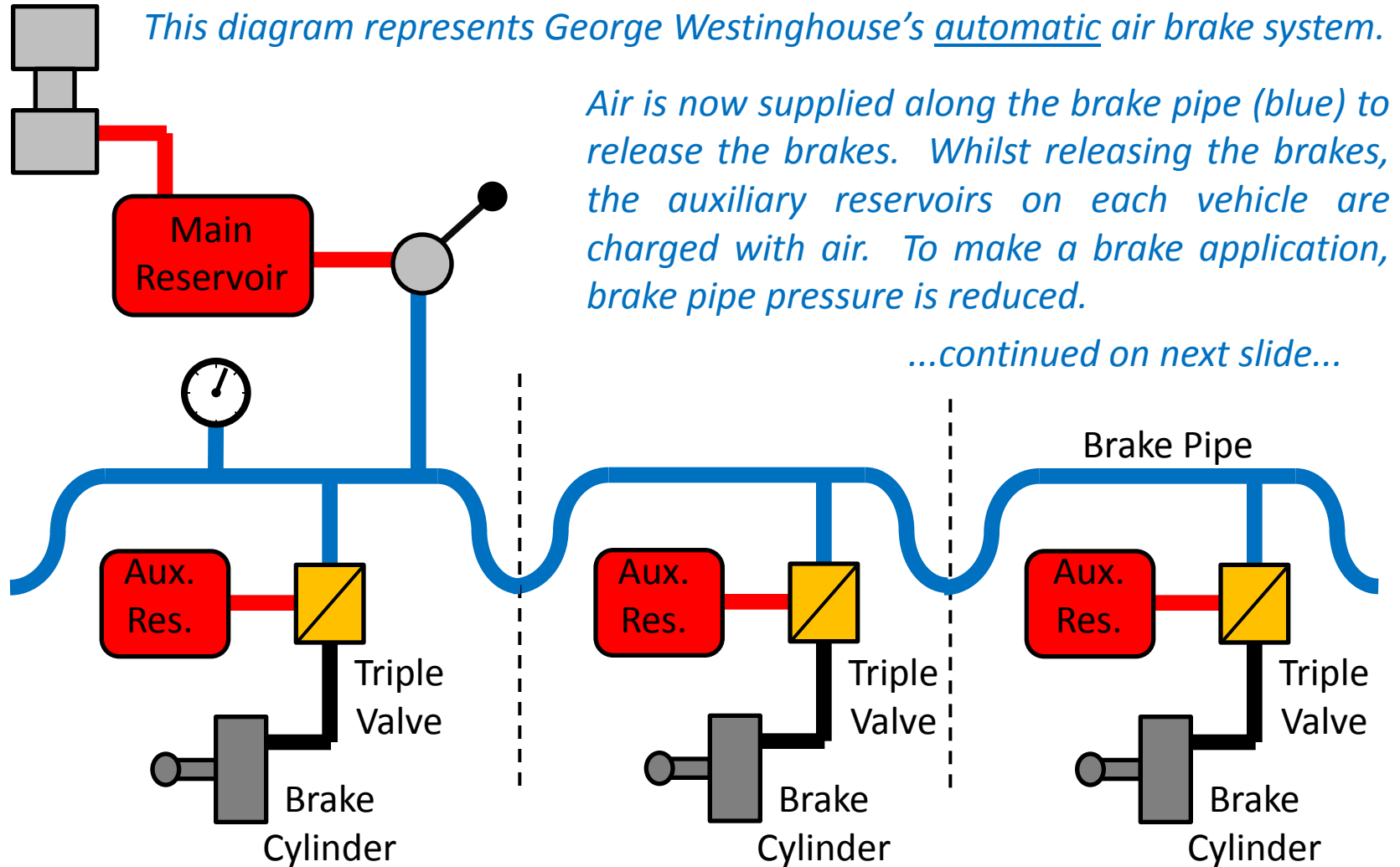
Air brakes

Answers:

- (1) The system is not fail safe in the event of a coupling breaking.*
- (2) As air enters the system, the brakes at the front of the train will apply first, causing the vehicles to run into each other. The same is true of vacuum brakes as described previously, but the effect tends to be worse with air brakes due to the speed with which air fills the first brake cylinders.*
- (3) On a long train, the rearmost brakes could be deficient. As more brake cylinders are filled with air, the reservoir pressure falls. This means that the air pressure could become deficient by the time all the brake cylinders of a long train have been filled with air.*

To solve all the above problems, George Westinghouse reconfigured his air brake system as shown in the next slide.

Alternatives



Air brakes

Answers:

When the brake pipe pressure is reduced, the triple valve automatically uses the air previously stored in the auxiliary reservoir to pressurise the brake cylinder.

This system has the required brake power ready and stored on each vehicle.

Brake propagation is fast because the driver's control valve only has to empty air from the brake pipe to make a brake application.

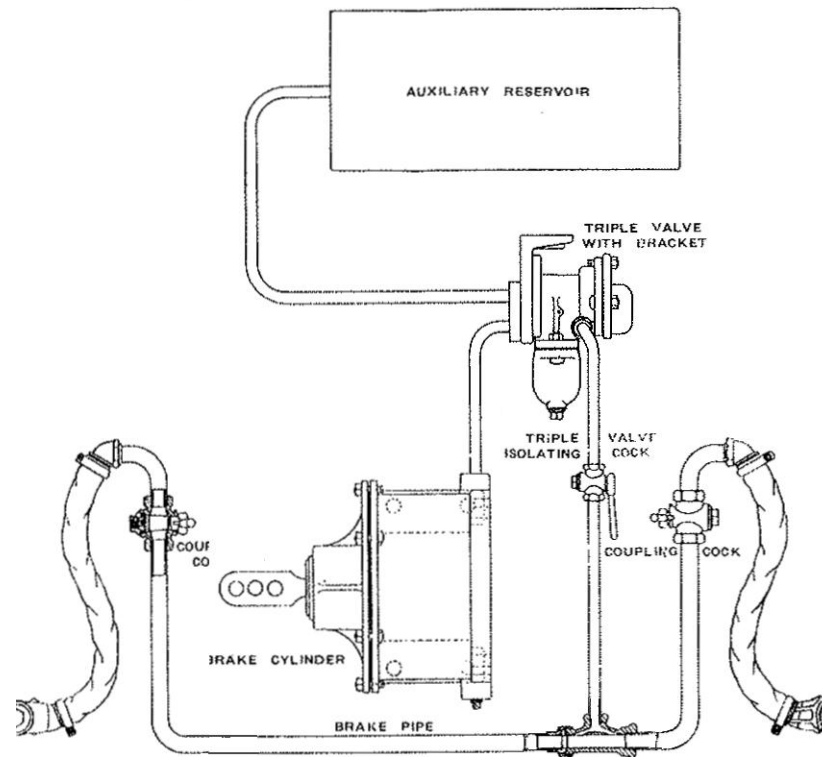
The following slides illustrate the air brake equipment as fitted to some British trains in the era of pre-grouping through to the 1950's.

Triple valve system

The system

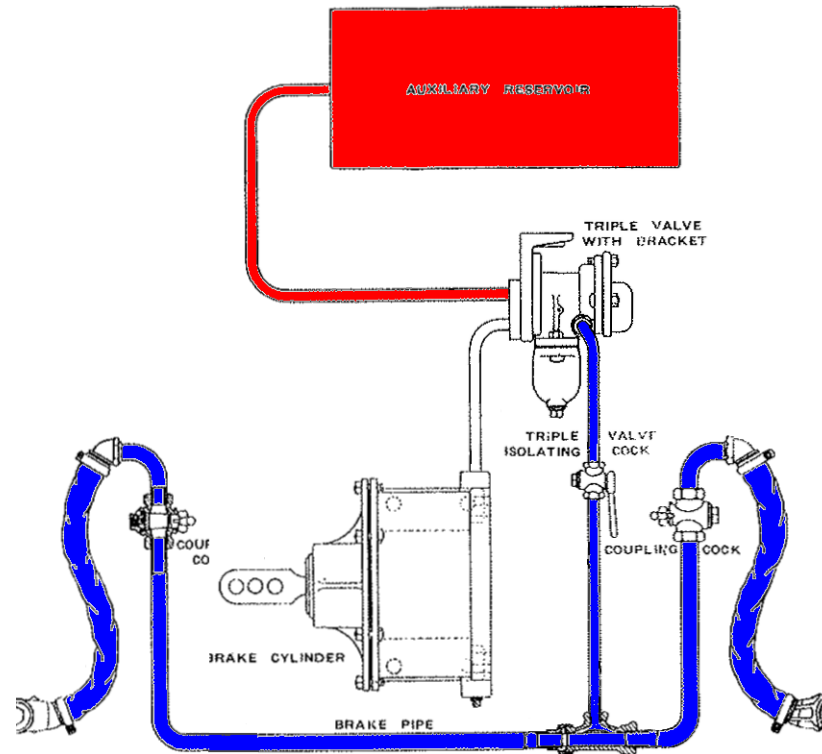
Triple valve system

This is the equipment fitted to trailing vehicles (circa 1890 to 1950).



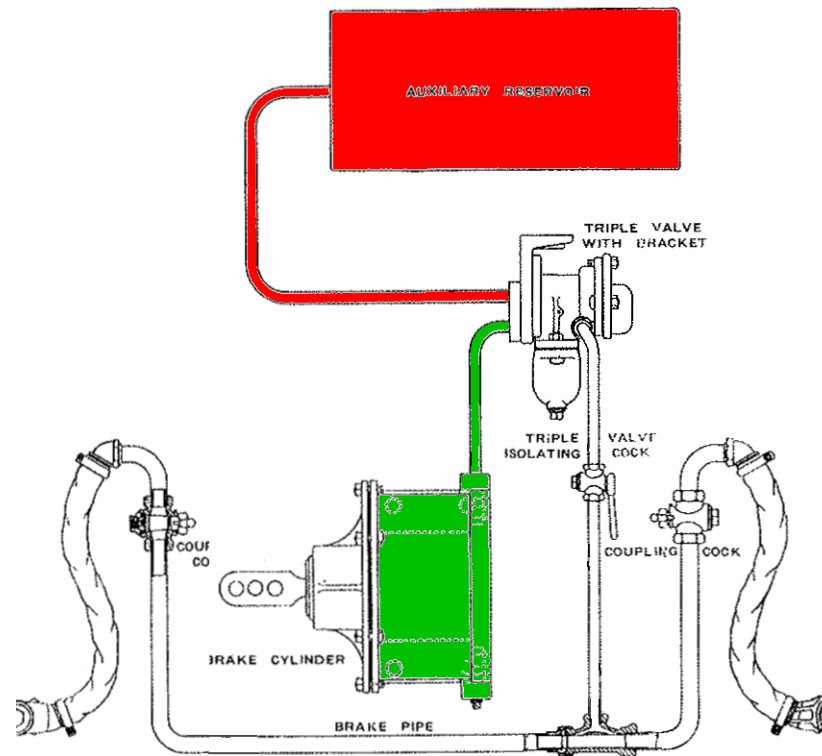
Triple valve system

When the system is first charged, or the brake is released, air pressure passes through the brake pipe and fills the auxiliary reservoir.



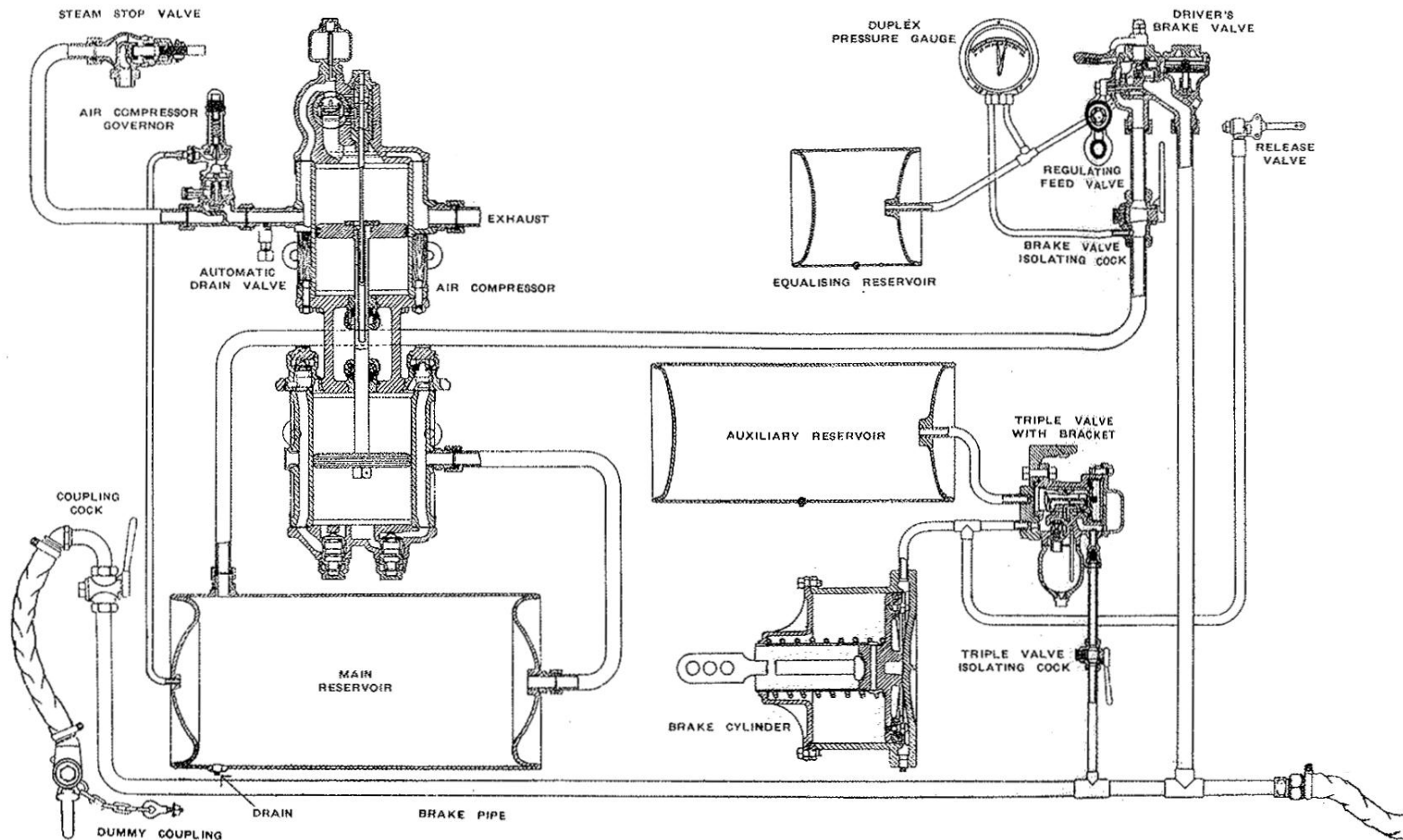
Triple valve system

When the brake pipe pressure is reduced, the air previously stored in the auxiliary reservoir is directed into the brake cylinder.



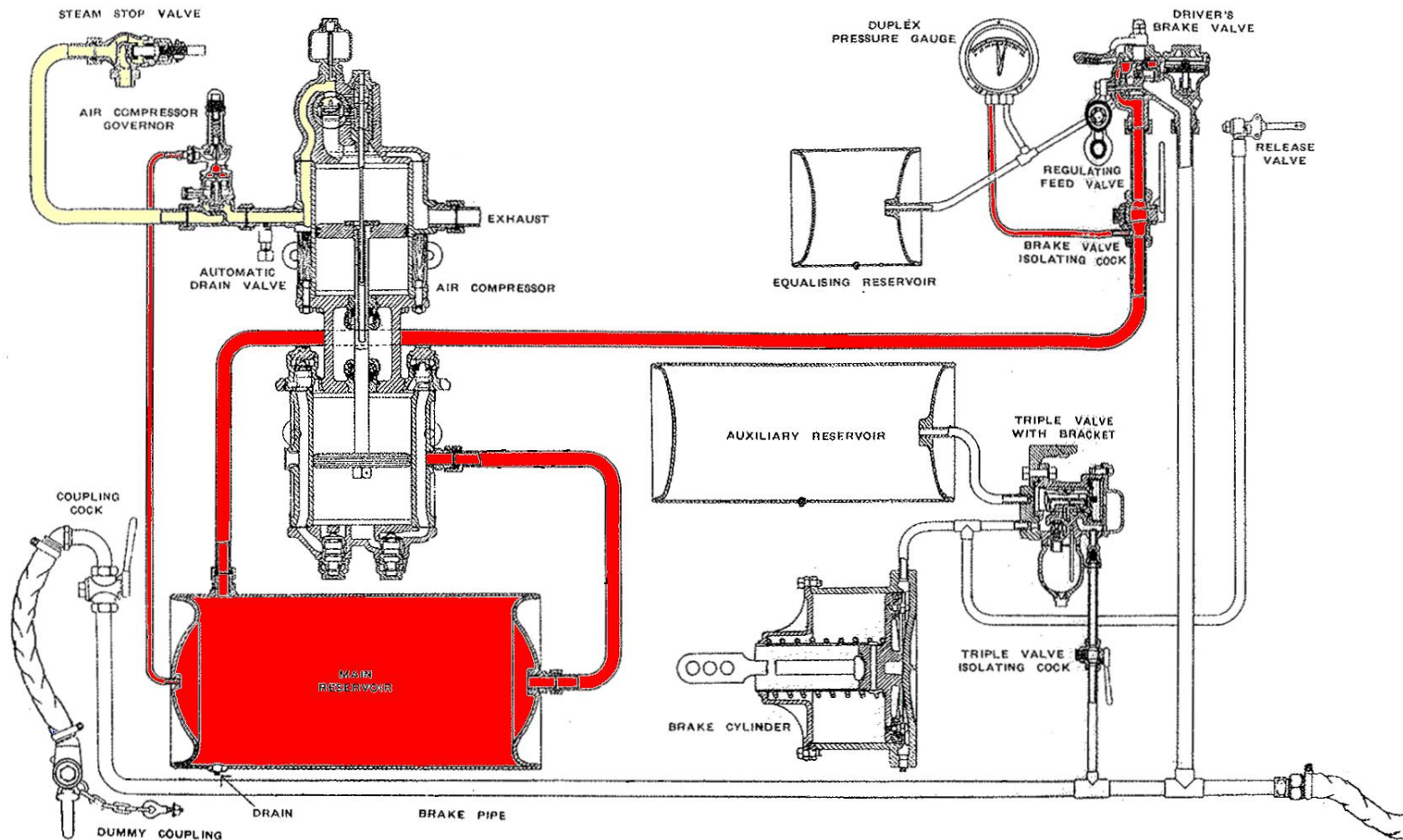
Triple valve system

This is the equipment fitted to locomotives (circa 1890 to 1950).



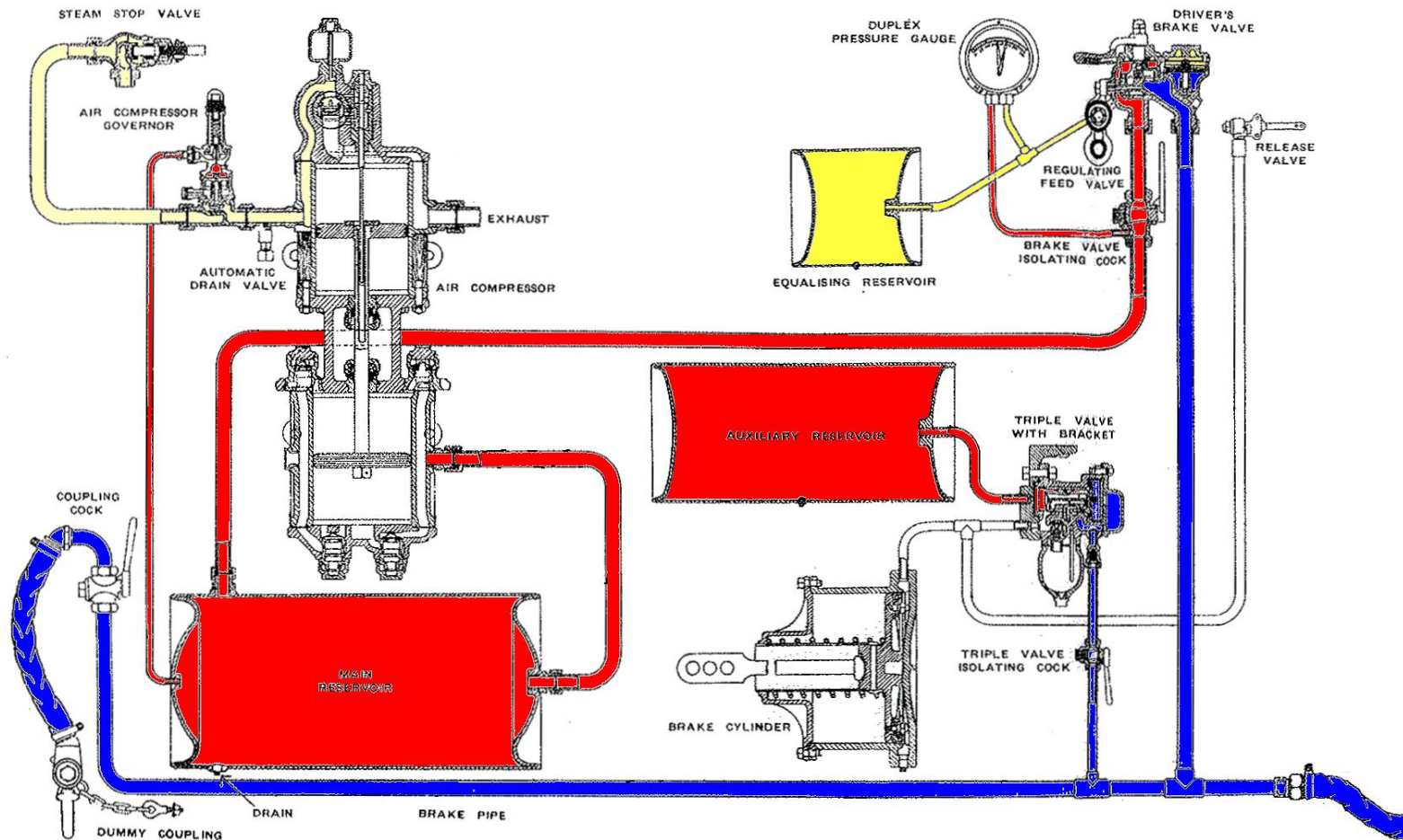
Triple valve system

The steam powered pump charges the large main air reservoir.



Triple valve system

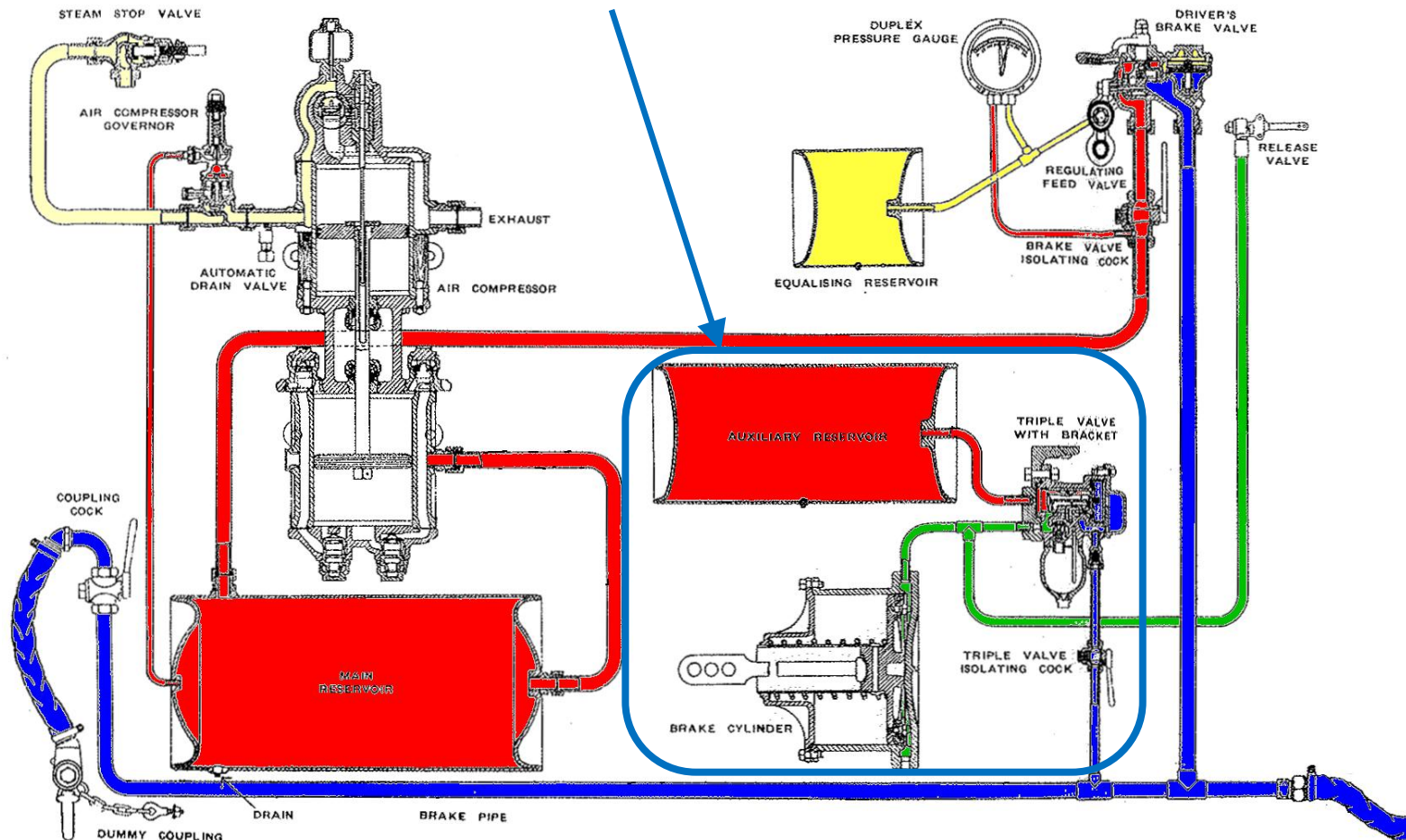
The driver's control valve allows air into the brake pipe.



The purpose of the equalising reservoir (yellow) is discussed later.

Triple valve system

The locomotive air brake is applied in the same way as the trailing vehicles.



A release valve in the cab permits the loco air brake to be released when on shed.

Air brakes

Steam powered pumps

The steam powered pump can be arranged as automatic or semi-automatic in its operation.

Automatic – the driver opens the steam valve and leaves it open. A governor device automatically turns off the steam supply to the pump when the main reservoir nears its maximum pressure. When the main reservoir pressure falls, the governor turns on the steam supply to recharge the reservoir.

Semi-automatic (no governor) – the driver only partially opens the steam valve to try to obtain a balance. As the pressure builds up in the main air reservoir it provides an increased back pressure on the air pump piston. If the steam valve is only partially opened, the number of strokes of the steam piston is reduced near to the maximum air pressure. When in balance, this rate of pumping is just sufficient to overcome leaks in the brake system.

continued...

Air brakes

Steam powered pumps continued

Regardless of whether the pump is automatic or semi-automatic, the main air reservoir must be fitted with a relief valve (safety valve). This will prevent the reservoir from becoming over pressurised due to either a failure of the governor valve (automatic system) or if the driver has opened the steam valve too far (semi-automatic).

The auxiliary reservoirs on the trailing vehicles are not generally fitted with a relief valve because their pressure cannot exceed that of the main air reservoir. In addition, some systems have a pressure reducing valve between the main air reservoir and the driver's control valve.

Air brakes

Direct air brake valve

As with vacuum brakes, the train air brake system can be supplemented by independent locomotive brakes.

A direct air brake valve takes air direct from the main air reservoir to the brake cylinder via an independent controller and a double check valve.

There were also versions of the Gresham and Craven steam brake valve that enabled steam braked locomotives to work in harmony with air braked trains.

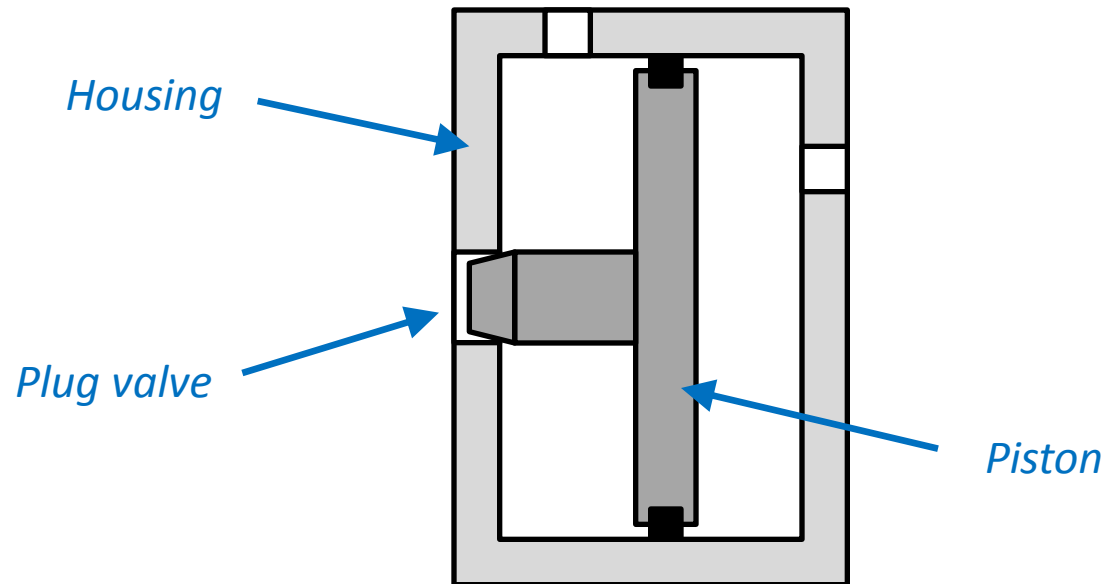
Triple valve system

The triple valve

Triple valve system

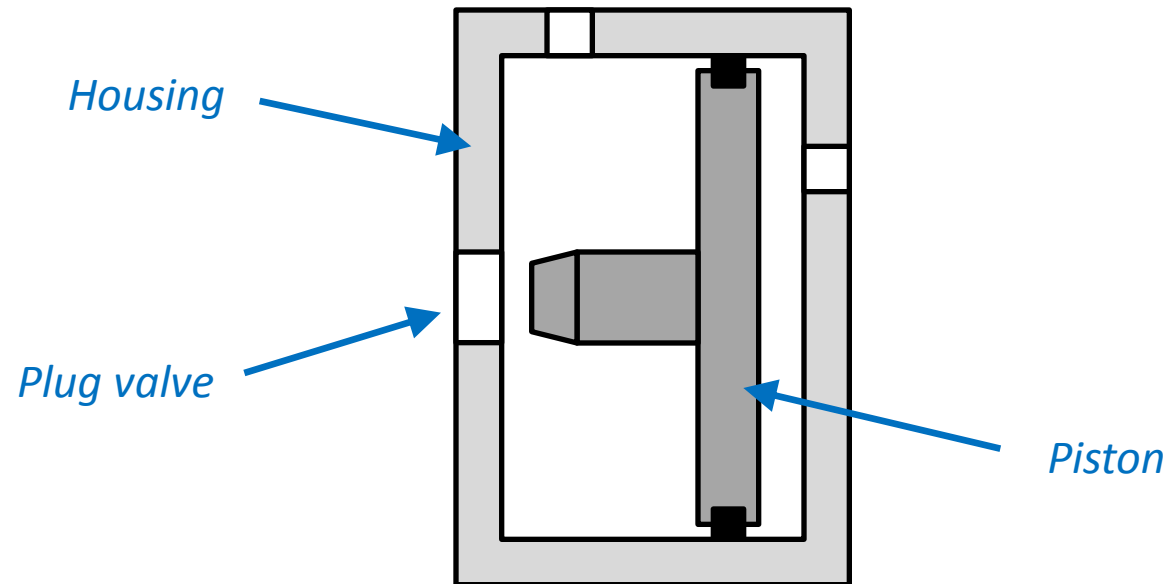
The key device in George Westinghouse's automatic air brake system is the triple valve. The following slides explain the operation of the triple valve.

To begin, consider the simplified triple valve as follows:



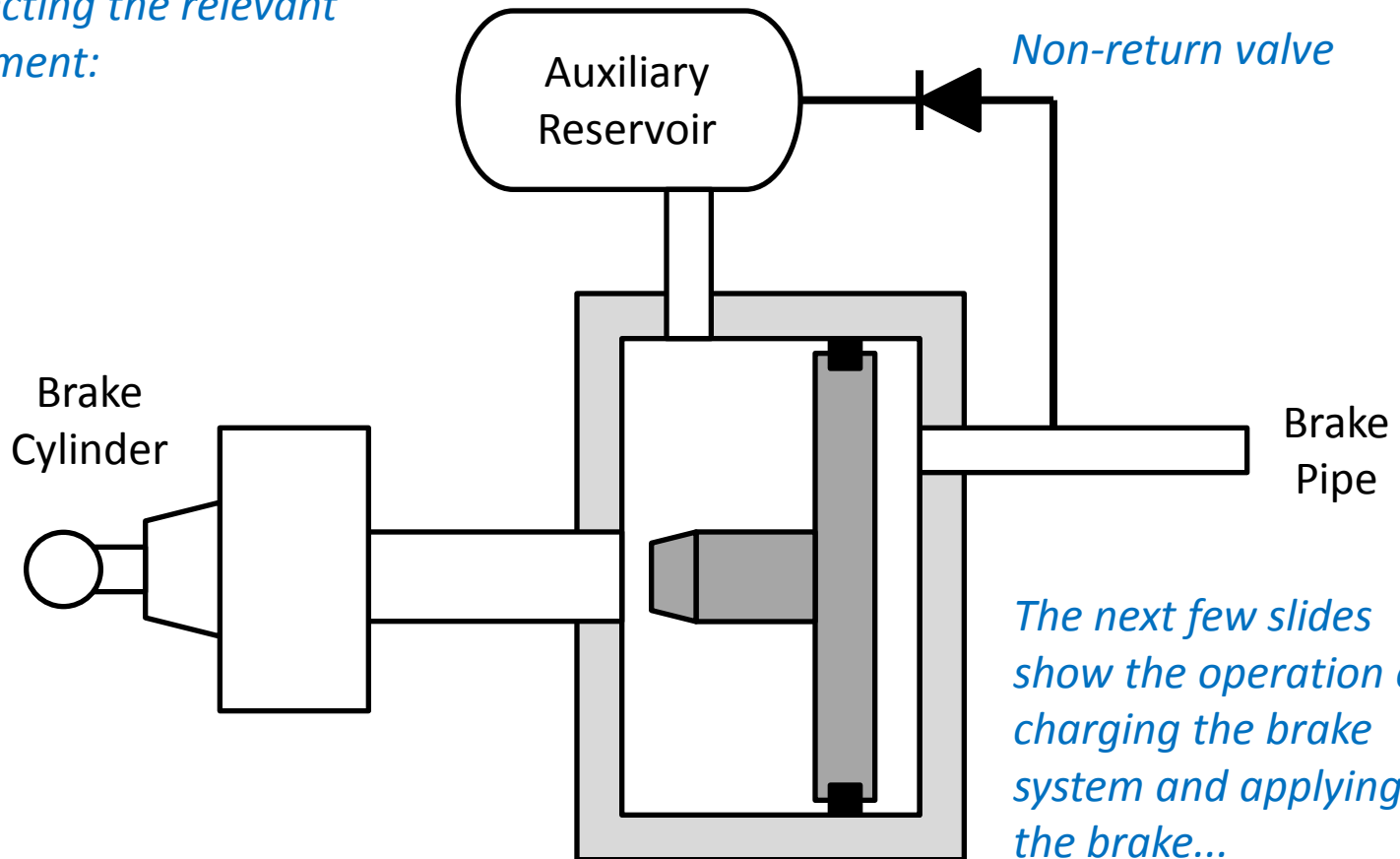
Triple valve system

Moving the piston to the right will open the plug valve, as shown below:



Triple valve system

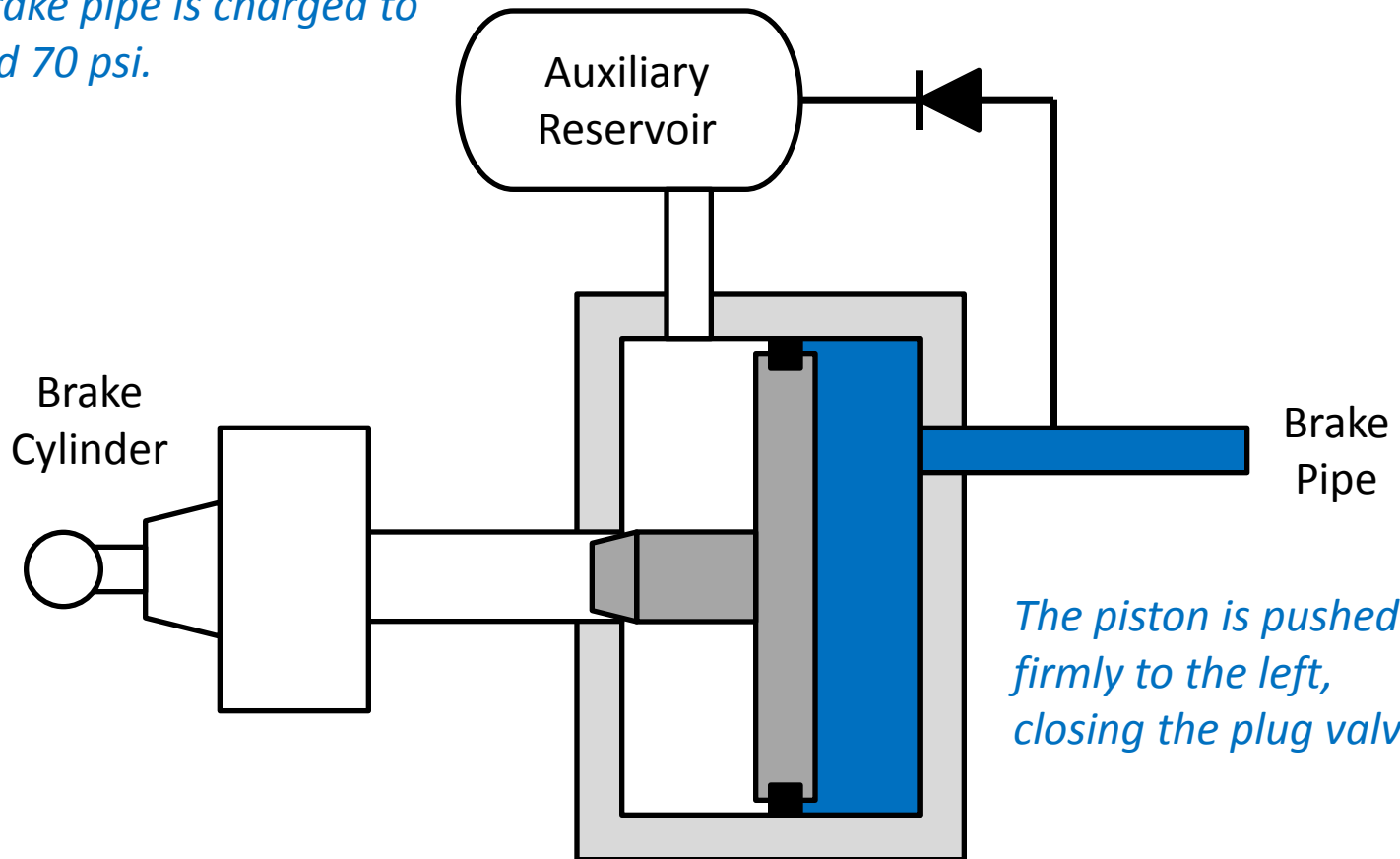
Connecting the relevant equipment:



The next few slides show the operation of charging the brake system and applying the brake...

Triple valve system

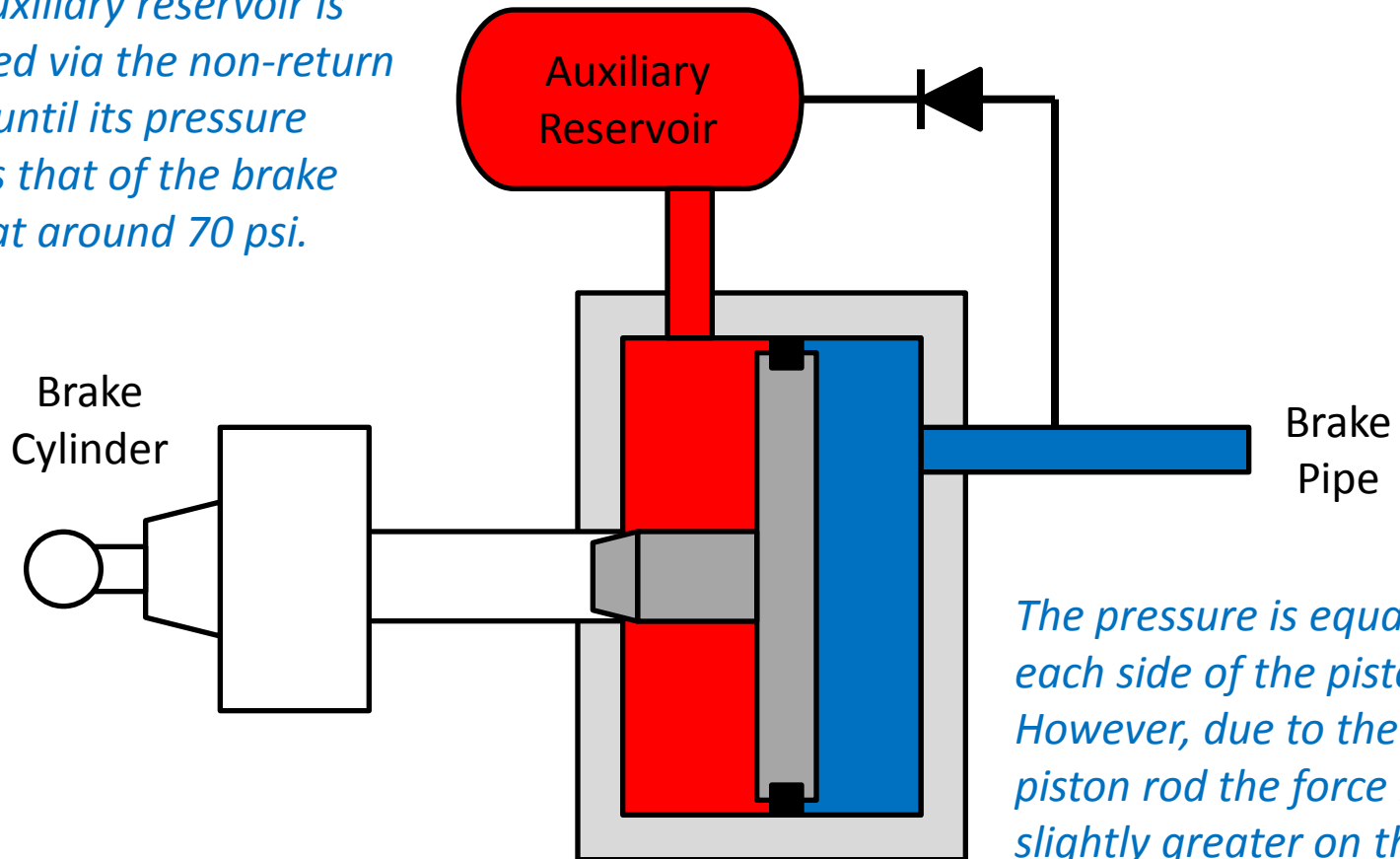
The brake pipe is charged to around 70 psi.



The piston is pushed firmly to the left, closing the plug valve.

Triple valve system

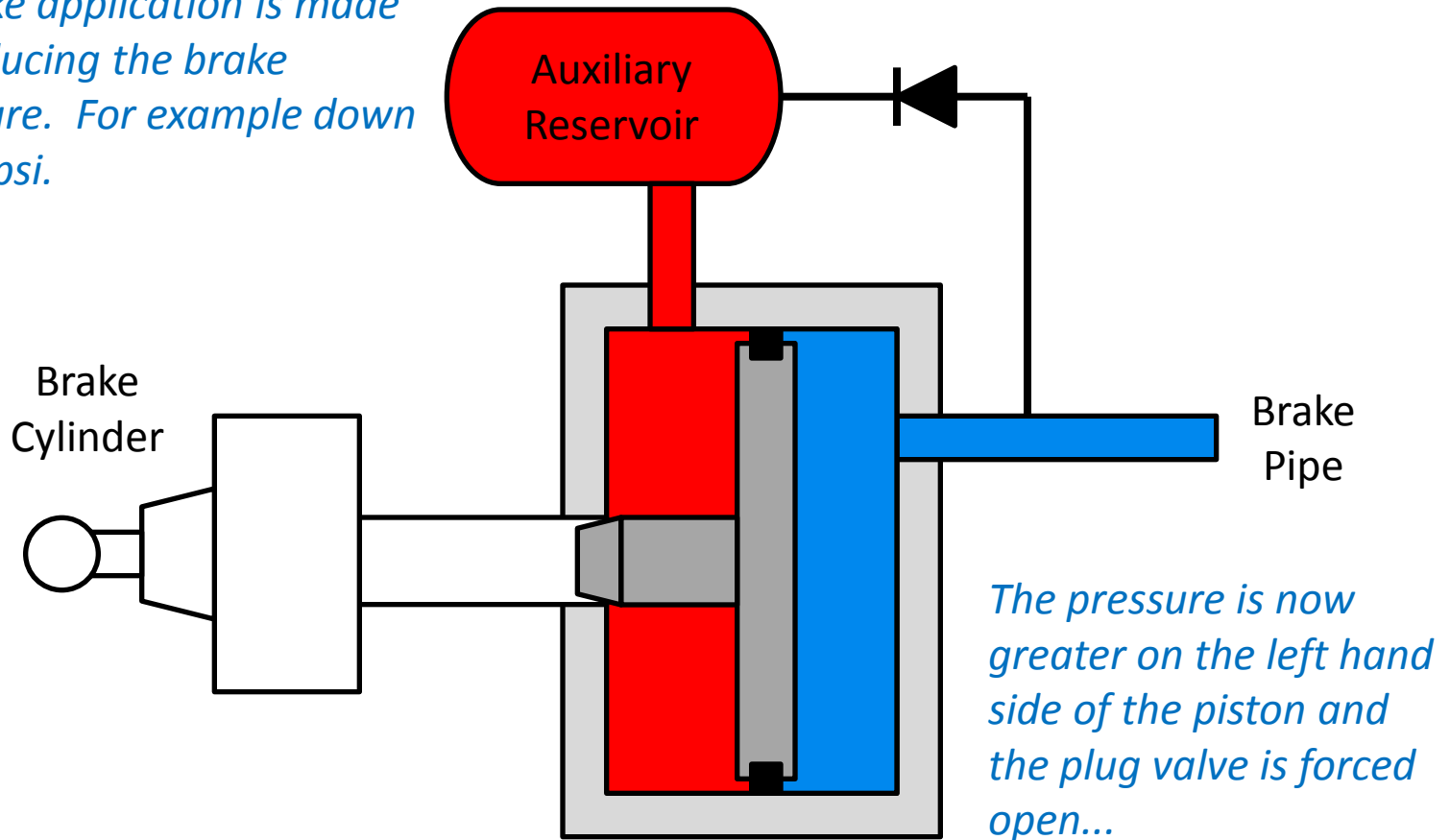
The auxiliary reservoir is charged via the non-return valve until its pressure equals that of the brake pipe, at around 70 psi.



The pressure is equal on each side of the piston. However, due to the piston rod the force is slightly greater on the right hand side, keeping the plug valve shut.

Triple valve system

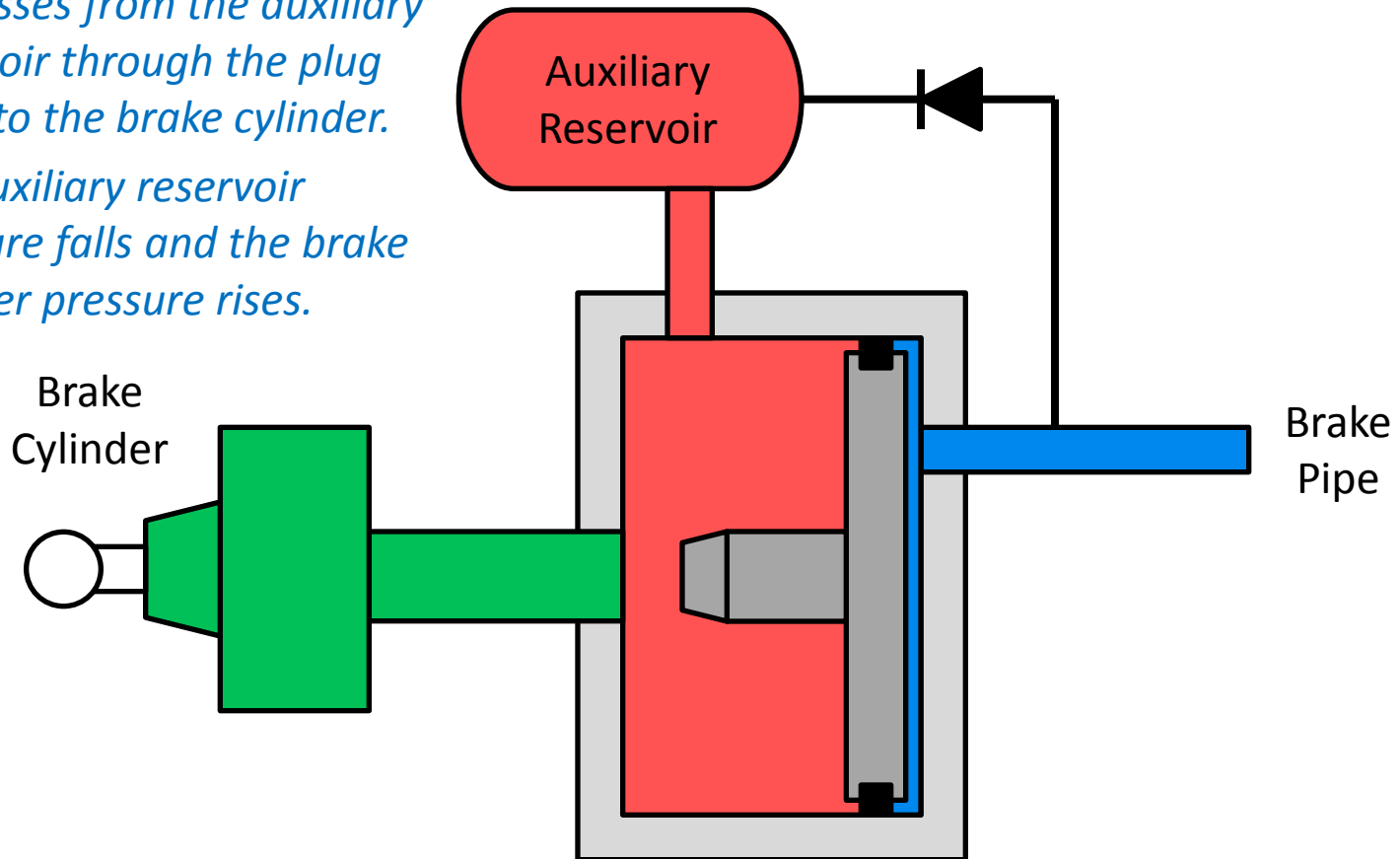
A brake application is made by reducing the brake pressure. For example down to 60 psi.



Triple valve system

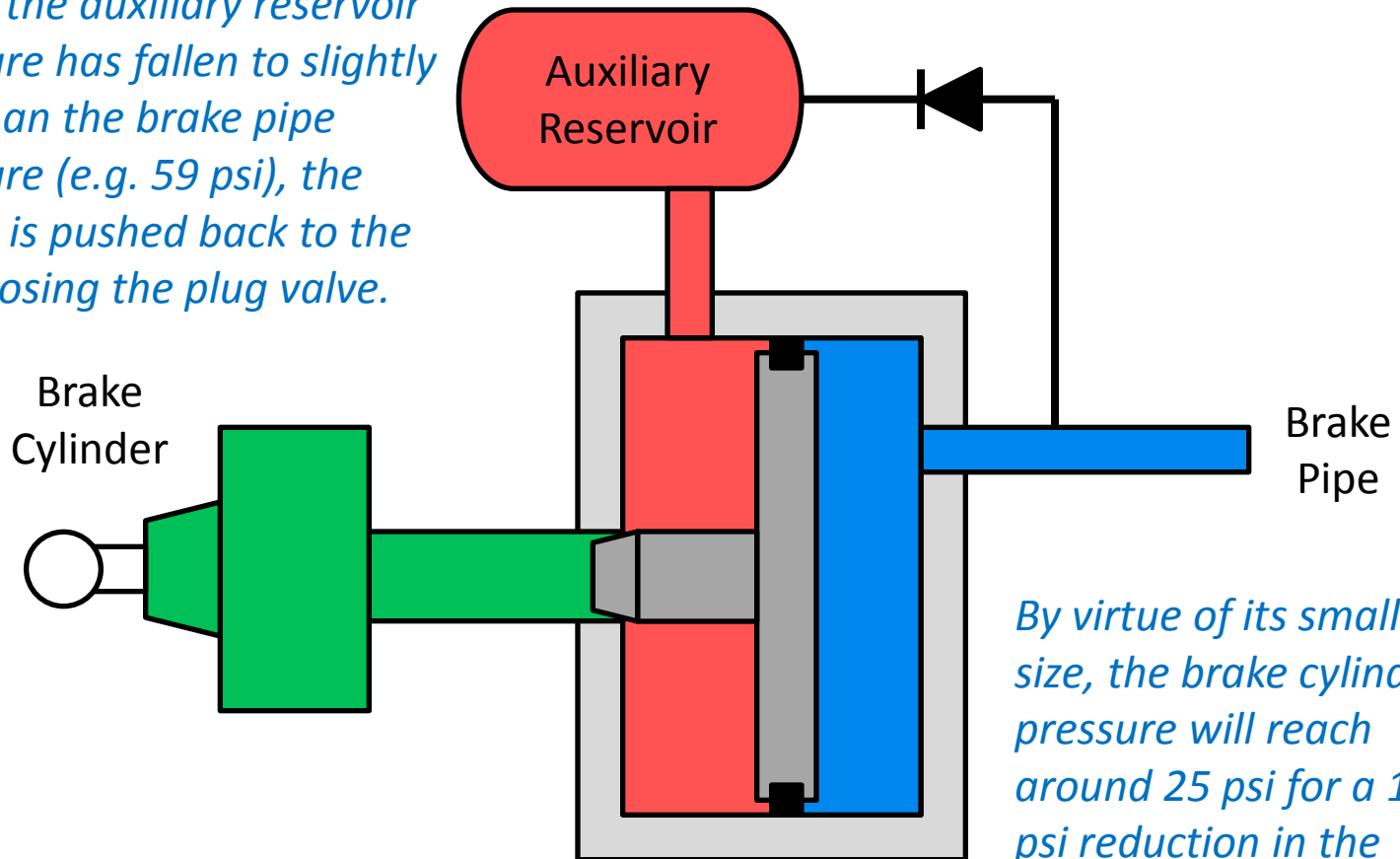
Air passes from the auxiliary reservoir through the plug valve to the brake cylinder.

The auxiliary reservoir pressure falls and the brake cylinder pressure rises.



Triple valve system

When the auxiliary reservoir pressure has fallen to slightly less than the brake pipe pressure (e.g. 59 psi), the piston is pushed back to the left, closing the plug valve.



By virtue of its smaller size, the brake cylinder pressure will reach around 25 psi for a 10 psi reduction in the auxiliary reservoir pressure.

Air brakes

Triple valve

To increase the brake force, the driver can make a further reduction in brake pipe pressure (say from 60 psi down to 55 psi). The auxiliary reservoir will give up more of its air to the brake cylinder.

Eventually, increasing the brake demand will result in the auxiliary reservoir and brake cylinder pressures equalising, at around 50 psi. This is also what happens if the brake pipe is completely vented. Note that engineers have to select the correct size of auxiliary reservoir to suit the brake cylinder size on each vehicle, so that each vehicle in a train will give the same maximum brake force. Too large a reservoir will give too high brake cylinder pressure.

This air brake system is very efficient because the brake pipe pressure only needs to be reduced by 20 psi to obtain the maximum brake cylinder force.

Question: *What is the problem with the simple triple valve illustrated above?*

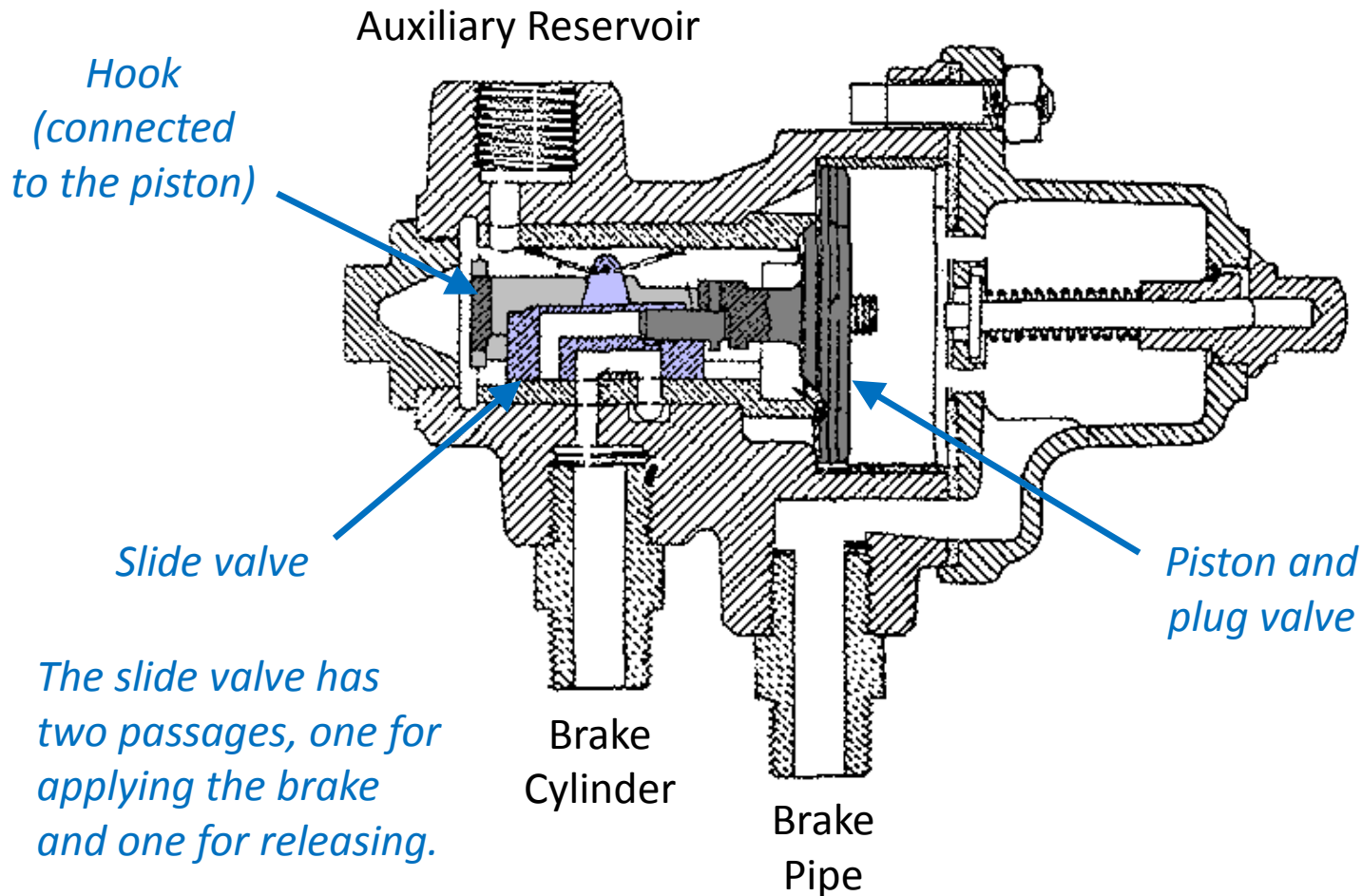
Air brakes

Answer:

There is no means of releasing air from the brake cylinder.

The actual triple valve has a slide valve to enable brake release, as shown on the next slide...

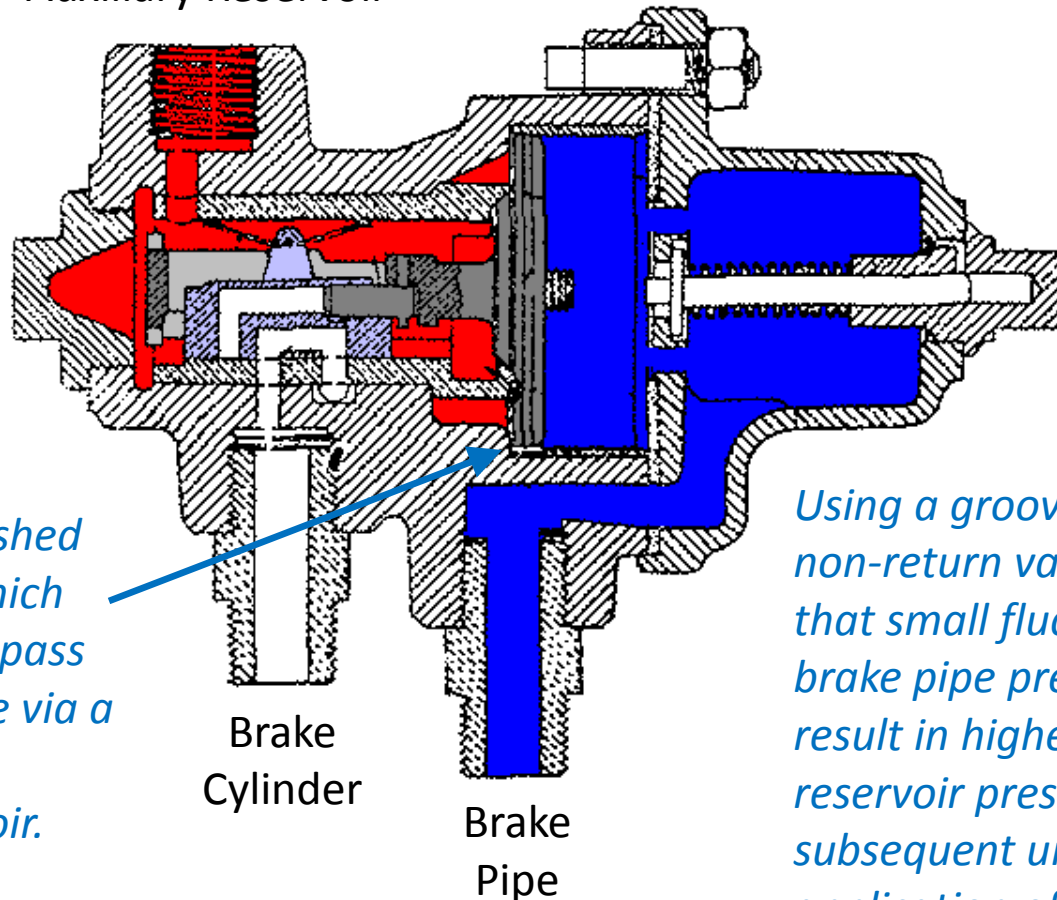
Triple valve system



Triple valve system

Charging the brake pipe to 70 psi:

Auxiliary Reservoir



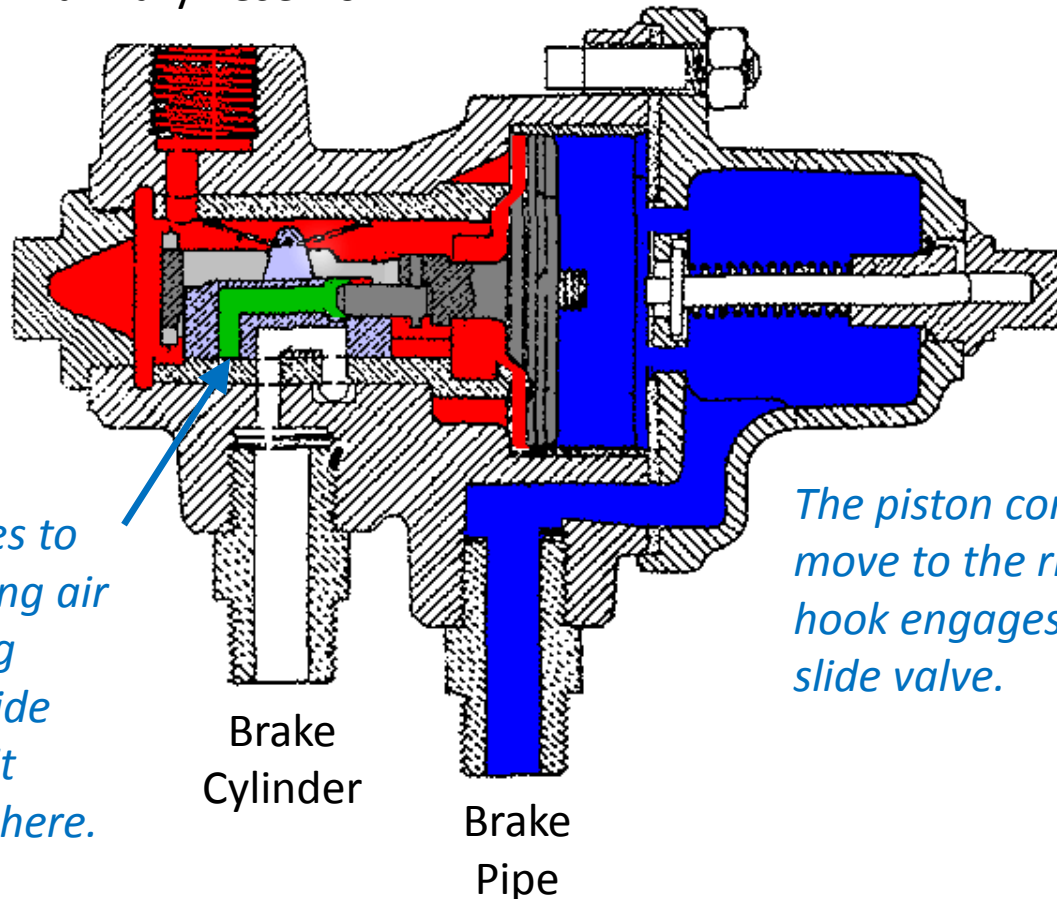
The piston is pushed to the left, in which position air can pass around the edge via a groove into the auxiliary reservoir.

Using a groove instead of a non-return valve means that small fluctuations in brake pipe pressure will not result in higher auxiliary reservoir pressure and a subsequent undesired application of the brakes.

Triple valve system

Brake pipe pressure is reduced to 60 psi:

Auxiliary Reservoir

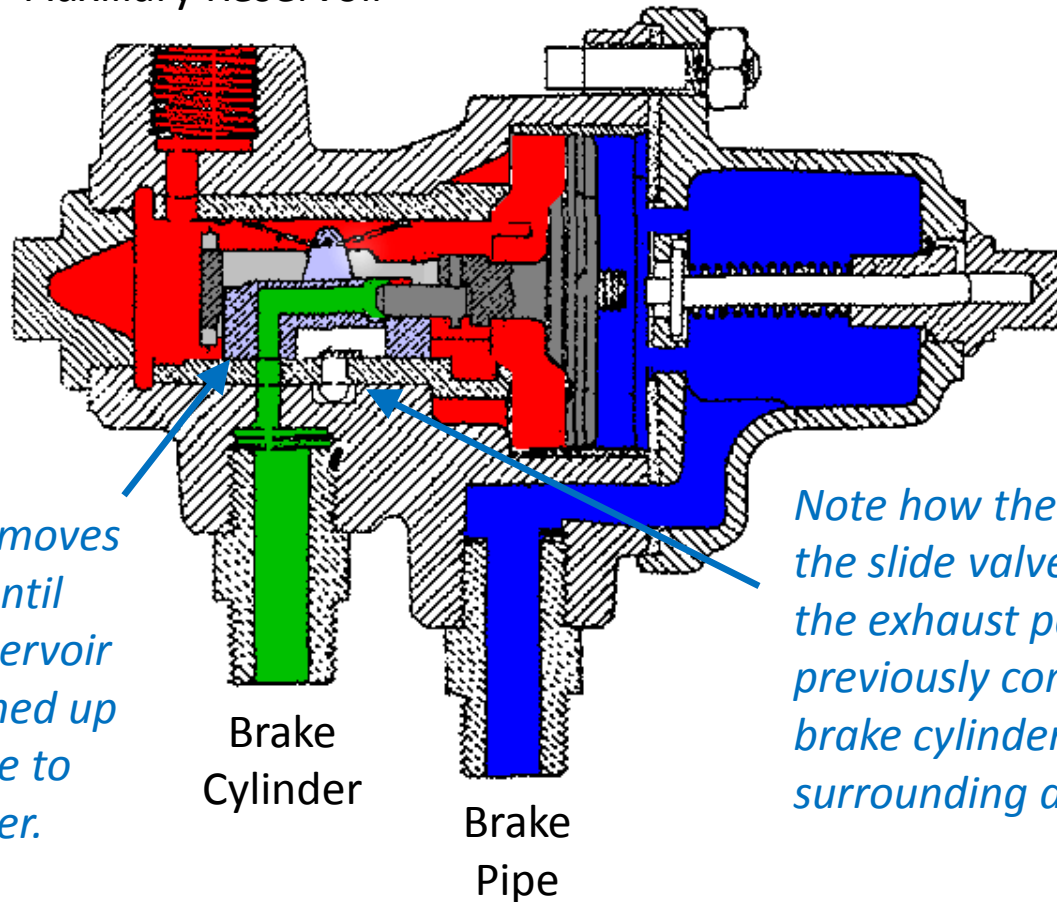


The piston moves to the right, allowing air through the plug valve into the slide valve, but note it cannot go anywhere.

The piston continues to move to the right until the hook engages with the slide valve.

Triple valve system

Auxiliary Reservoir



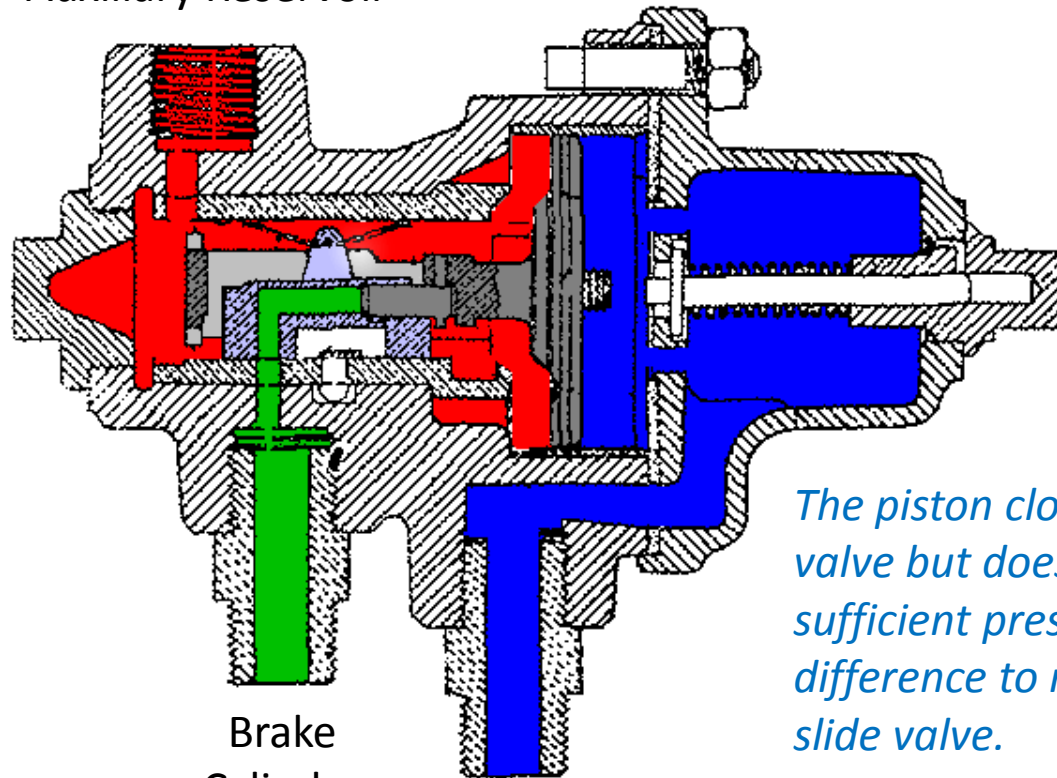
The piston now moves the slide valve until the auxiliary reservoir air passage is lined up with the passage to the brake cylinder.

Note how the movement of the slide valve has isolated the exhaust passage that previously connected the brake cylinder to the surrounding atmosphere.

Triple valve system

Auxiliary reservoir pressure falls until it is slightly less than the brake pipe:

Auxiliary Reservoir



Brake
Cylinder

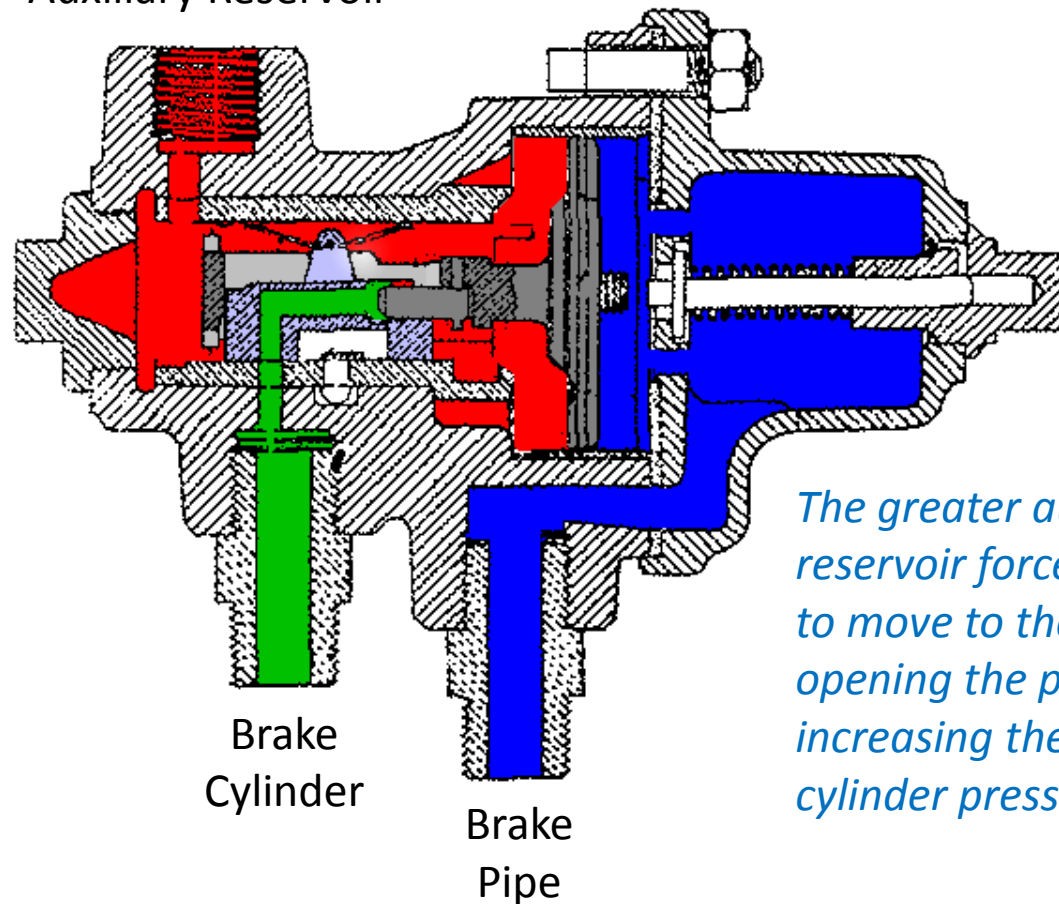
Brake
Pipe

The piston closes the plug valve but does not have sufficient pressure difference to move the slide valve.

Triple valve system

Brake pipe pressure is reduced to 55 psi, to increase the brake demand:

Auxiliary Reservoir

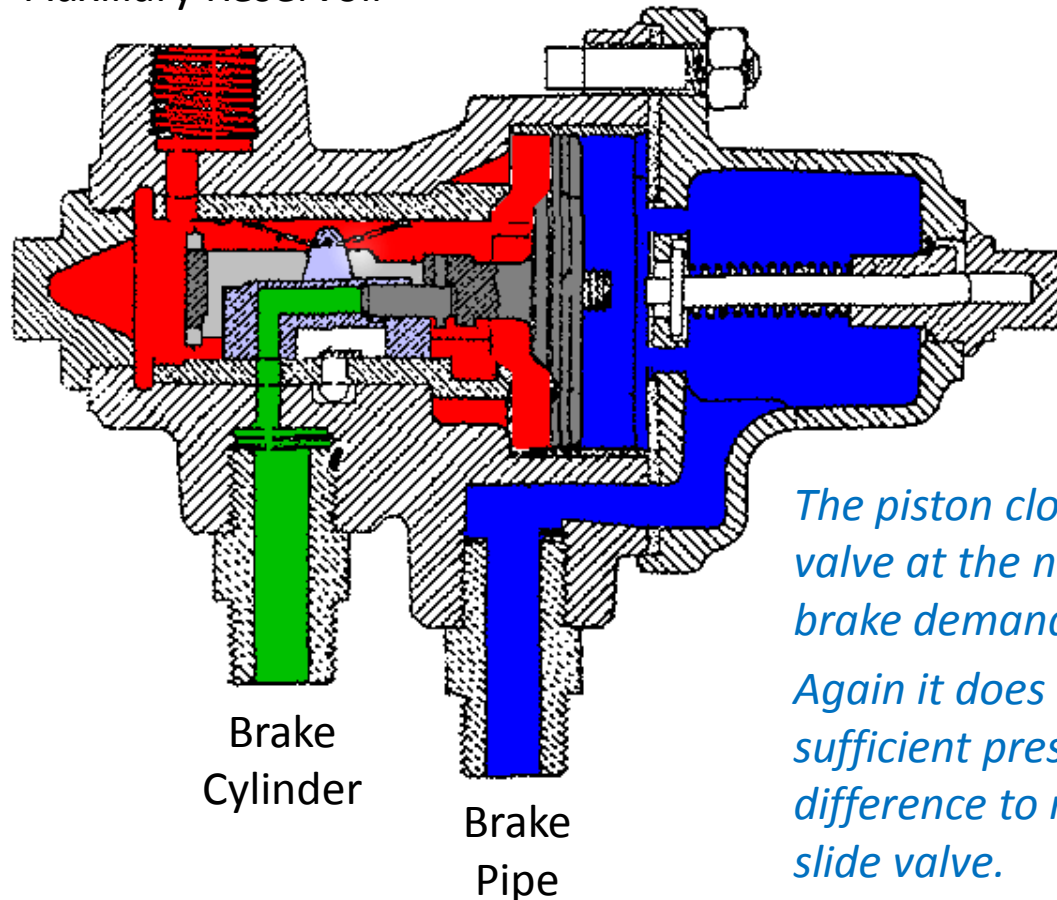


The greater auxiliary reservoir forces the piston to move to the right, opening the plug valve and increasing the brake cylinder pressure.

Triple valve system

Auxiliary reservoir pressure falls until it is slightly less than the brake pipe:

Auxiliary Reservoir



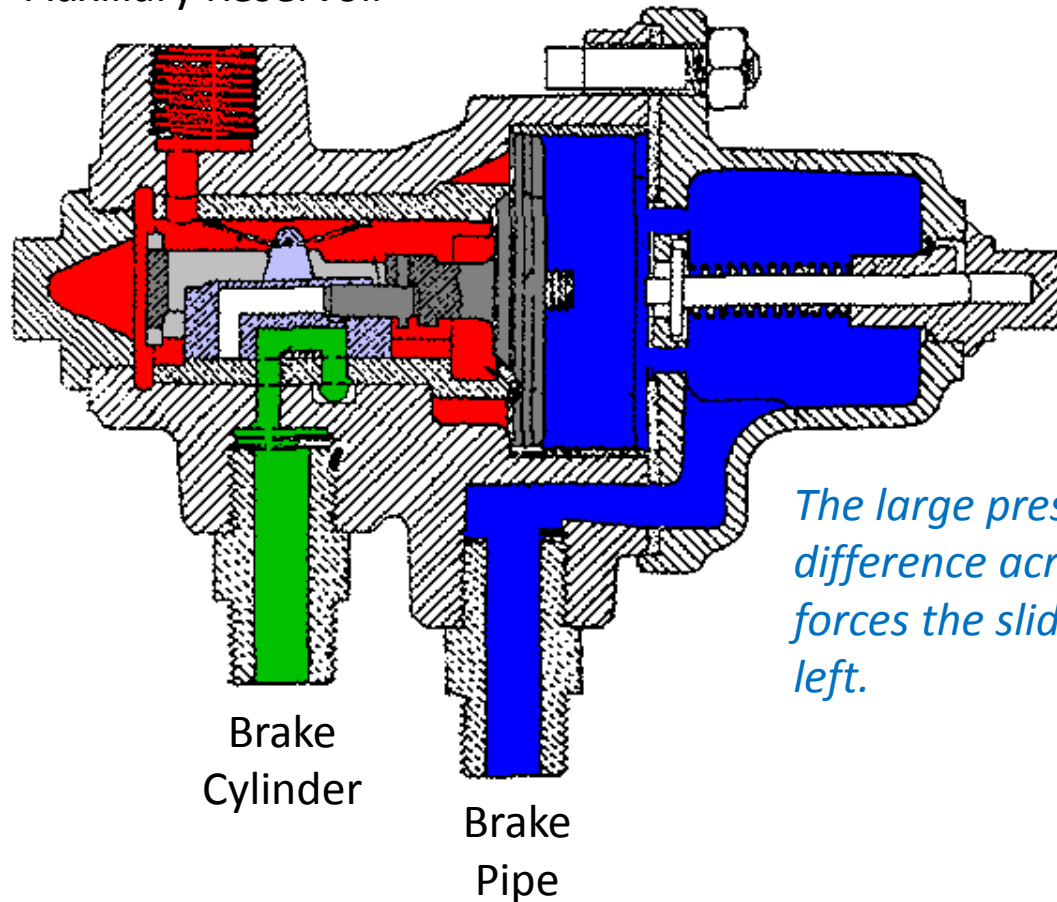
The piston closes the plug valve at the new higher brake demand.

Again it does not have sufficient pressure difference to move the slide valve.

Triple valve system

Brake pipe pressure is recharged to 70 psi to release the brake:

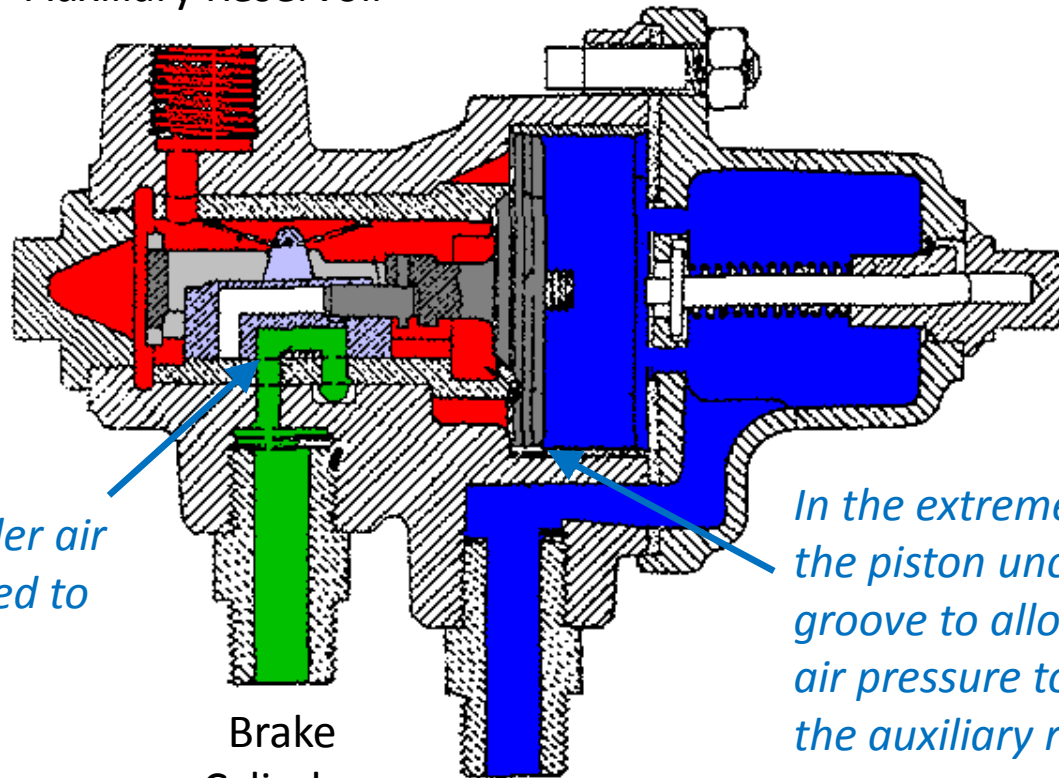
Auxiliary Reservoir



The large pressure difference across the piston forces the slide valve to the left.

Triple valve system

Auxiliary Reservoir



The brake cylinder air pressure is vented to the surrounding atmosphere.

Brake
Cylinder

Brake
Pipe

In the extreme left position, the piston uncovers the groove to allow brake pipe air pressure to recharge the auxiliary reservoir.

Air brakes

Question:

What are the two problems with the triple valve system?

Air brakes

Answers:

- (1) After making the initial brake application, the brake force can only be increased, it cannot be eased. In other words, there is no 'graduable' release. If a driver were to attempt to ease the brake, the rise in brake pipe pressure would push the triple valve pistons fully over and release all brake cylinder pressure to atmosphere. This would be dangerous because the auxiliary reservoirs can only recharge if the brake pipe pressure is fully recharged.*
- (2) The rate of recharging the auxiliary reservoirs depends on the size of the locomotive's main air reservoir, the power of its pump and on how many vehicles there are in the train (i.e. the number and volume of auxiliary reservoirs). However, the brake cylinder release takes place over a fixed time and is generally much quicker than the recharging of the auxiliary reservoirs. This means that after the brakes are released, the auxiliary reservoirs will initially be unable to make a fully effective brake application. This phenomenon is known as 'exhaustibility'.*

Air brakes

Discussion

If a railway uses the basic triple valve system, it must make sure that its drivers understand that the system cannot graduable release and is exhaustible.

Due to the above, the system can be challenging to operate, particularly if you consider the scenario of entering a terminus station and having made too great an application of the brake. What to do? Is there time for a release and reapply? Or can you stop short without causing an obstruction? It is probably for these reasons that the original Westinghouse brake system was not adopted during the grouping era on Britain's railways (1923-1947).

Despite its negative points, any driver who encounters the air brake system will notice that its response is much faster than the vacuum brake system. Also, if the locomotive's main air reservoir is large and the train is short, exhaustibility does not tend to be a problem, due to the rapidity with which the auxiliary reservoirs are recharged.

Air brakes

Discussion

As a final note about this system, exhaustibility reduces the effectiveness of the brake, it does not make the brake immediately useless.

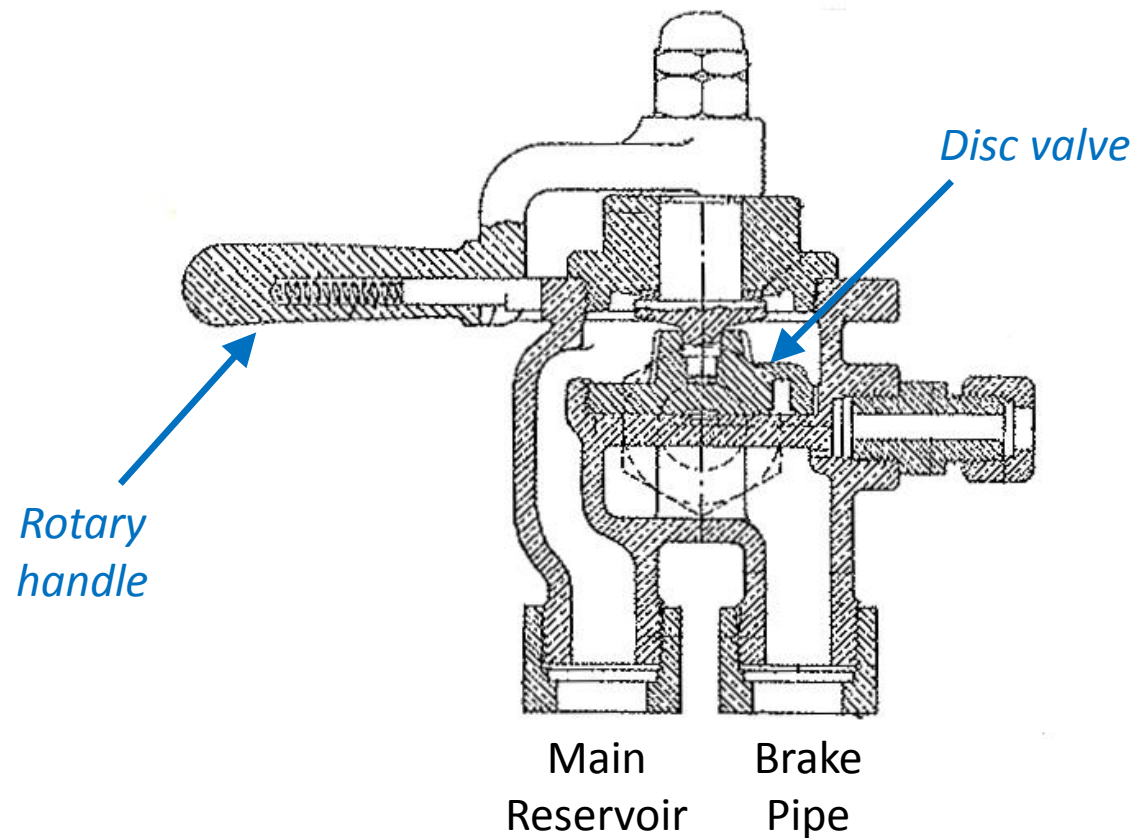
If the brakes are applied, then released, then reapplied before the auxiliary reservoirs have recharged, there will still be air pressure to pass from the auxiliary reservoir to the brake cylinder. However, instead of obtaining 50 psi maximum brake cylinder pressure, it will only now achieve around 35 psi. If the process repeats, then there will be less maximum brake cylinder pressure next time, maybe only 25 psi. Repeated several times, the brake system will eventually be drained of air, but it does not happen with just the first attempt.

Triple valve system

Driver's control valve

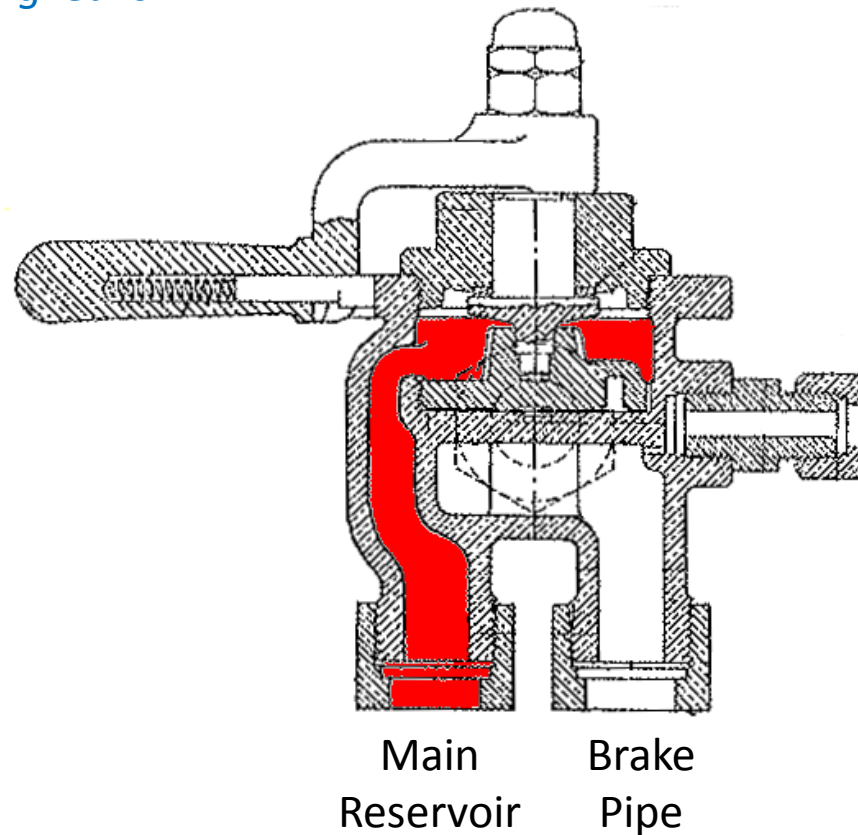
Triple valve system

Here is the simplest type of air brake valve. It has a rotary handle connected to a disc valve. The valve has three positions: release, lap and apply.



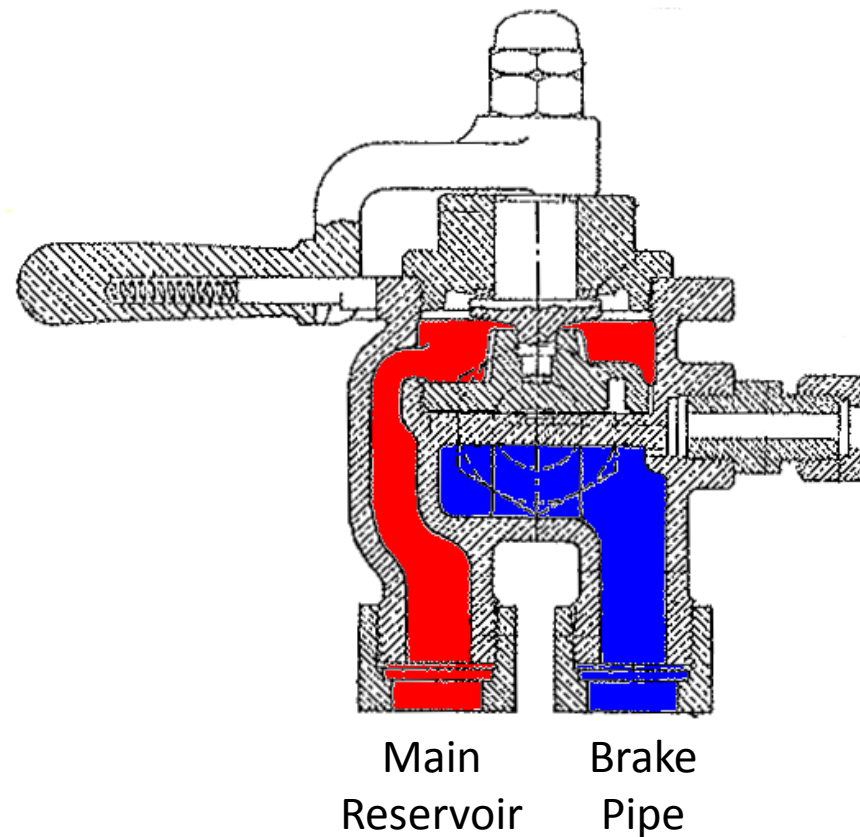
Triple valve system

Air is supplied to the controller from the main air reservoir. The air passes into the chamber on the upper side of the disc valve. The pressure pushes down on the disc valve, preventing leaks.



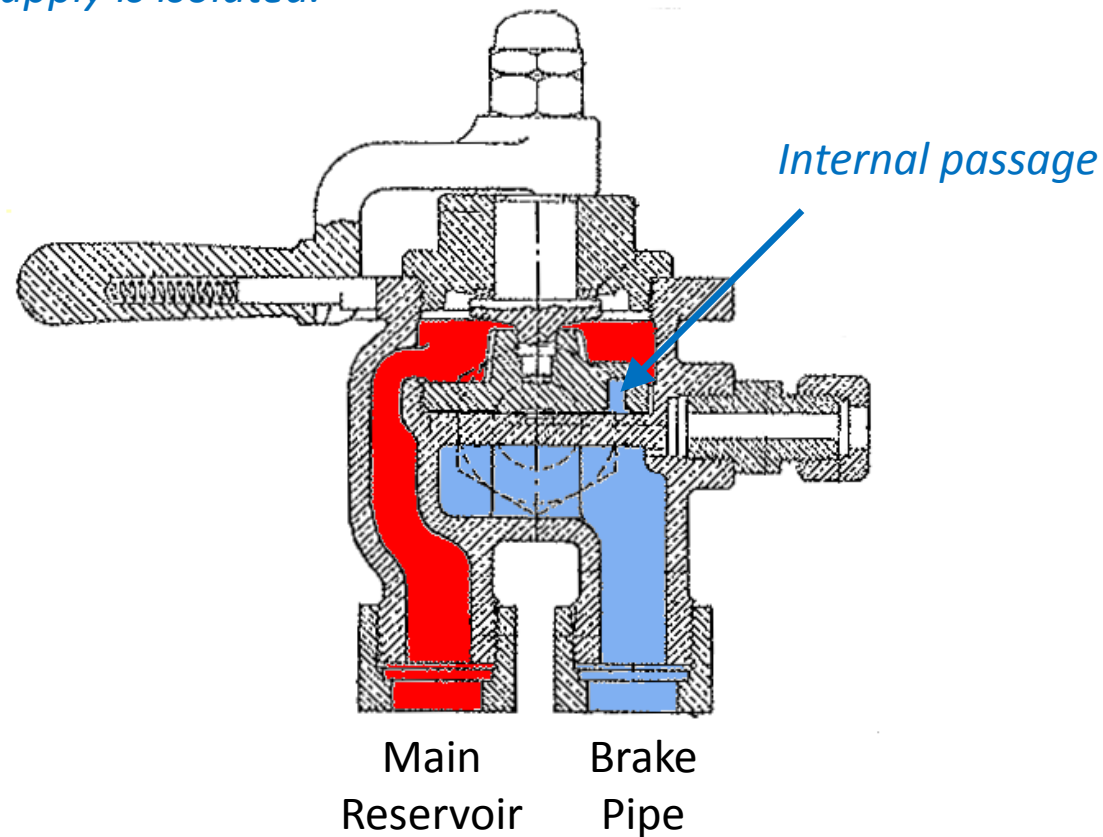
Triple valve system

When the controller is moved to the brake release position, air passes through a hole in the disc valve which is now lined up with the brake pipe passage.



Triple valve system

When the controller is moved to the brake apply position, an internal passage in the disc valve connects the brake pipe with the surrounding atmosphere. The main air reservoir supply is isolated.



Triple valve system

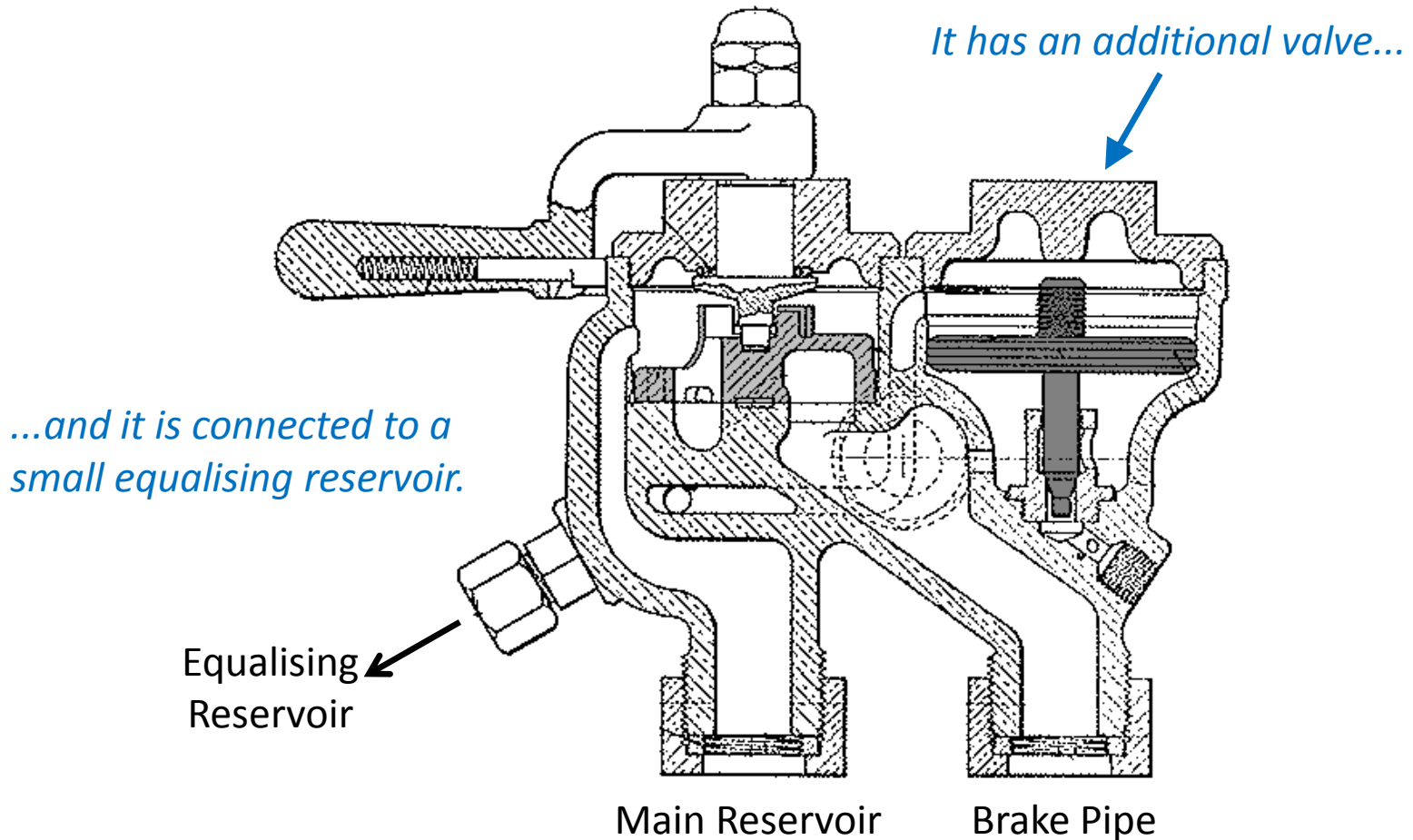
In the lap position, the brake pipe is isolated from both the main reservoir and the surrounding atmosphere. Brake pipe pressure will be held at its current level except for the effects of leakage, which are much less than a vacuum brake system.

All of the early air brake controllers had a lap position, the speed of propagation of compressed air making it unpractical for continuous type controllers.

Only a few locomotives remained fitted with the basic controller described above. Most were fitted with a slightly more sophisticated version, shown overleaf...

Triple valve system

You will probably recognise this controller from many text books.



Triple valve system

So what are the additional valve and equalising reservoir for?

This is best explained by first considering the basic type of 3 way valve. If the train length were to be decreased, the volume of air in the brake pipe will also decrease (because it is shorter). Therefore, to make the same brake application with a shorter train will require the driver to open the control valve for less time.

This means that the controller will feel different depending on the length of the train.

If misjudged, the driver could make a more severe application than was desired, and as explained previously the exhaustibility of the air brake system could make the error difficult to correct.

Triple valve system

With the more sophisticated controller, the normal applications of the brake are made using the equalising reservoir and the additional valve. The additional valve is automatic, the driver only has to operate the rotary handle as before.

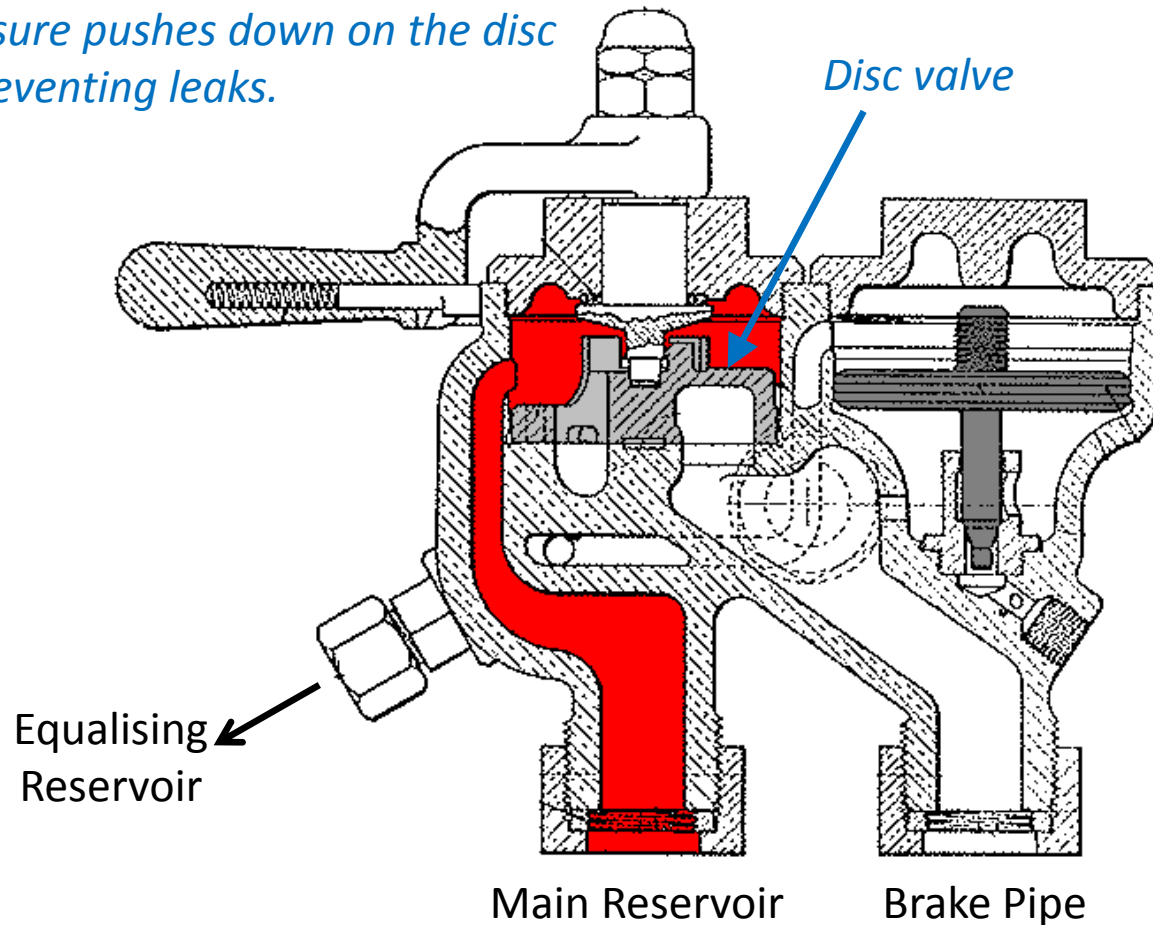
The equalising reservoir is a fixed volume of air, regardless of the train length. The equalising reservoir is charged to the same pressure as the brake pipe when the brakes are released.

The additional valve is a relay valve. When normal service brake applications are made, air is released to atmosphere from the equalising reservoir. The relay valve then replicates the pressure drop to the brake pipe. The next few slides will illustrate...

Triple valve system

Air pressure from the main reservoir enters the top of the controller.

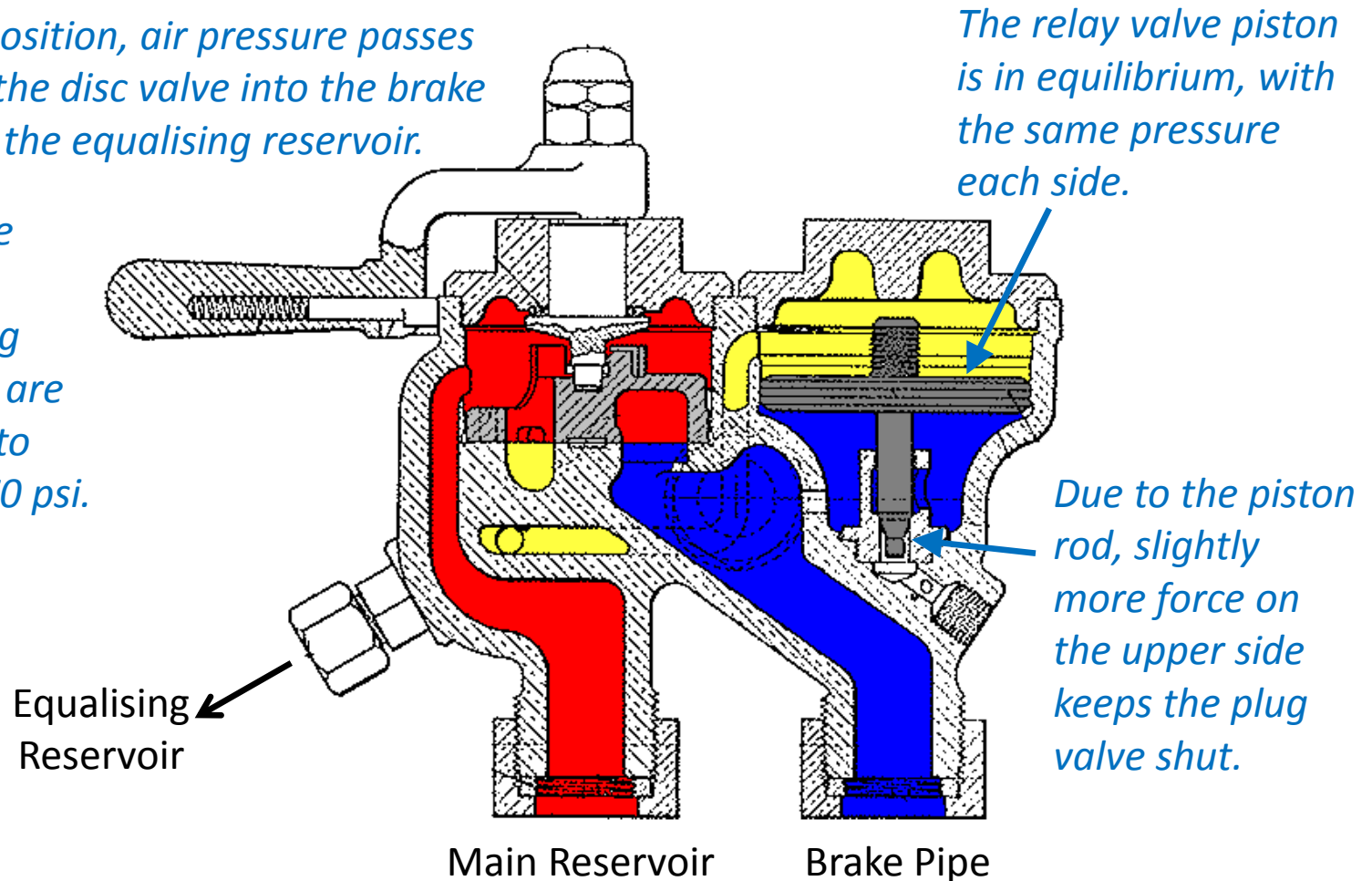
The pressure pushes down on the disc valve, preventing leaks.



Triple valve system

With the control handle in the brake release position, air pressure passes through the disc valve into the brake pipe and the equalising reservoir.

The brake pipe and equalising reservoir are charged to around 70 psi.

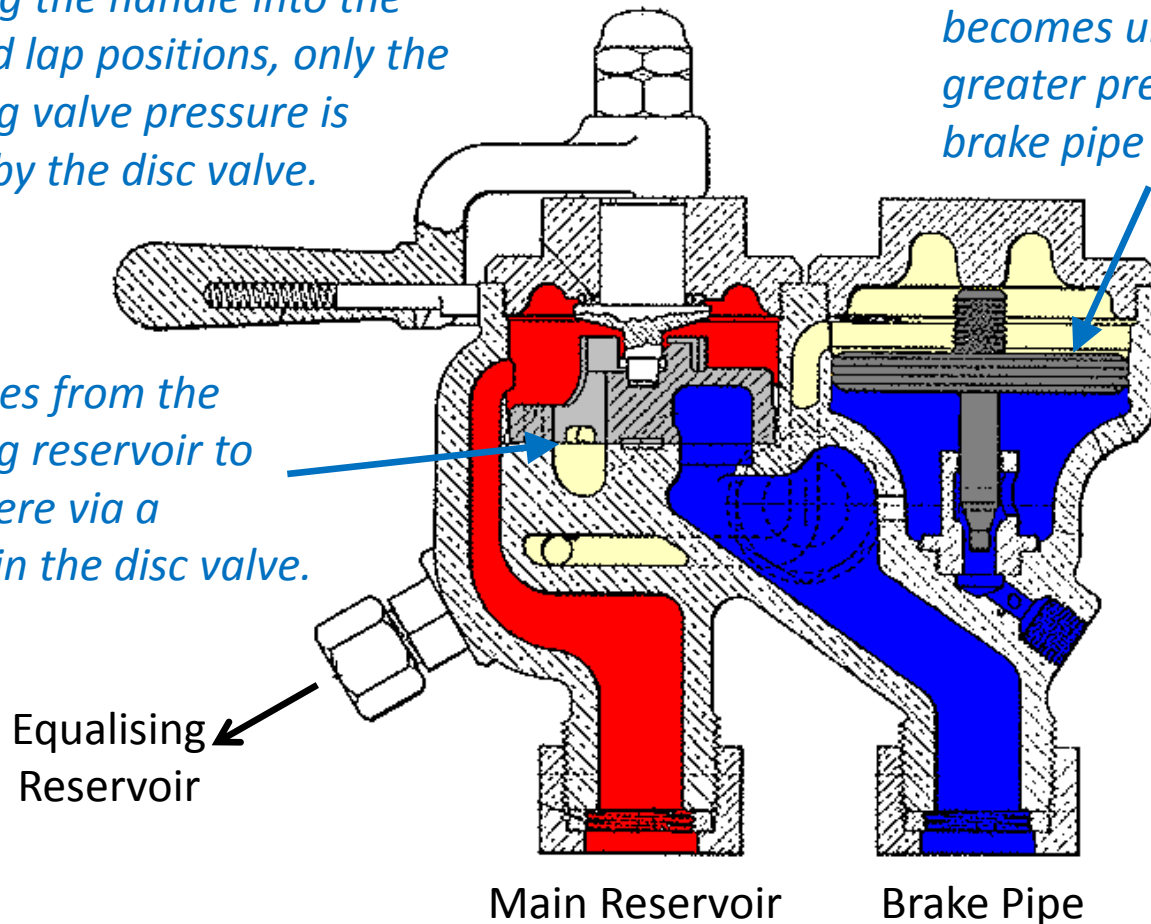


Triple valve system

When a brake application is made by moving the handle into the apply and lap positions, only the equalising valve pressure is reduced by the disc valve.

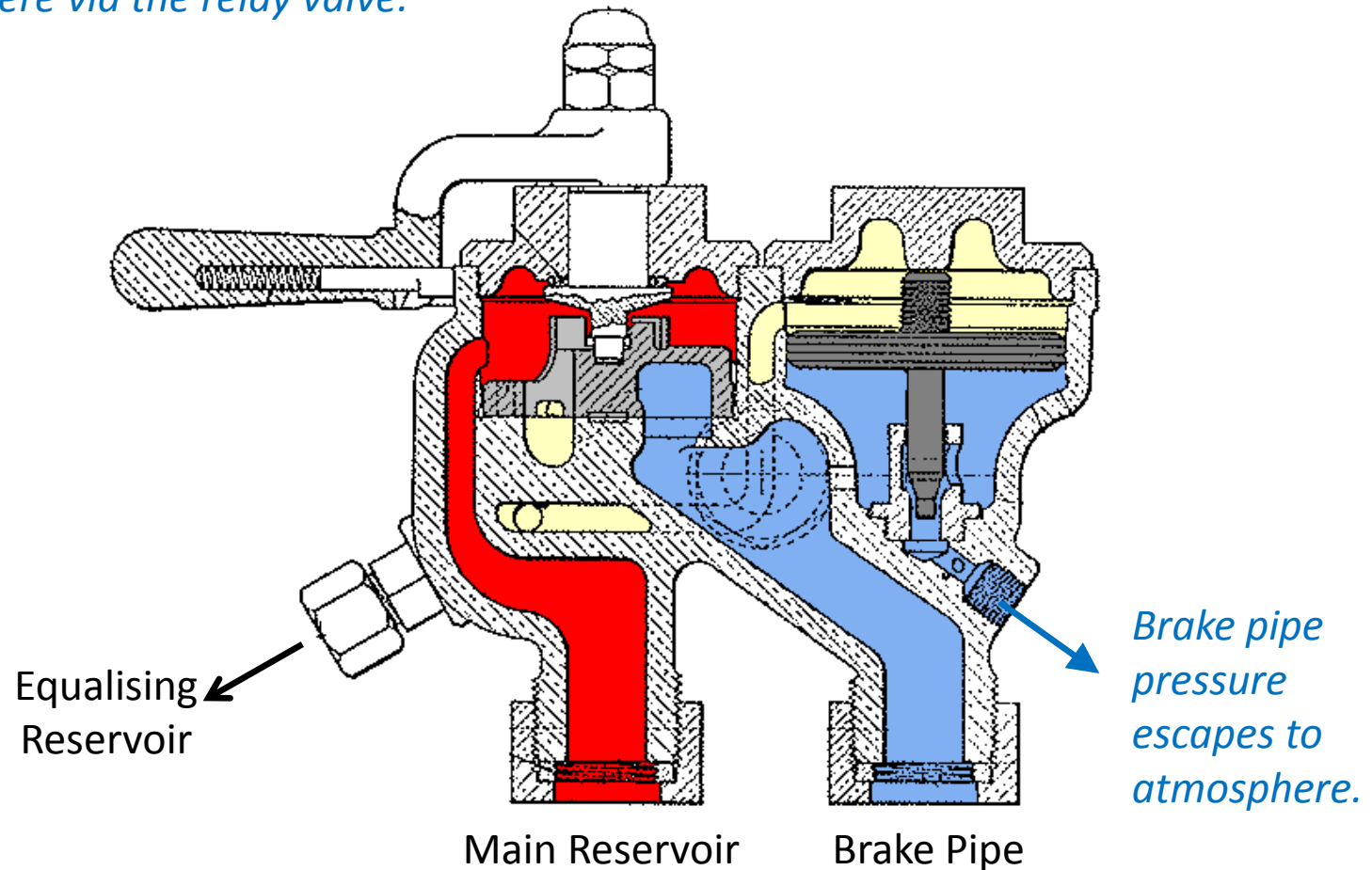
The relay valve piston becomes unbalanced. The greater pressure in the brake pipe lifts the piston.

Air escapes from the equalising reservoir to atmosphere via a passage in the disc valve.



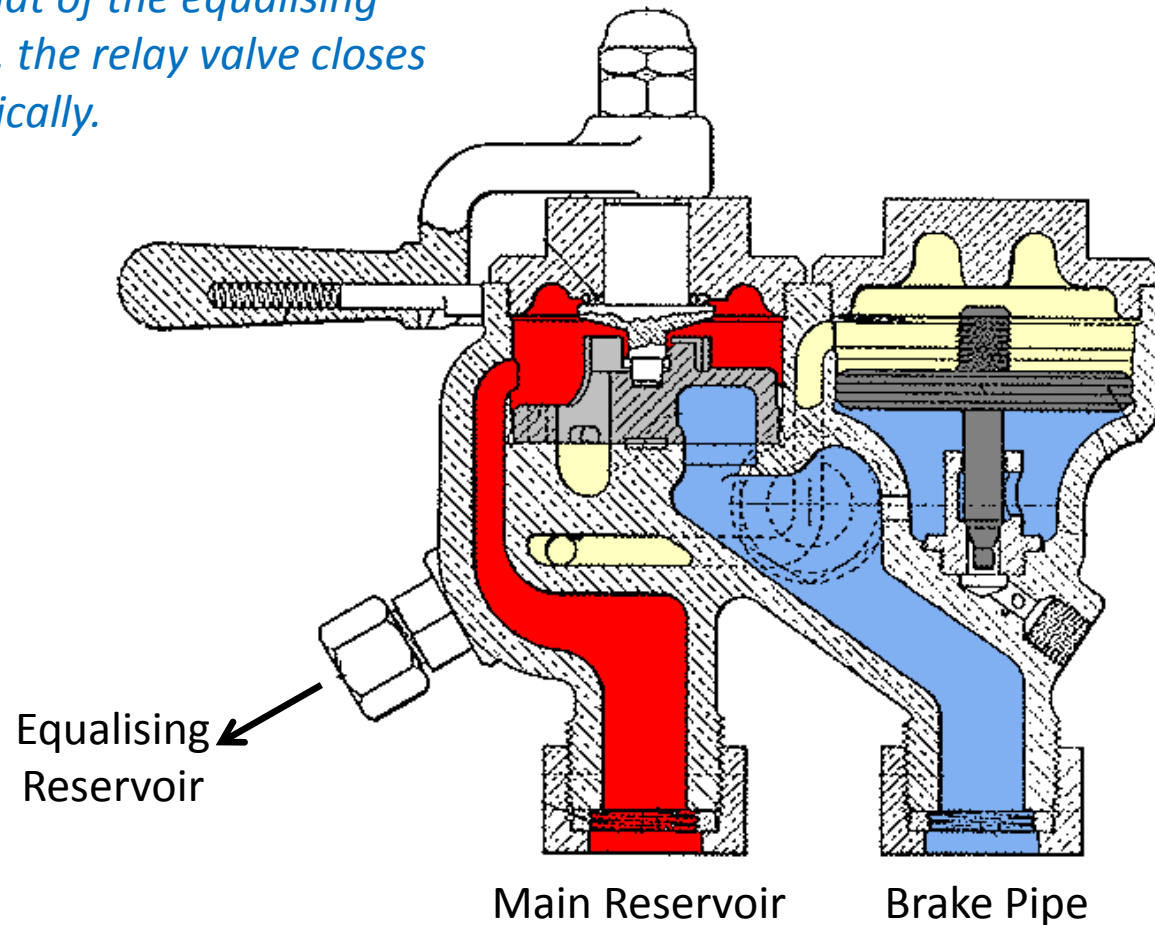
Triple valve system

Brake pipe pressure is released to atmosphere via the relay valve.



Triple valve system

When the brake pipe pressure equals that of the equalising reservoir, the relay valve closes automatically.



Triple valve system

With this type of controller, the 'feel' of the brake controller is always the same, regardless of the length of the train. Movement of the control handle releases air from the equalising reservoir and the relay valve automatically replicates the pressure drop in the brake pipe, however long it takes.

There is one position of the controller that is different. In the emergency brake position, the disc valve will vent air directly from the brake pipe to atmosphere. This ensures a fast brake application.

As with the simple controller, releasing the brake has to be done completely in one attempt (there is no graduable release). Air flows from through the disc valve from the main air reservoir into the brake pipe.

The main air reservoir is often arranged to be at higher pressure (e.g. 100 psi) than the brake pipe release pressure (70 psi). To make this possible a pressure reducing valve is fitted between the main air reservoir and the driver's controller.

Triple valve system

Overcoming the drawbacks

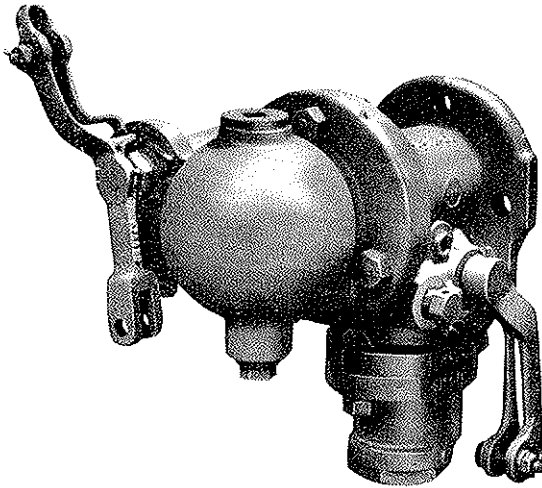
Triple valve system

Drawbacks:

1. Exhaustibility
2. No graduable release

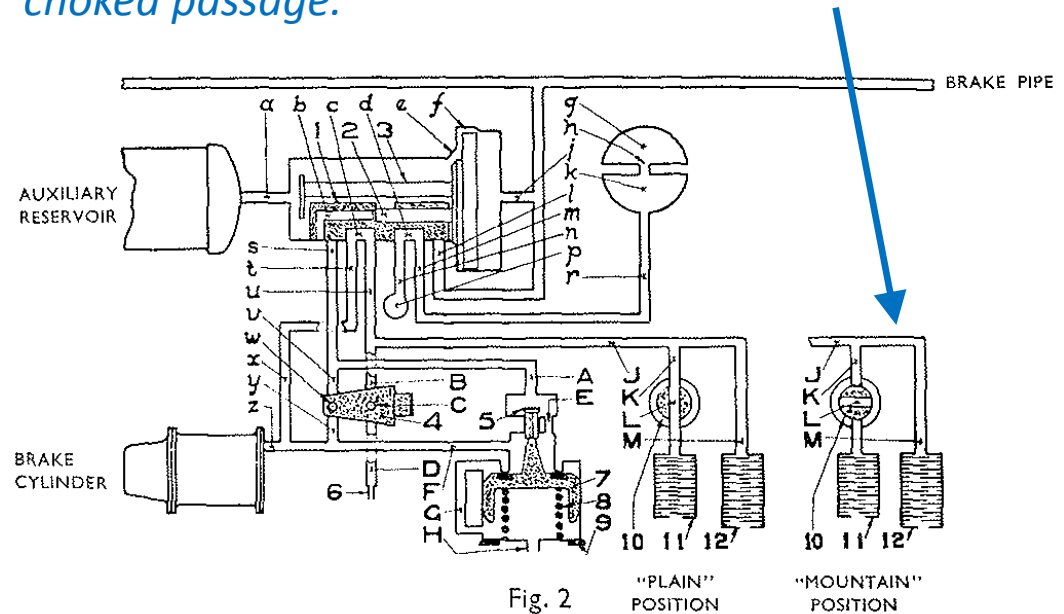
The next few slides detail what was done to overcome the problems of exhaustibility and no graduable release that were inherent in the original Westinghouse automatic air brake system.

Triple valve system



An early attempt to solve the exhaustibility problem was the Westinghouse Triple Valve with Mountain Cock. Prior to a train operating over a route with steep gradients, the crew would move a handle on the side of each triple valve. This redirected the brake cylinder exhaust through a choked passage.

This increased the time taken for the brakes to release. If this time increase is sufficient, the air reservoirs will be recharged before the brake release is complete.



Triple valve system

Whether or not the time delay was sufficient depended on the size of the locomotive's main air reservoir and the length of the train (i.e. how quickly the reservoirs take to recharge).

Further, the triple valve with mountain cock did not provide the ability to ease the brake (graduable release). Therefore it was not the ultimate solution...

Triple valve system

In Europe, trains operate to tight timescales and freight trains use the same lines as express passenger trains. Therefore, it was decided that the air brake system would have to provide graduable release and inexhaustibility.

The achievement of this came to fruition in the early 1950's with the introduction of the distributor valve, which will be described fully in the next section.

The distributor valve will only allow brake cylinder air pressure to exhaust to atmosphere if there is enough air pressure in the auxiliary reservoir to recharge the brake cylinder to its maximum pressure. In other words, the auxiliary reservoir has to be recharged to permit the brake cylinder pressure to release.

There is a myth that the modern pneumatic air brake system can be exhausted but this is not true (provided that all components are functioning correctly). No matter how careless the driver is with the control valve, the system cannot be exhausted of air. The distributor valves will not allow it.

Triple valve system

Some of the very early promotional material for distributor valves in the UK defined them as triple valves, and some types have been subsequently logged on the national parts database as triple valves. However, triple valves are not used on the UK mainline railways today. The incorrect definitions are worth bearing in mind. Some heritage railways do use triple valves.

The distributor valve comes with a compromise. When releasing the brakes of a very long train, the rearmost auxiliary reservoirs take longer to recharge. This leads to a situation where the driver may think that the brakes have all released when in reality the rearmost vehicles still have a slight brake application. This causes a dragging brake at the rear of the train, and if the driver has started to accelerate the dragging brake can cause damage by heating the wheels or by causing the wheels to slide on the rails. The latter will lead to flats on the wheel treads.

It is for this reason that the USA has never adopted the distributor valve system...

Triple valve system

In the USA an improved system has been developed based on the triple valve system.

The new system comprises two triple valves and two reservoirs. An auxiliary reservoir of air is used to apply the service brake, whilst an emergency reservoir provides a back up source of air that can be used to apply the brakes when the brake pipe pressure is reduced to zero. There are further refinements, including a valve to use brake cylinder air to assist in recharging the emergency reservoir.

The housing containing the two triple valves and associated spool valves is known simply as the “control valve”. The two reservoirs of air are usually contained in one actual reservoir which has a dividing wall.

This improved system provides direct and quick release. It prevents there being a dragging brake. However, the system cannot provide graduable release.

Distributor system

The system

Distributor system

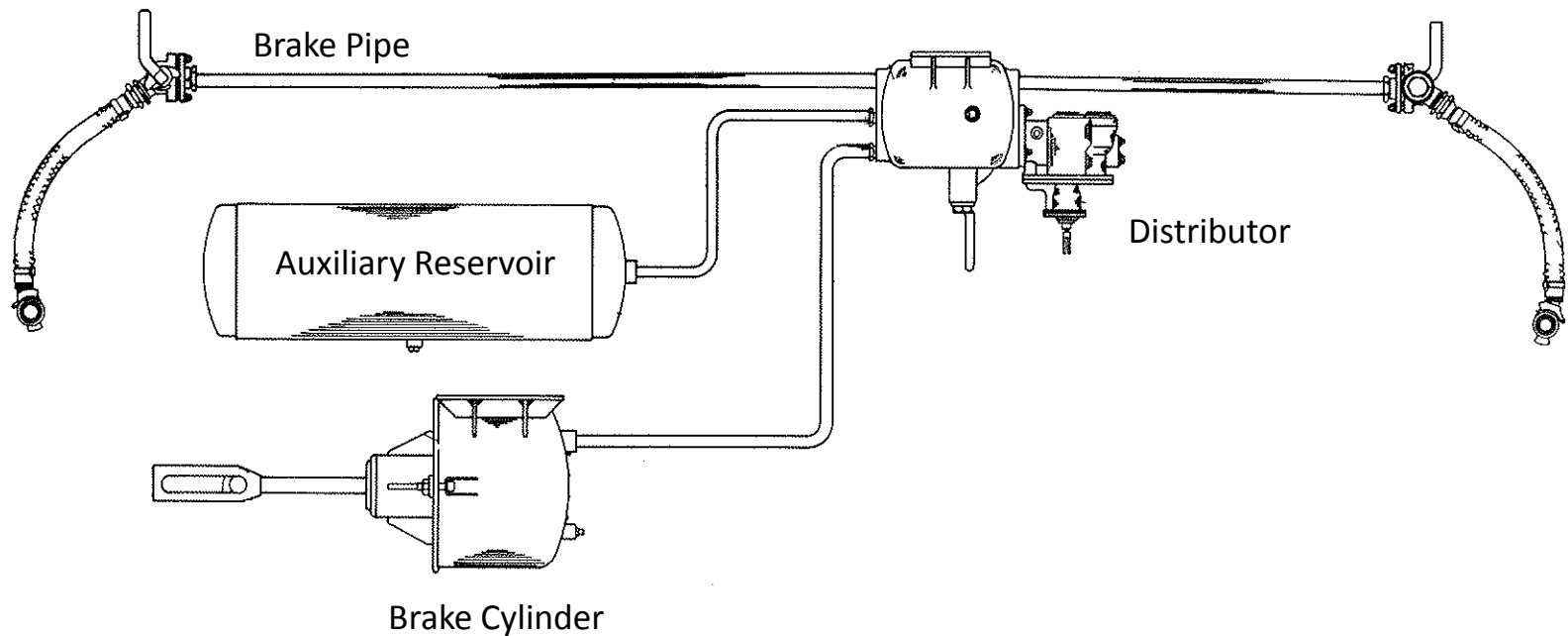
The next few slides illustrate the distributor system. This system is used throughout Europe and many other parts of the world.

The distributor system is applied to conventional trains with a locomotive hauling trailing vehicles. For the most part this means freight trains and conventional trailing coaches.

Modern multiple unit passenger trains use electro-pneumatic brakes, which are described in the last section of these notes.

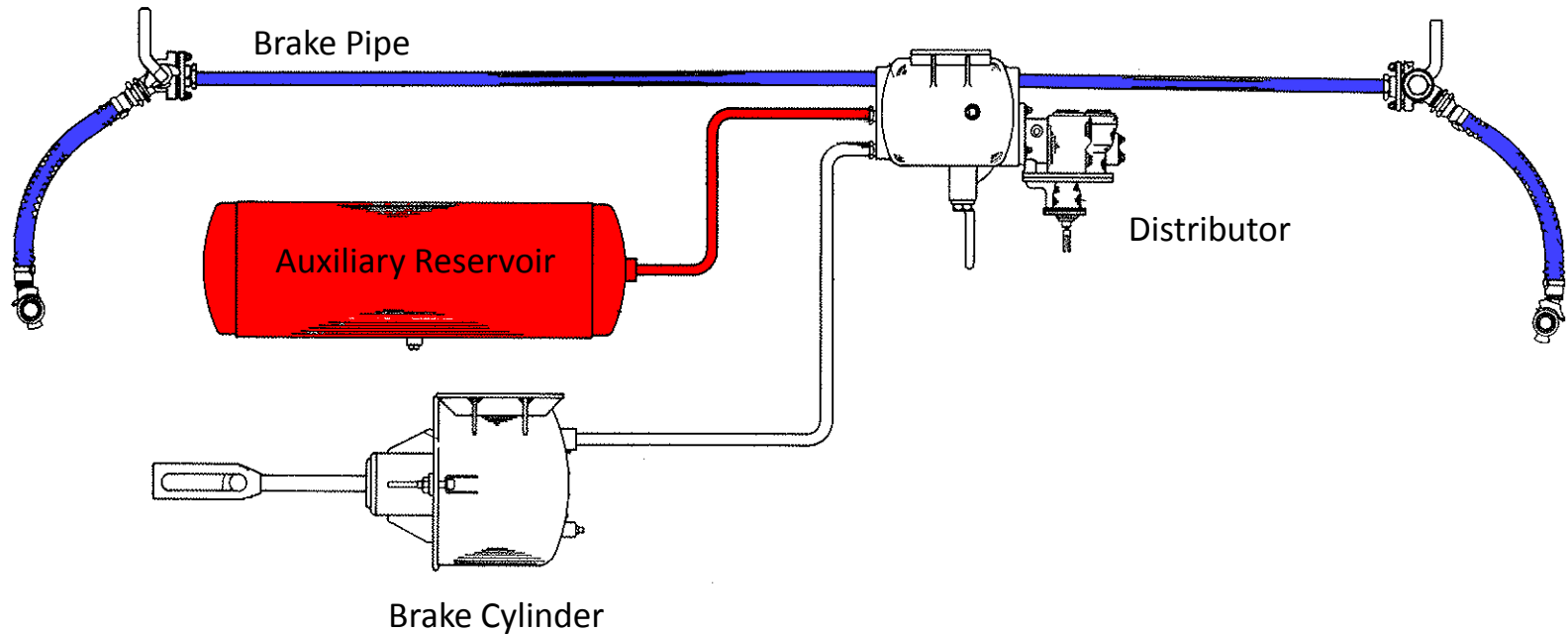
Distributor system

This is the equipment fitted to the trailing vehicle:



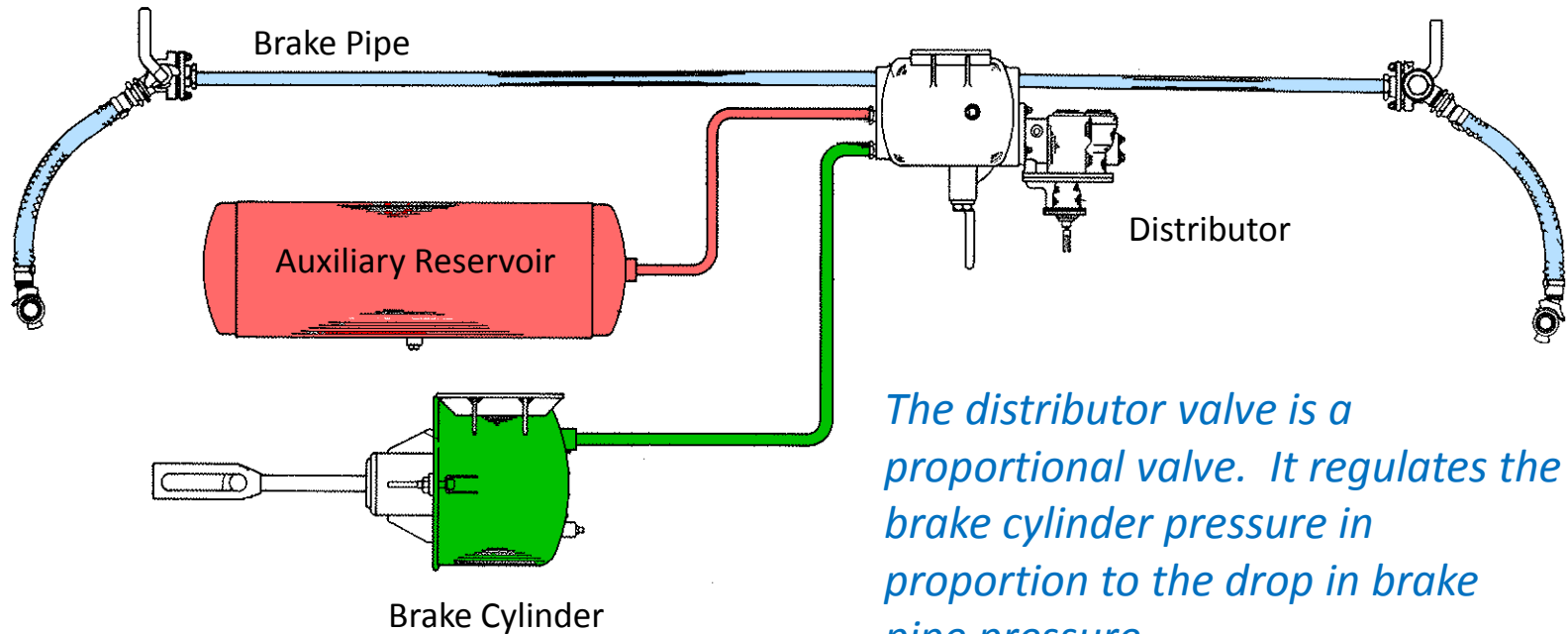
Distributor system

When the brake pipe is charged with air to a nominal pressure of 72 psi, the auxiliary reservoir is charged via the distributor valve to the same pressure.



Distributor system

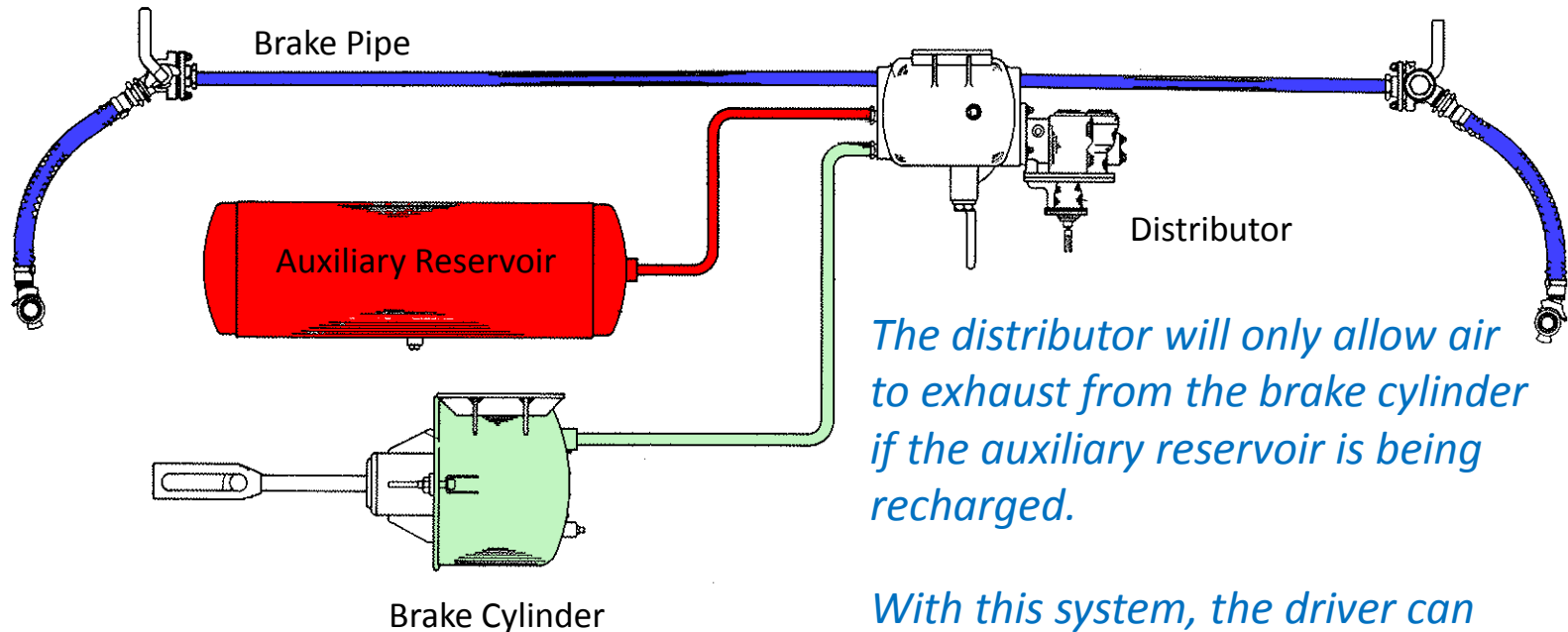
When brake pipe pressure is reduced, the distributor valve senses this drop in pressure and allows auxiliary reservoir air pressure to enter the brake cylinder.



The distributor valve is a proportional valve. It regulates the brake cylinder pressure in proportion to the drop in brake pipe pressure.

Distributor system

When brake pipe pressure is increased, the distributor valve uses this air pressure to recharge the auxiliary reservoir. At the same time the distributor valve reduces brake cylinder pressure by allowing its air to exhaust to the surrounding atmosphere.



The distributor will only allow air to exhaust from the brake cylinder if the auxiliary reservoir is being recharged.

With this system, the driver can ease the brake (graduable release).

Distributor system

The distributor valve

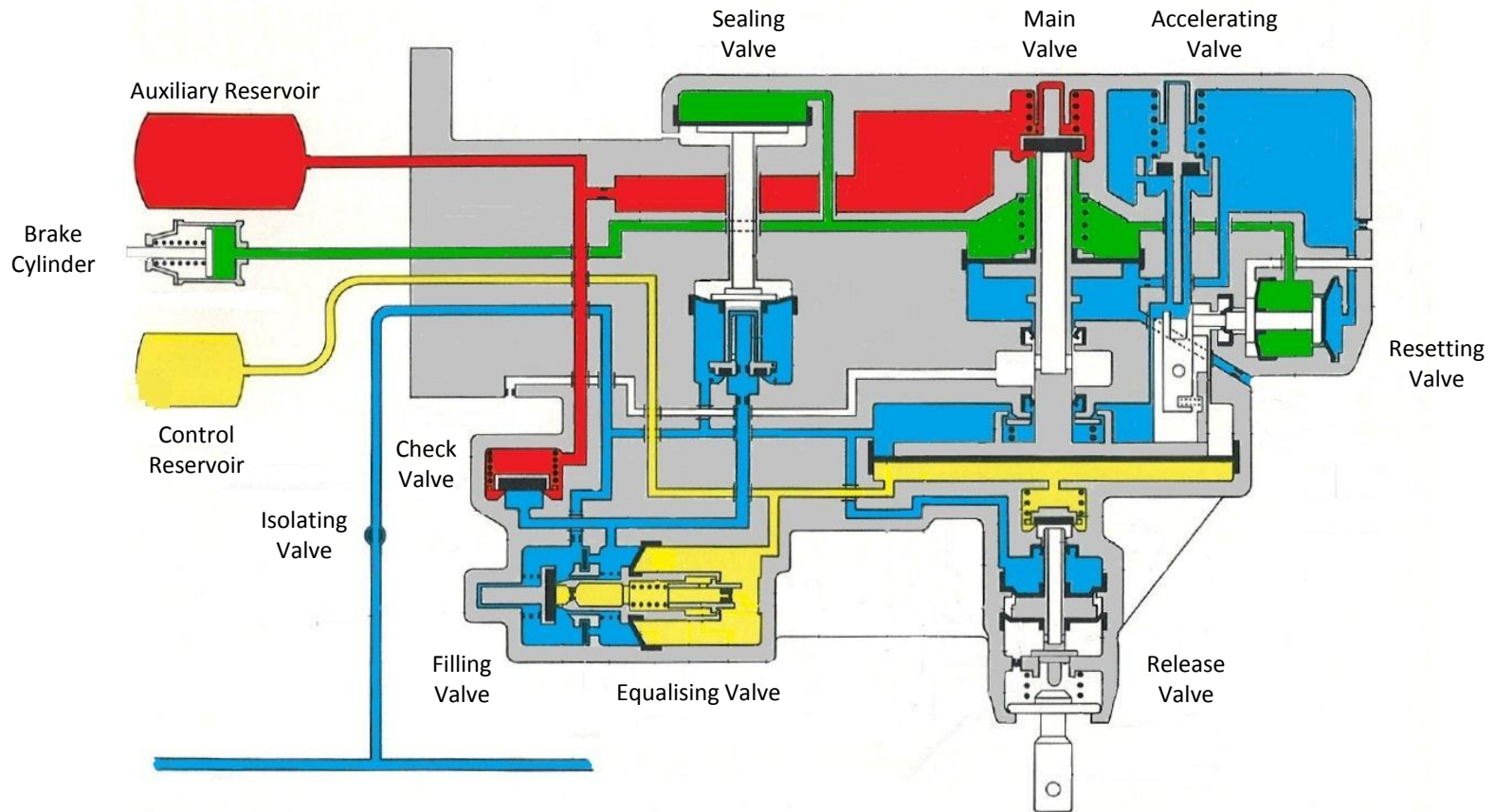
Distributor system

The distributor valve is a complex component comprising over 100 parts. Inside it are valves to control maximum pressure, initial admission pressure, brake propagation and system release. It is beyond the scope of these notes to explain the distributor valve.

Drivers on today's modern railway are not expected to understand the brake valve components, only how to operate the system.

An example schematic of a distributor valve is provided overleaf. This is actually one of the simplest examples for it does not include a limiting valve, inshot valve, empty load valve, variable load valve or passenger/goods changeover valve.

Distributor system



Distributor system

Due to the complexity, distributor valves should only be overhauled by experienced suppliers. After overhaul they are tested for correct function using special test rigs.

The distributors are designed for quick removal and replacement on the vehicle. Just three fasteners secure them to a mounting bracket with all the relevant pipe connections. Therefore, a running depot will simply change the complete distributor if it gives a problem, and will return it to the supplier.

For reference, a new distributor valve will cost around £1,500 at 2010 prices. The valves require overhaul every 5 years at a cost of around £250. The distributor system is a very good system but it is also an expensive one.

Distributor system

Driver's control valve

Distributor system

As with the distributor valve, modern driver's control valves are complex.

Again it is beyond the scope of these notes to explain all the functions, but for reference the controller includes a pilot valve, relay valve, overcharge valve, sealing valve and emergency application valve.

The driver's control valve is a proportional self-lapping valve. The handle is rotated one way to increase brake pipe pressure and the other way to reduce it. The position of the handle will give a corresponding pressure in the brake pipe and it will maintain this pressure by compensating for leaks.

Distributor system

There are certain positions that are notched. These are the running position and the emergency position.

To move the handle from the running position to make the initial application of the brake requires the handle to be pushed past a notch in the mechanism. This enforces an initial drop in brake pipe pressure of around 4 psi, the purpose of which is to ensure that the distributor valves are activated successfully.

Distributor system

Although the driver's control valve is very user friendly when making normal brake applications, to setup the system requires additional knowledge on the part of the driver.

The distributors work by memorising the brake release pressure in a chamber known as the control reservoir. They compare this pressure with the reduced brake pipe pressure to obtain the pressure drop that has been made. However, there is a problem because not all locomotives will give the same release pressure. It is nominally 72 psi but on any given locomotive could be as high as 74 psi or as low as around 69 psi.

When a locomotive is uncoupled from the train, the distributors retain the release pressure of that locomotive in their memory (control reservoir). If the next locomotive that couples onto the train cannot generate as much release pressure (e.g. 70 psi as opposed to 72 psi) then the driver will not be able to fully release the brakes.

Distributor system

The distributors can be reset by operating brake release cords on each vehicle. However, this is time consuming so two methods of remotely resetting the brake system have been devised. One is known as “overcharge” and the other is known as “control reservoir dump valve”.

Overcharge

This is sometimes referred to as a “high pressure release” and it is the preferred method of the international union of railways (UIC). The driver’s control valve has a “release” position adjacent to the running position. Having coupled a new locomotive to a train, the driver places the control valve into the “release” position. This charges the brake pipe to a pressure of 80 psi. When the pressure gauge has settled the driver returns the controller to the “running” position. It will then take several minutes for the distributors to reset themselves to the normal brake release pressure of that locomotive (69 – 74 psi). During this time the driver should avoid making a brake application because the distributors will memorise an excessive pressure and the process will have to be repeated.

Distributor system

Control reservoir dump valve

On some railways (e.g. Irish Rail), and in special cases in the UK, the locomotive is not provided with means to overcharge the brake pipe pressure. Instead each distributor is fitted with a control reservoir dump valve. This valve automatically reduces the pressure in the control reservoir when the brake pipe pressure is reduced to zero. In other words, placing the controller into the emergency position reduces the memory pressure in the distributor. This reduction will not affect the emergency application, because the pressure drop is still well in excess of what is required. However, when recharging the brake from the emergency position, the locomotive will pick up the reduced pressure and then take it up to its own specific release pressure. The brake is reset.

Operationally this system is straightforward, whenever changing the locomotive, the brake pipe is emptied. Then the resetting of the brake is automatic. The only note of caution is that a partial brake release cannot be made after an emergency brake or the subsequent normal brake applications will be deficient. The brake must be fully released after the brake pipe has been a zero pressure.

Twin pipe system

Overview

Twin pipe system

In summary, the disadvantage of the distributor system is that the brake release is delayed if there is an insufficient supply of air pressure to refill all the auxiliary reservoirs in the same time period.

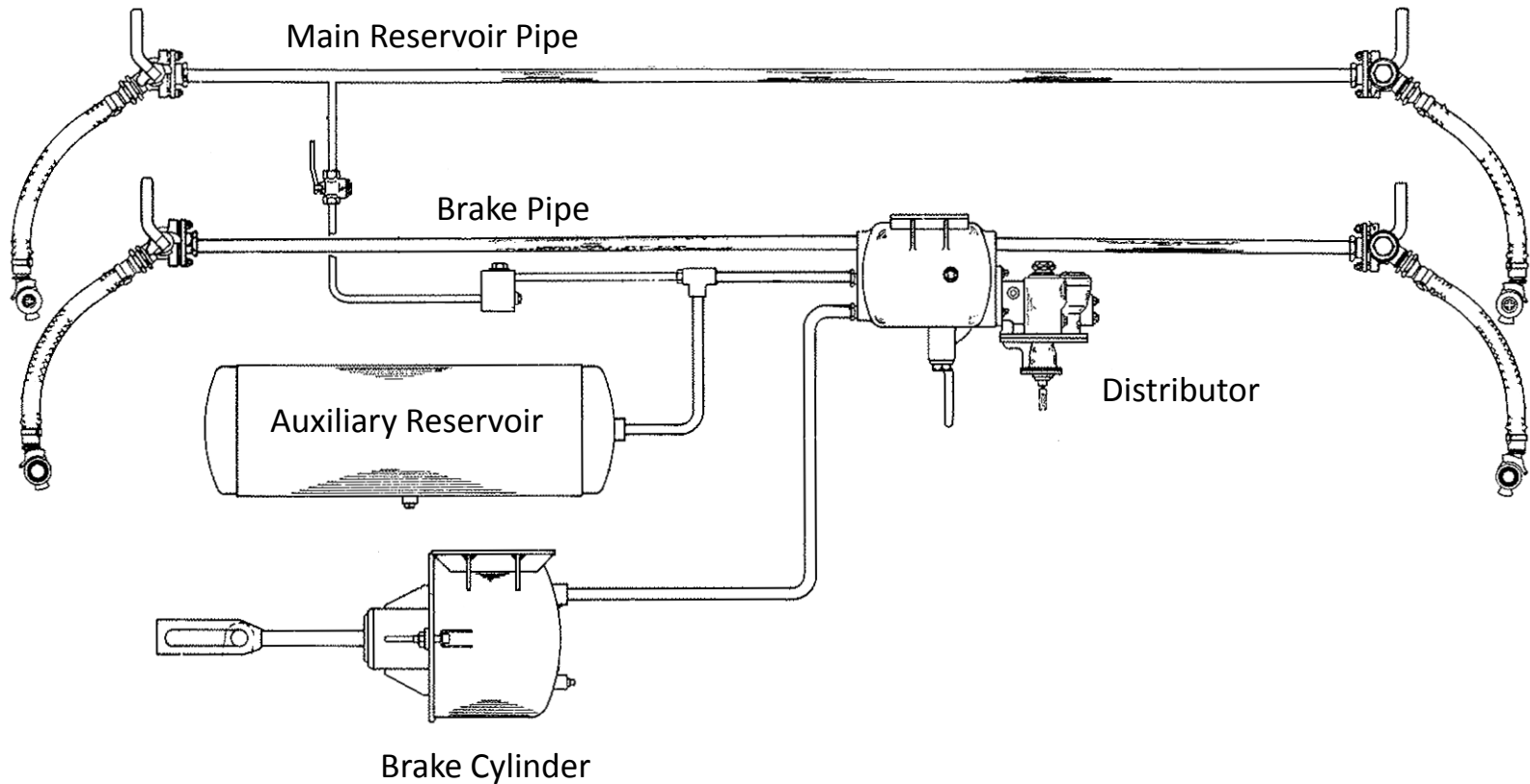
On long trains this can lead to dragging brakes at the rear of the train that may go unnoticed by the driver.

This problem can be overcome by the twin pipe system. In this system the auxiliary reservoirs start refilling from the moment a brake application is made. This refilling is made possible by a second pipe known as the main reservoir pipe, which connects the locomotive's main air reservoir directly to all the auxiliary reservoirs.

The next few slides demonstrate the twin pipe system.

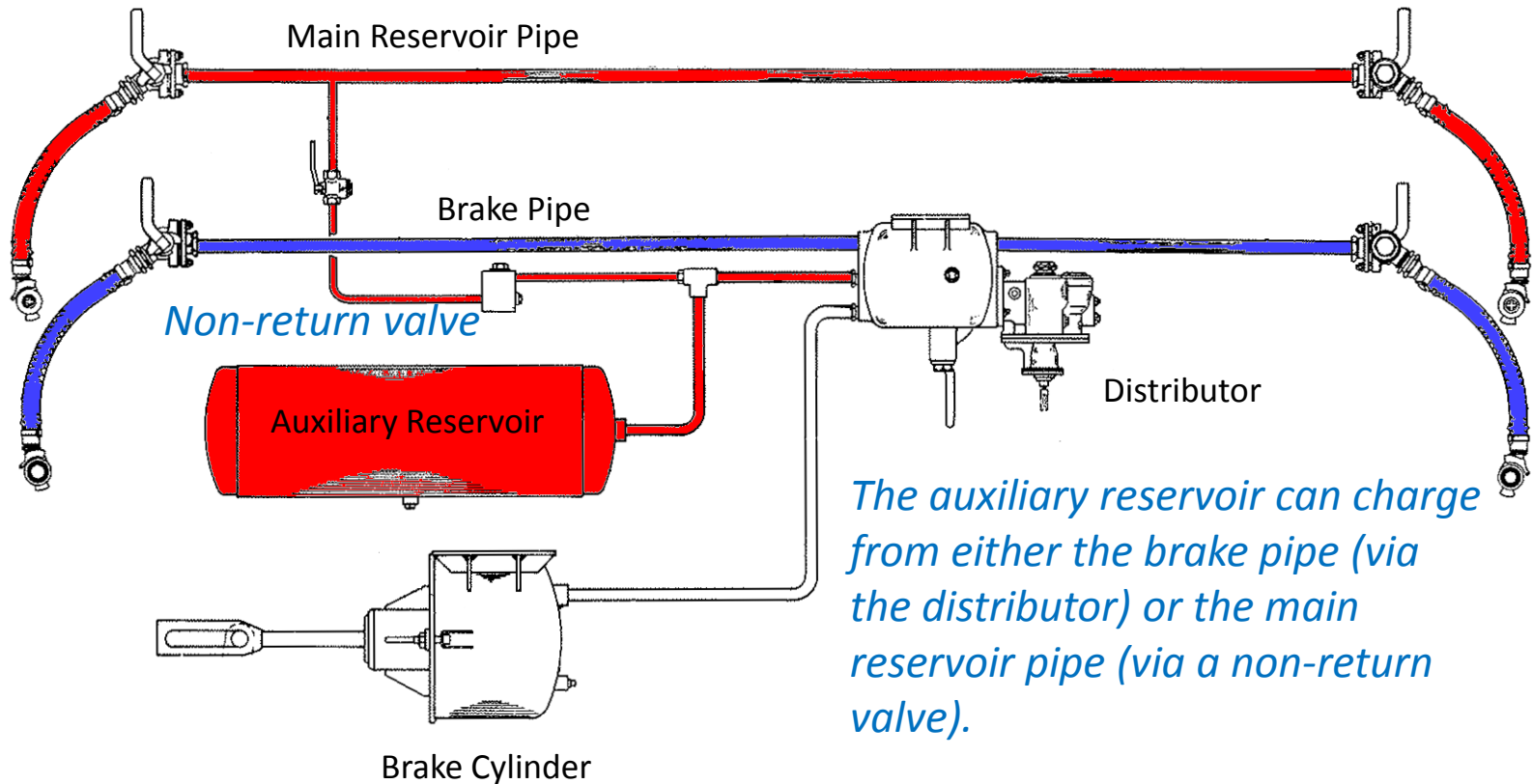
Twin pipe system

This is the twin pipe system as fitted to trailing vehicles.



Twin pipe system

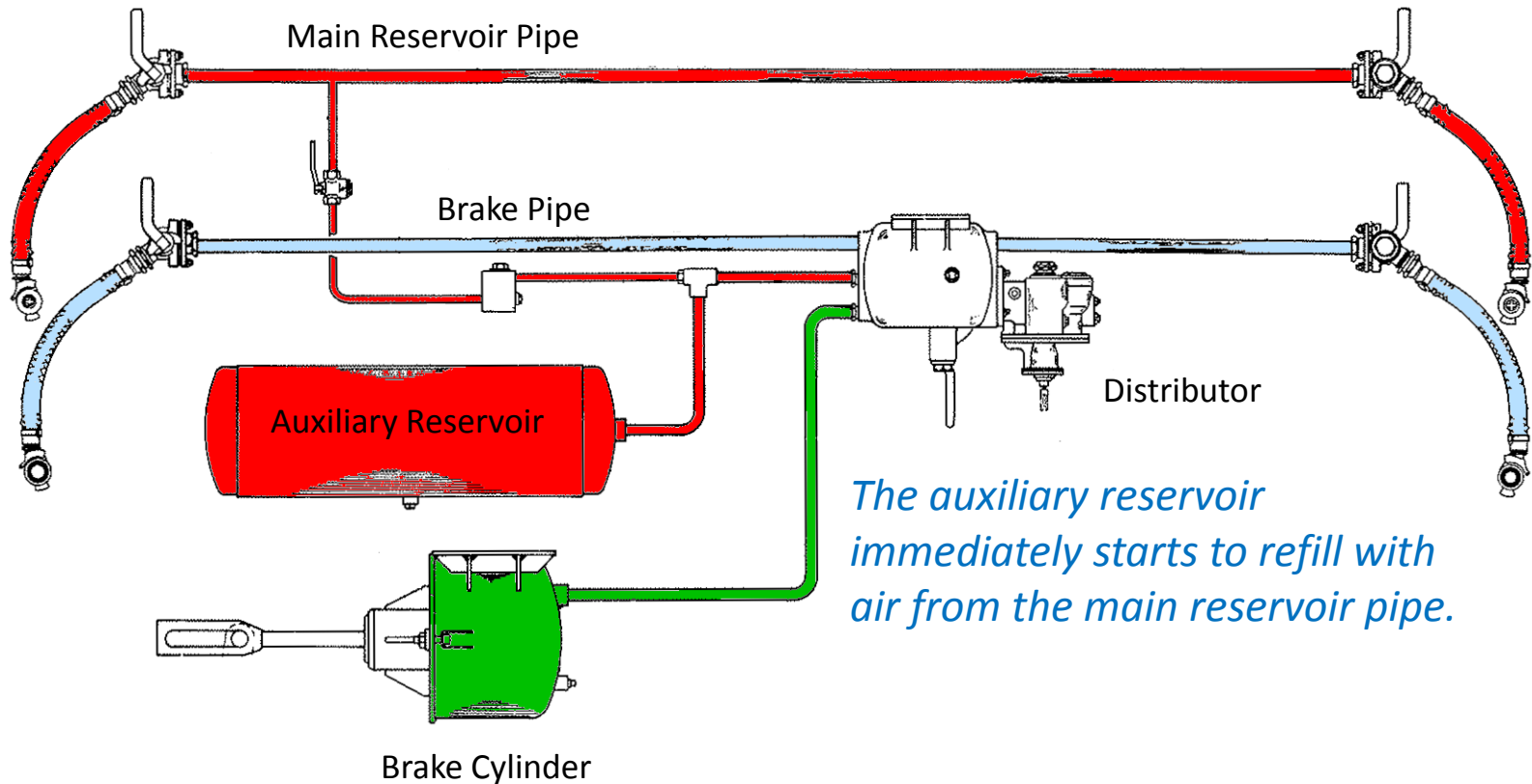
When the system is charged with air, both the brake pipe and main reservoir pipe are charged with air.



The auxiliary reservoir can charge from either the brake pipe (via the distributor) or the main reservoir pipe (via a non-return valve).

Twin pipe system

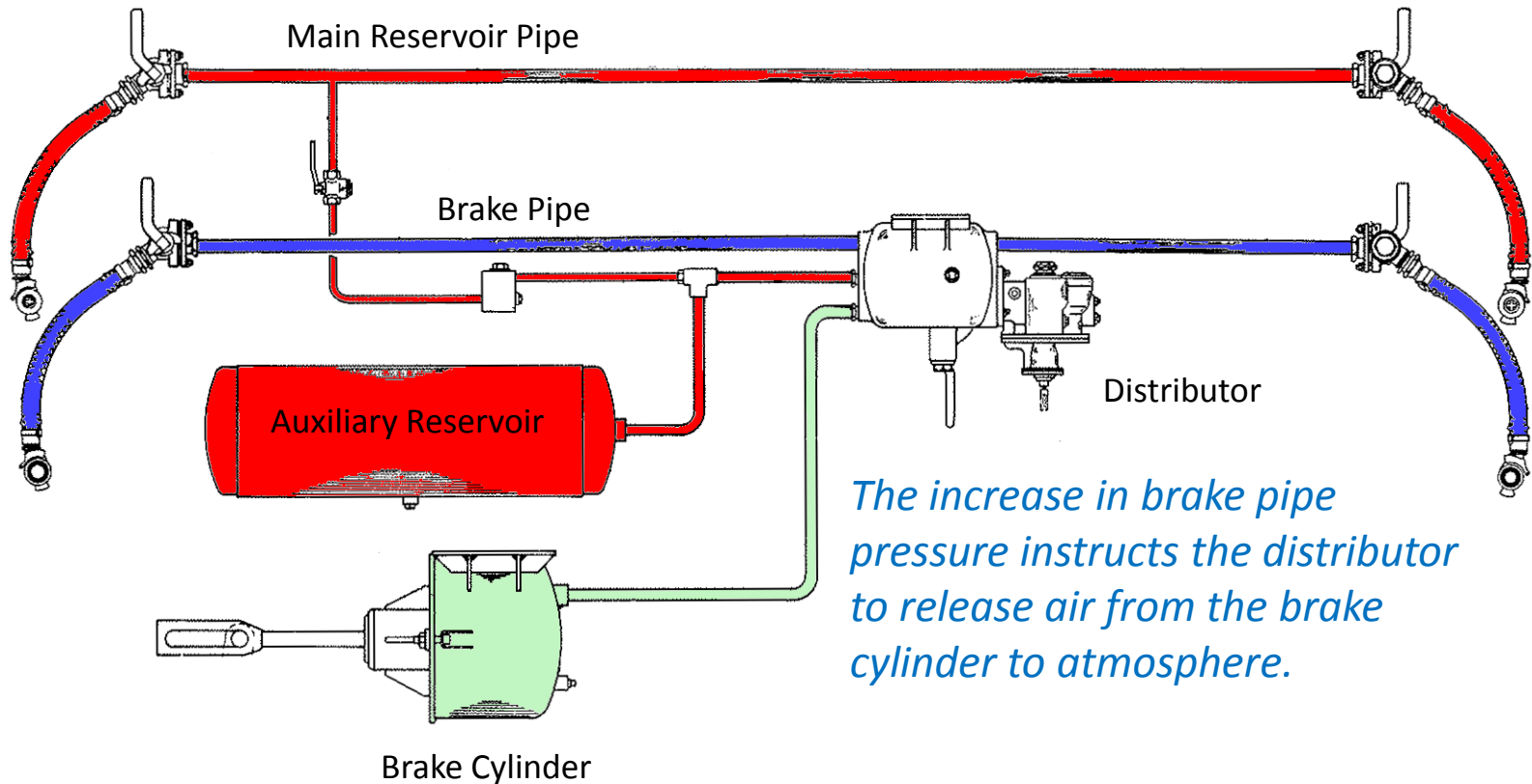
When a brake application is made by reducing the brake pipe pressure, air from the auxiliary reservoir is admitted to the brake cylinder.



The auxiliary reservoir immediately starts to refill with air from the main reservoir pipe.

Twin pipe system

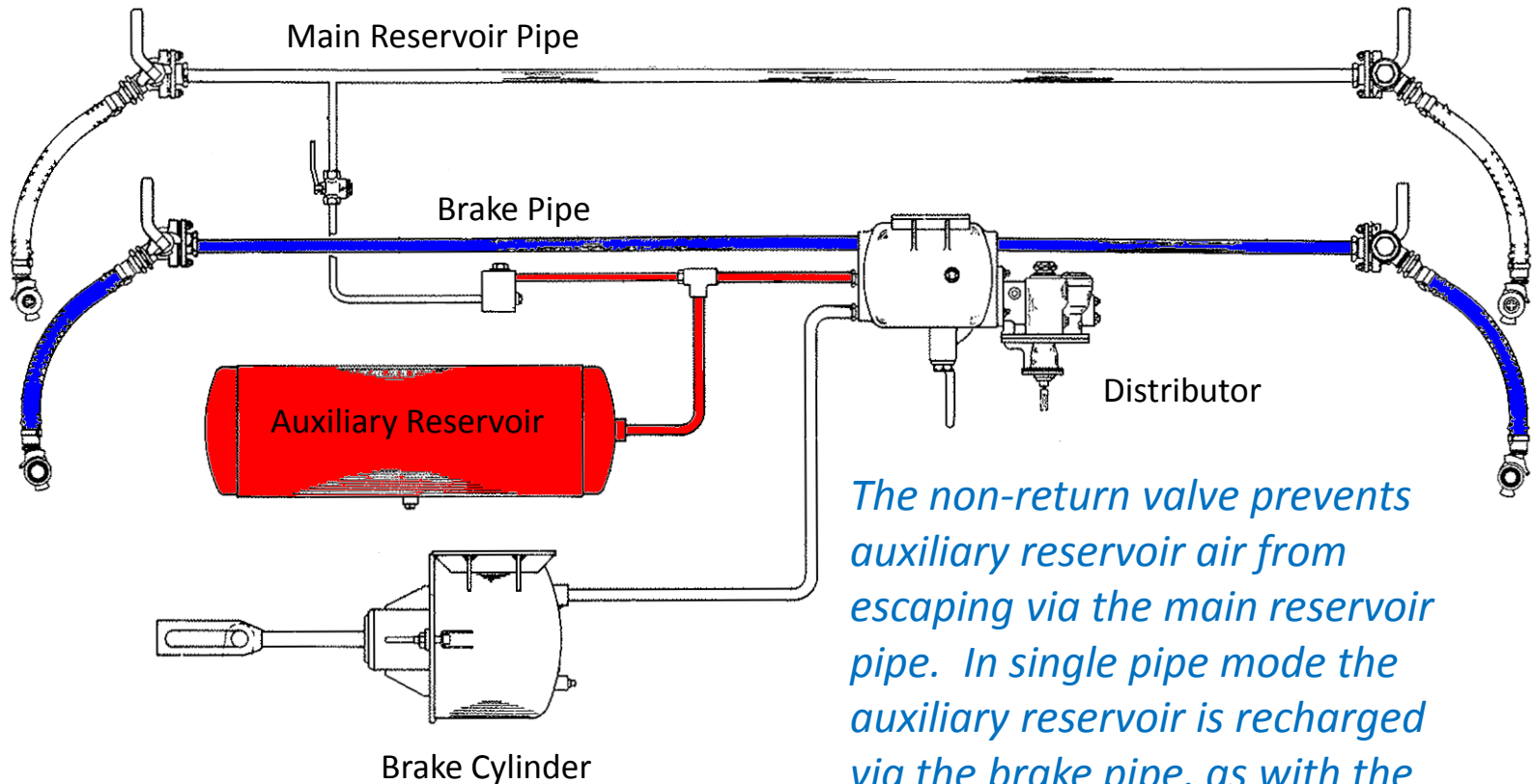
When the brake is released, the auxiliary reservoirs are already full of air. Therefore, only the volume of air in the brake pipe needs to be refilled.



The increase in brake pipe pressure instructs the distributor to release air from the brake cylinder to atmosphere.

Twin pipe system

The twin pipe system can be operated without the main air reservoir pipe being connected, as shown below.



The non-return valve prevents auxiliary reservoir air from escaping via the main reservoir pipe. In single pipe mode the auxiliary reservoir is recharged via the brake pipe, as with the single pipe system.

Twin pipe system

There is an important point to be made about the use of, or isolation of, the main reservoir pipe.

Traditionally when working in twin pipe mode, the auxiliary reservoir will charge to around 100 psi because its supply is the main air reservoir and not the brake pipe. This makes the brake application quicker as the higher pressure flows faster through the distributor. Therefore, with this system the main reservoir pipe must either be connected on the whole train or none of the train.

The latest interoperability standards now require pressure reducing valves to ensure that the brake application speed is the same for vehicles on single or twin pipe systems.

Twin pipe system

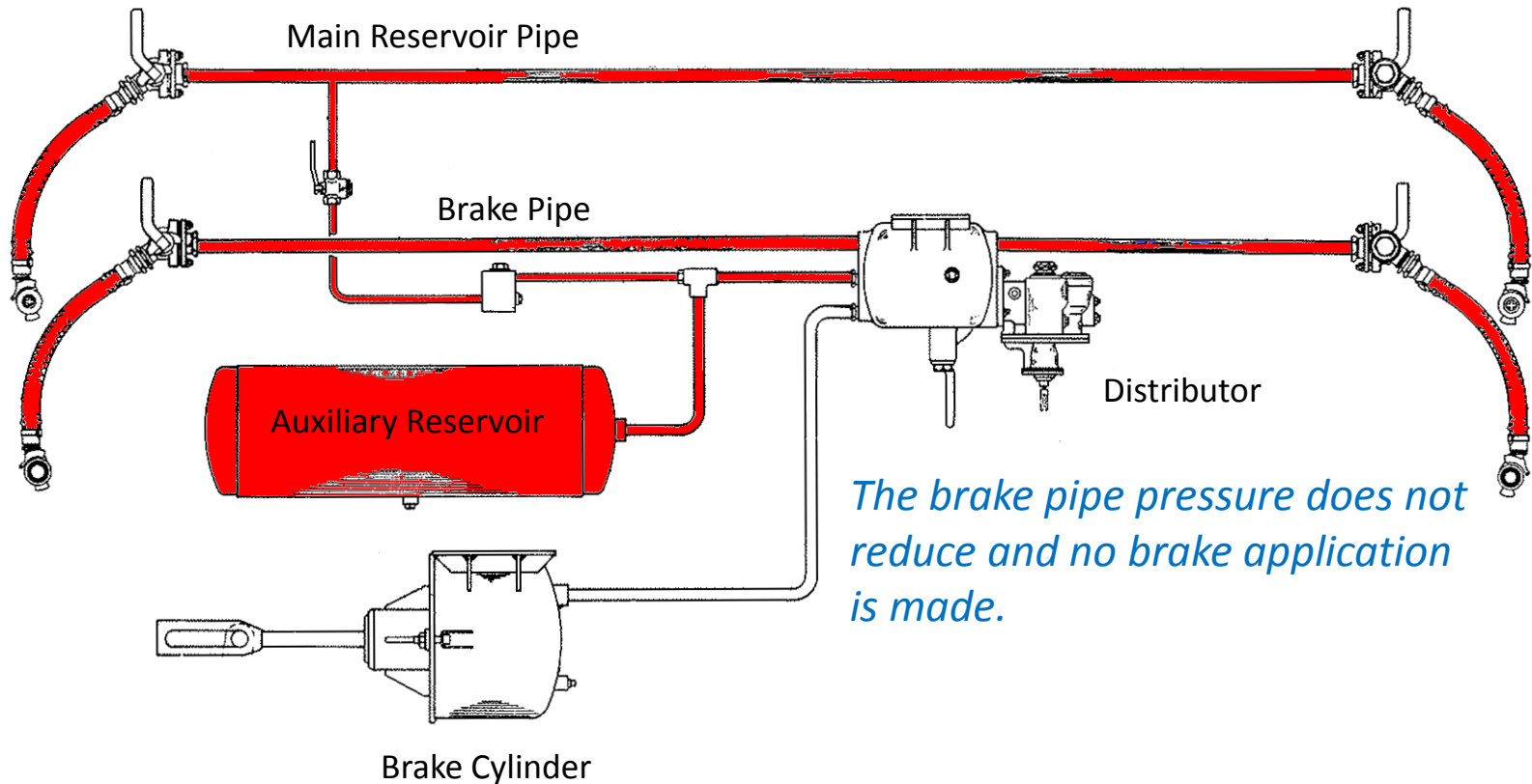
It may appear that the twin pipe system is the ultimate in pneumatic braking for railway vehicles?

Not quite so, because twin pipe working brings a new hazard which is known as a cross feed.

Now that there is a main reservoir pipe always charged with high pressure air even during braking, a single valve failure in just one distributor of the train can permit air to flow from the main reservoir pipe into the brake pipe. This supply of air (the cross feed) will fight the driver's attempted reduction in brake pipe pressure.

Twin pipe system

Dangerous situation: a failure of the distributor permits main reservoir pipe air pressure to cross feed into the brake pipe.



Twin pipe system

Designers try to ensure that the supply of air from the locomotive's main air reservoir is not sufficient to beat the rate at which the driver's control valve can empty air from the brake pipe. To do this, chokes are sometimes fitted between the main air reservoir and the main air reservoir pipe.

The end hose couplings of the main air reservoir pipe have integral check valves. These ensure that air cannot flow from a main reservoir pipe into the brake pipe in the event of the pipes being incorrectly connected together. This prevents a cross feed. Only when two main reservoir hose couplings are placed together are the integral check valves forced open.

Irish Rail use an alternative and arguably more fail safe solution. The main reservoir pipe hose couplings are deliberately a different size so that they won't connect to the brake pipe hose coupling.

Alternatives

Vale of Rheidol Railway

Kirklees Light Railway

Alternatives

The traditional railway air brake systems described previously are generally quite expensive to install. They contain many refinements that enable them to be used on high speed passenger trains (up to 125mph) and long freight trains (up to 2000 tonnes in the UK).

On heritage railways operating at 25mph, such an advanced system is not necessary. A number of independent railways have developed their own air brake systems that make use of commercially available (i.e. non specialist) air valves and fittings.

A couple of examples are illustrated in this section.

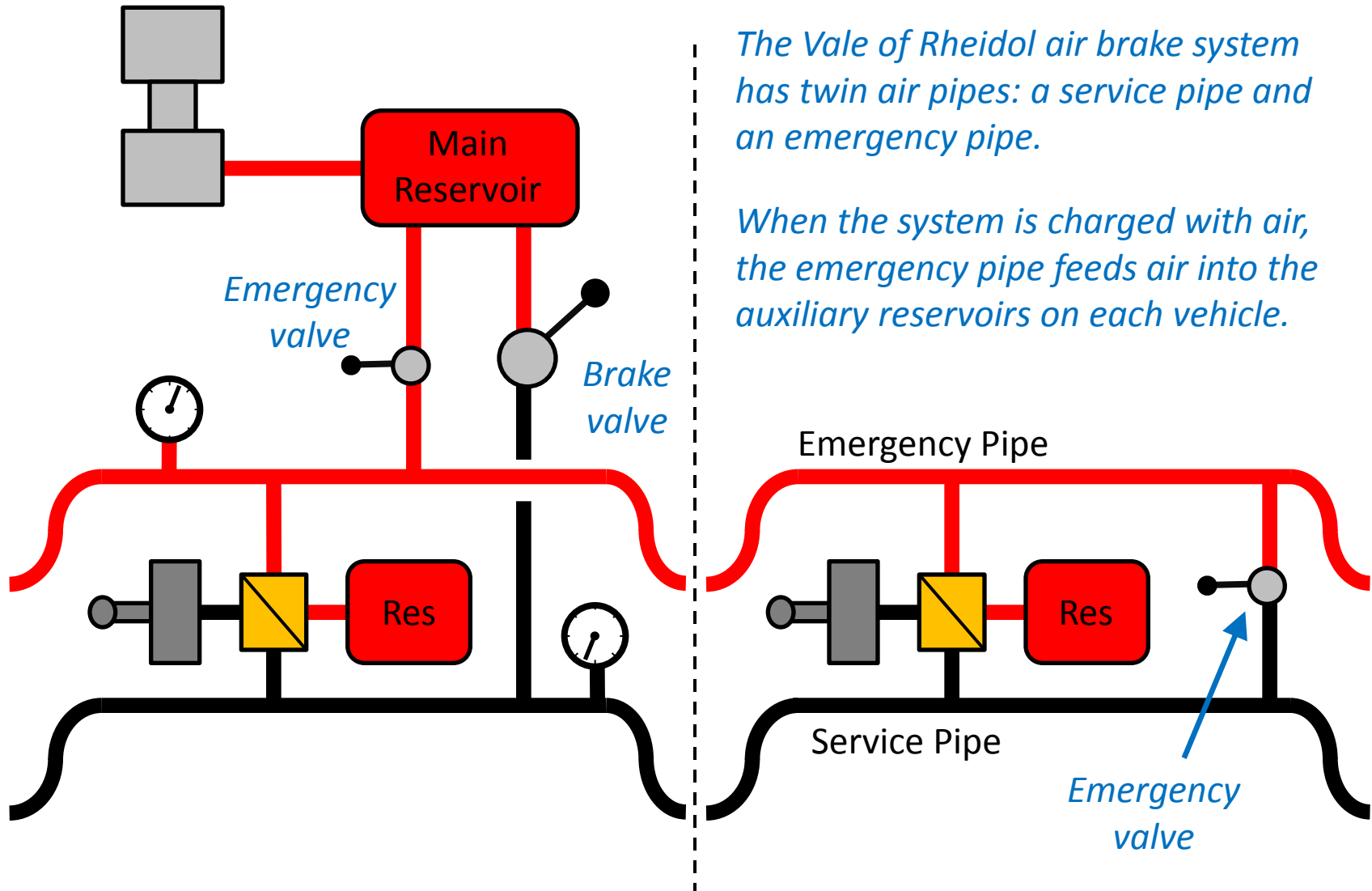
Alternatives



Example 1

*The Vale of Rheidol
Railway*

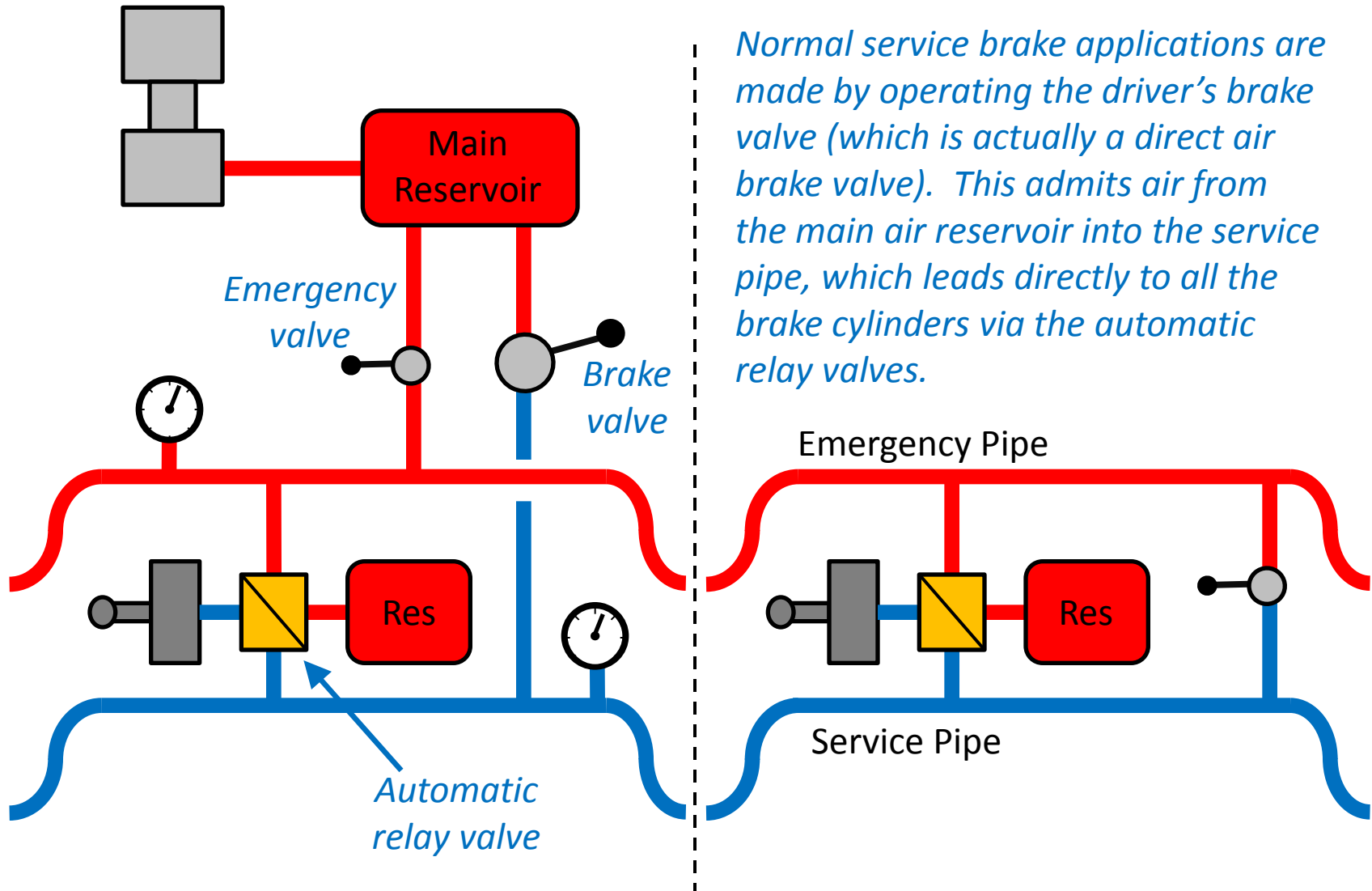
Alternatives



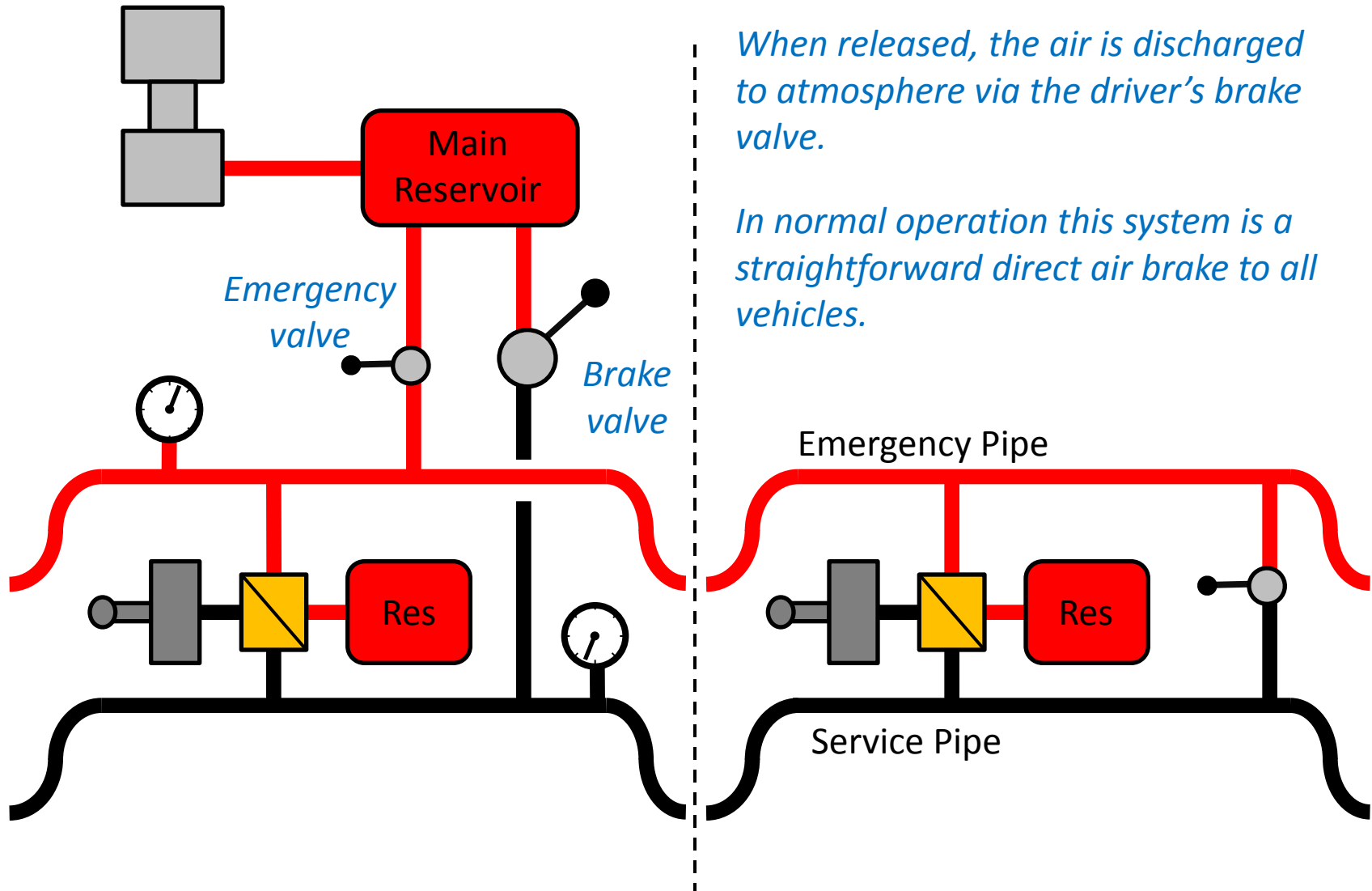
The Vale of Rheidol air brake system has twin air pipes: a service pipe and an emergency pipe.

When the system is charged with air, the emergency pipe feeds air into the auxiliary reservoirs on each vehicle.

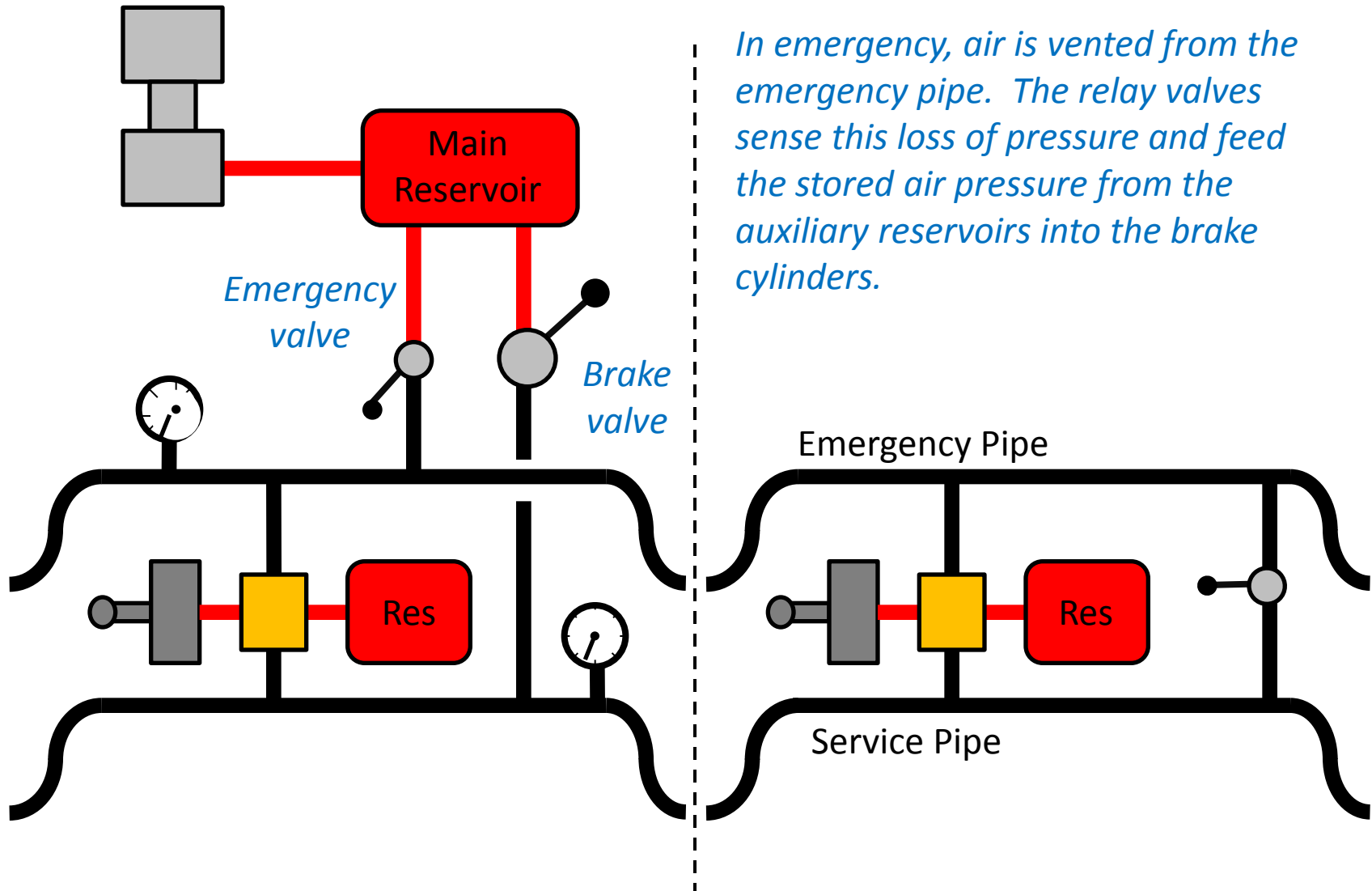
Alternatives



Alternatives



Alternatives



Alternatives

The air brake system used on the Vale of Rheidol Railway has the same problem as the vacuum brake system of the Ffestiniog and Welsh Highland Railways. Air pressure in the service pipe enters the brake cylinders at the front of the train before those at the rear, potentially causing the couplings to jolt if the brake application is severe.

However, for the speed of operation on the Vale of Rheidol this simplified air brake system has proved to be acceptable, and has permitted the use of commercially available air fittings and valves. This provides a considerable cost saving over the equivalent specialist railway brake equipment.

Question: *What is the fundamental difference between the Vale of Rheidol's air brake system and the conventional railway twin pipe system?*

Alternatives

Answer:

On the Vale of Rheidol both air pipes must be connected. One for the service brake and one for the emergency brake. Without the second pipe there can be no brake continuity.

The conventional railway twin pipe system can be operated without the second pipe (the main reservoir pipe). It is the brake pipe that provides the brake continuity as well as the service brake.

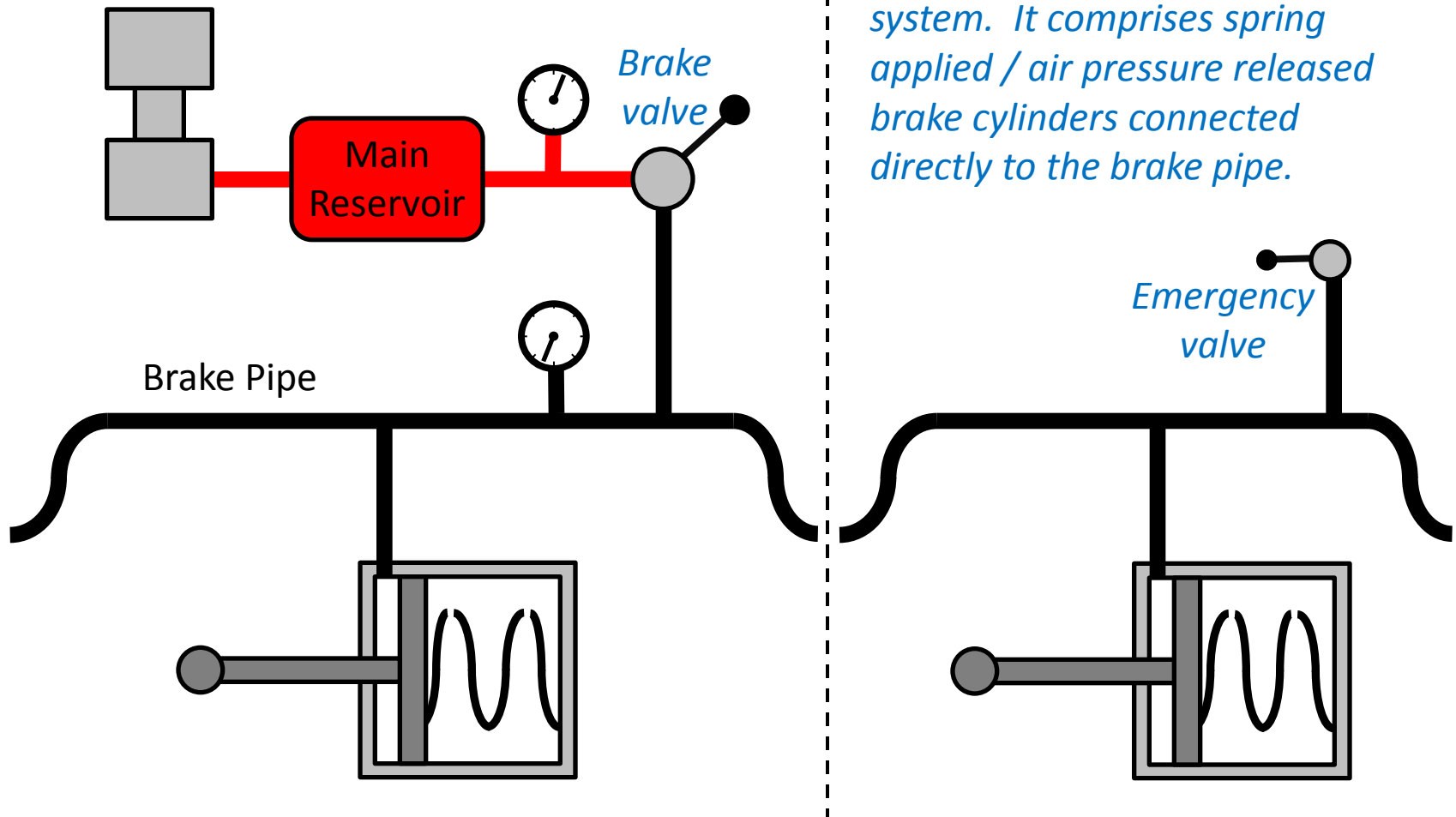
Alternatives



Example 2

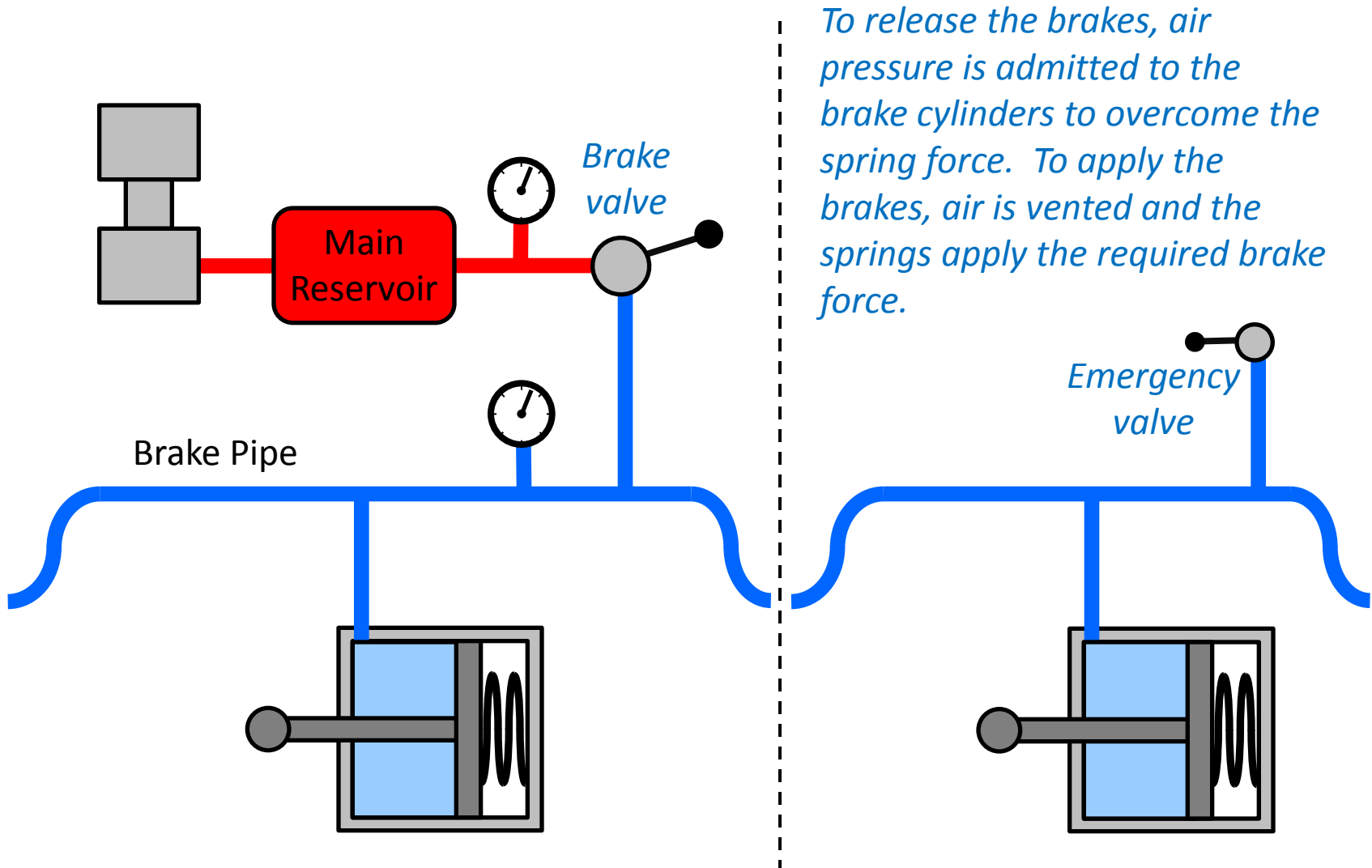
*The Kirklees Light
Railway*

Alternatives



This is possibly the most simple type of railway air brake system. It comprises spring applied / air pressure released brake cylinders connected directly to the brake pipe.

Alternatives



Alternatives

Spring applied / air pressure released brakes are popular on miniature railways and are inherently fail safe. The springs mitigate the need for stored air pressure and therefore double up as parking brakes. No separate handbrake is required.

However the system is relatively basic. It can be difficult to obtain the same spring force on different vehicles. For example, the springs give less force as they extend, so a vehicle with worn brake blocks (i.e. greater slack in the system) will be subjected to less brake force.

Air versus vacuum

Summary

Air versus vacuum

The following slide lists the general advantages and disadvantages of air and vacuum brakes.

It is a useful summary of the main points. However, as the previous sections of these notes has demonstrated, there are actual numerous different types of air brake system. Each of these different types has relative advantages and disadvantages.

Air versus Vacuum

Air brakes

- High pressure
 - Energy efficient
- Fast propagation of brake
 - Greater control
- Air pump
 - Many moving parts
 - Requires more attention
- End cocks
 - Can cause hazards
- Technically superior

Vacuum brakes

- Low pressure
 - Susceptible to leaks
- Slow propagation of brake
 - Requires driver anticipation
- Ejector
 - No moving parts
 - High reliability
- No isolating cocks
 - inherently fail safe
- Ideal for heritage lines

EP brakes

Overview

Air versus vacuum

As a conclusion to these notes, the principle of the modern electro-pneumatic brake is described.

This will illustrate the state of art in terms of passenger train braking, and will provide the reader with an appreciation of the historic nature of the vacuum brake system.

The vacuum brake technology used by the Ffestiniog and Welsh Highland Railways is dated to the 1930's. It is perfectly acceptable for use today, but compared to the state of the art braking systems requires more driver skill to obtain optimum performance.

EP brakes



*Power / brake
controller*

Brake gauge

*This is the cab of a
Turbostar diesel multiple
unit, also known as a
Class 170.*

*There is a combined
power / brake controller.*

*There is only one brake
gauge, indicating main
reservoir pressure and
brake cylinder pressure.*

EP brakes

The power / brake controller is an electrical device. Both the power and braking of the train are controlled electrically.

Instead of a pneumatic brake pipe there are control wires.

There is a main reservoir pipe to charge the auxiliary reservoirs.

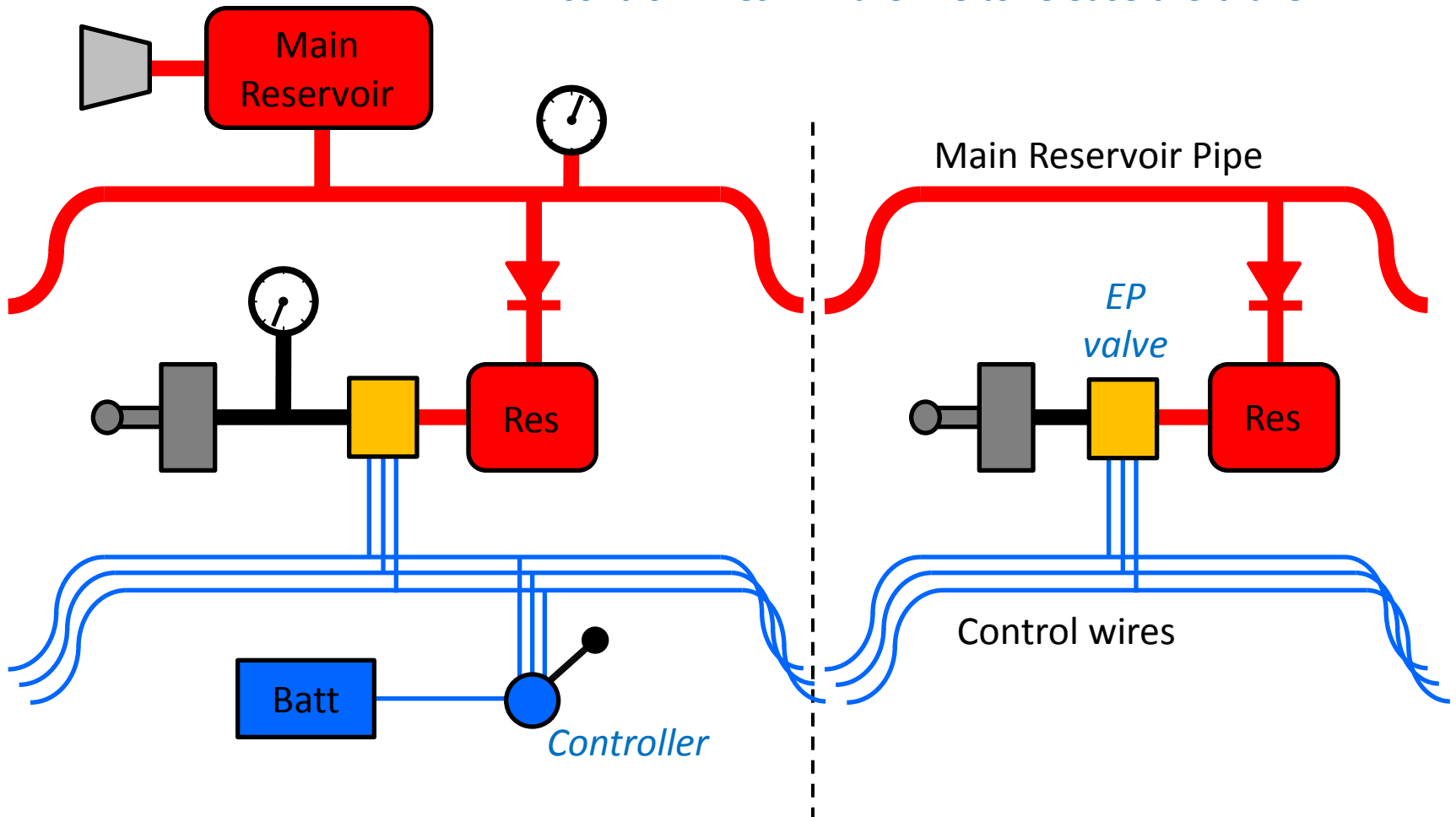
The braking is controlled in fixed steps. Step 1 for the initial light brake application. Step 2 to incrementally increase the brake force. And so on.

The next few slides illustrate the release, service brake and emergency brake.

EP brakes

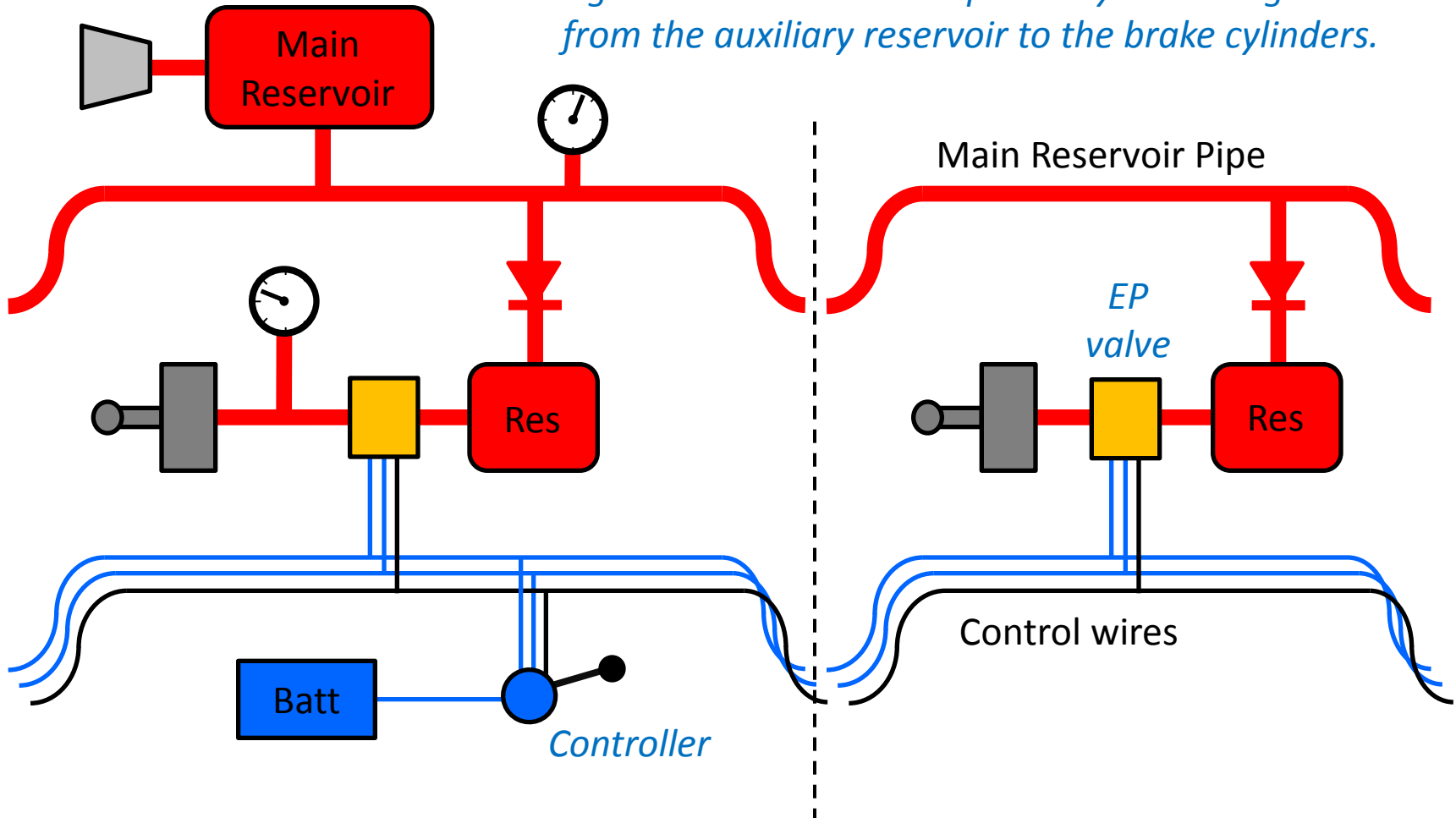
Brake release

The controller sends electrical signals along the control wires. All are live to release the brake.



EP brakes

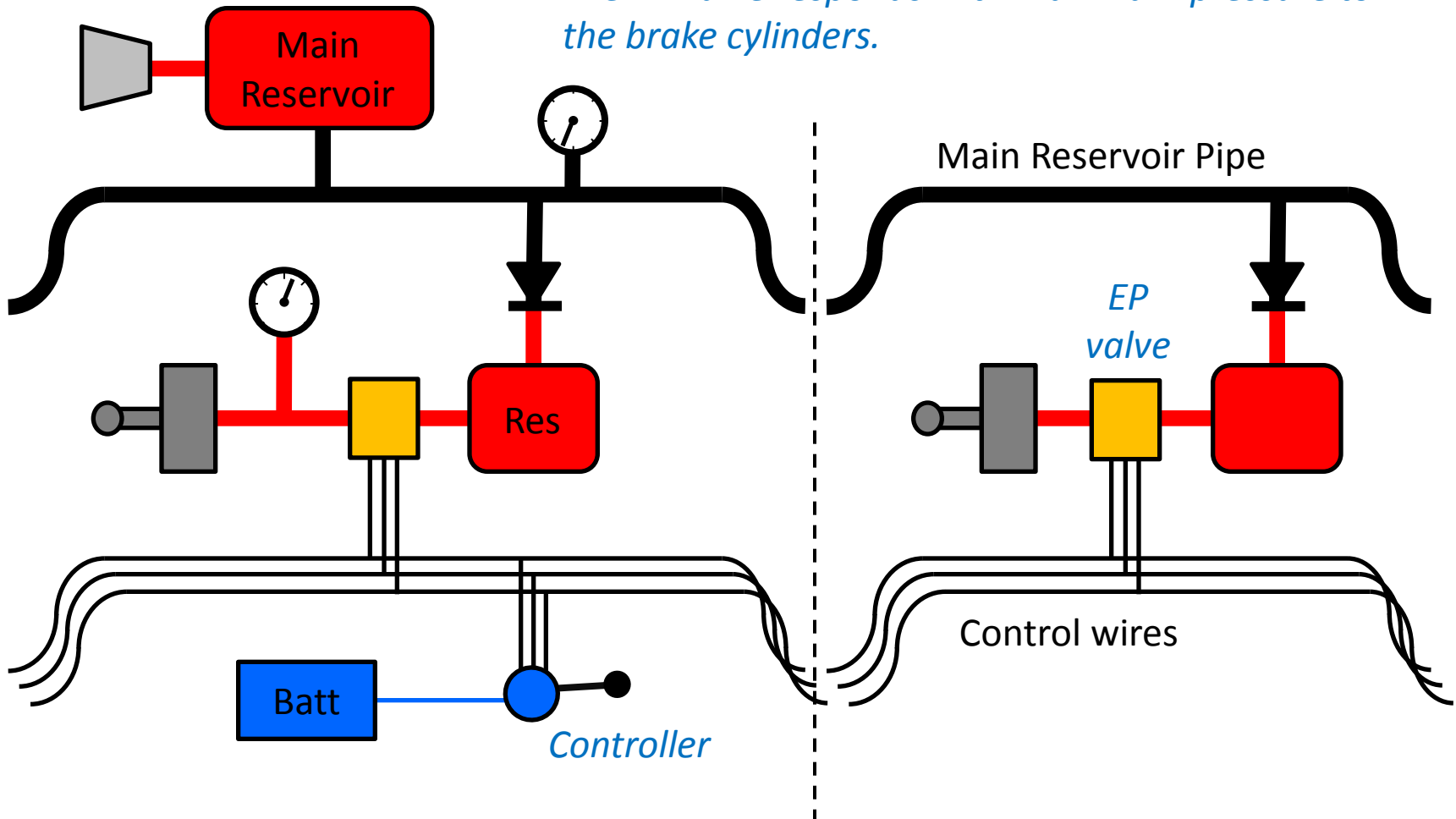
Service brake



EP brakes

Emergency brake

*All of the electrical signals are lost / turned off.
The EP valve responds with maximum pressure to
the brake cylinders.*



EP brakes

The advantage of the EP brake system is that electrical signals travel much faster than compressed air. Therefore, on making a brake application, all the train brakes will apply instantaneously. This is true whether there are just 2 cars or 12 cars in the train.

Exclusions

Summary

Air versus vacuum

Hopefully the above has been a useful insight into train brake systems, their component parts and operation.

After so many slides it may be tempting to consider the above as comprehensive, but there is much more to the subject of train brakes.

The final slide lists some of the topics that have not been covered in these notes.

Exclusions

- Modern brake equipment
 - Empty load braking / Load proportional braking
 - Hydraulic / pneumatic parking brakes
 - Goods / passenger changeover
 - Timings (application / release / charging)
- EP brake methods
 - Hardwiring / Multiplexing
 - Wheel slip protection
- Brake rigging
 - Clasp brakes / pusher brakes / disc brakes
 - Slack adjusters