Train Brakes

These are the notes of a presentation made by Dominic Wells specially for the locomotive crews of the Ffestiniog and Welsh Highland Railways in 2011.

For best viewing, set the size to show one whole page only, and use the "Page Down" button to move through the slides.

If in doubt about any of the information contained within this presentation, please contact the author via Boston Lodge Works.

Contents

Brief history

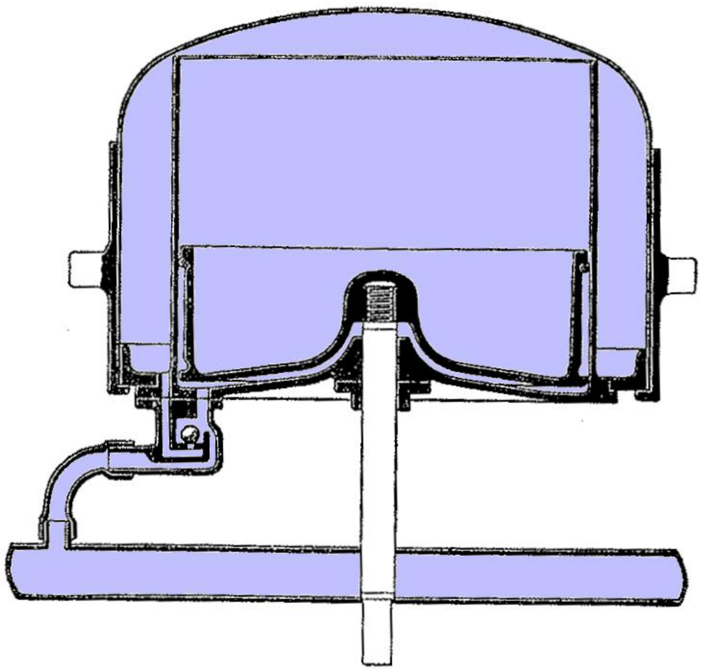
- 1829 – Rocket had no brake
  - first railway fatality
  - handbrakes introduced
- 1869 – Westinghouse straight air brake
- 1889 – Armagh disaster
  - Continuous braking compulsory for passenger trains
  - Automatic air brake & Automatic vacuum brake
- 1956 – Introduction of distributor valve
- 1970s – Proliferation of electro-pneumatic brakes

Vacuum brakes

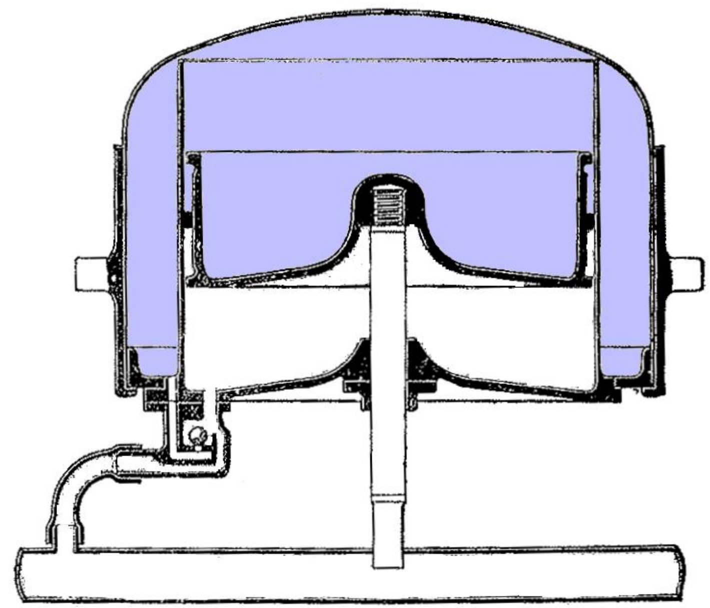
Introduction and principles

Vacuum brakes

Here are the familiar diagrams of the vacuum brake. The purple areas represent a vacuum.



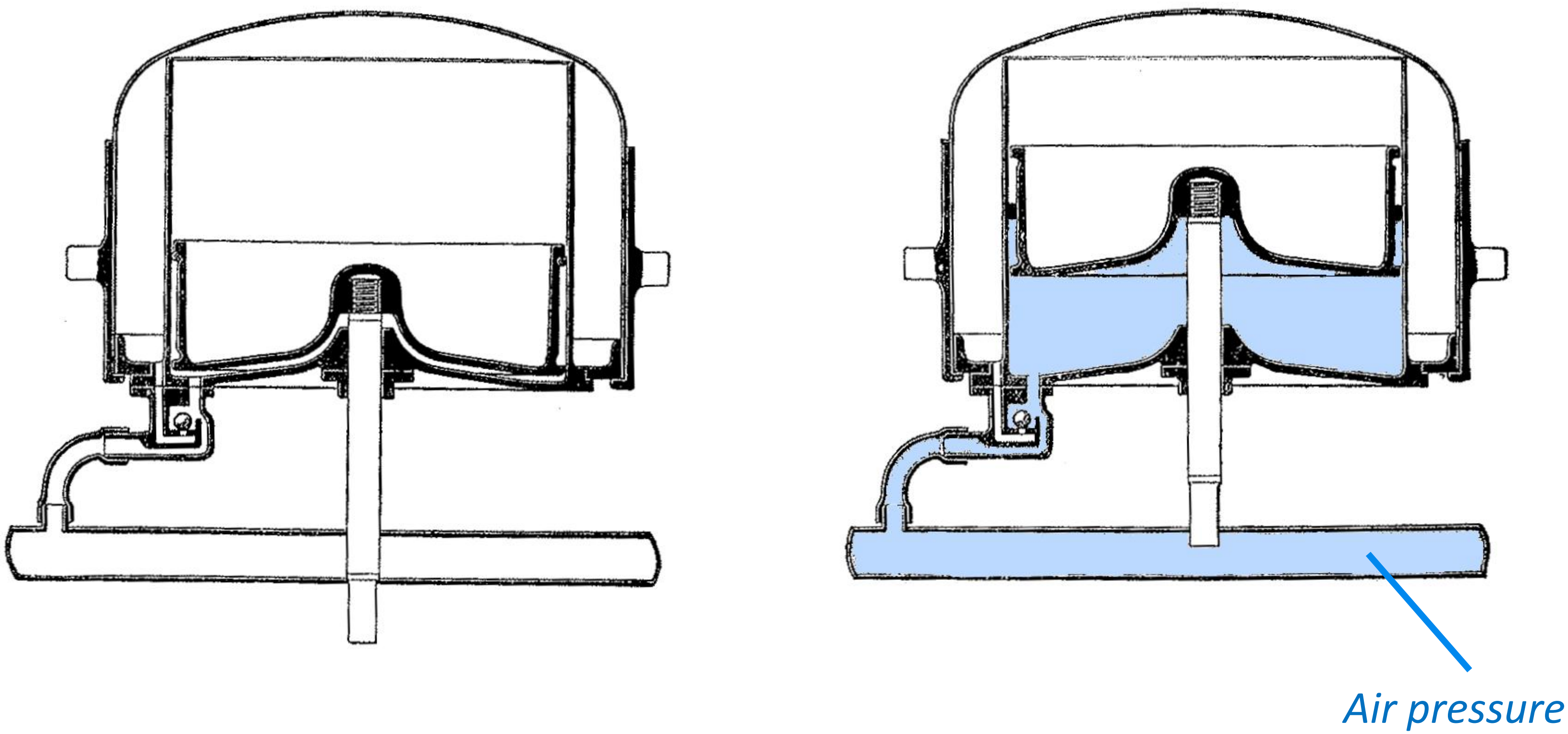
Brake released – piston falls under its own weight and moves the brake blocks away from the wheels.



Brake applied – piston forced upwards when vacuum is destroyed in brake pipe. Brake blocks pulled onto the wheels.

Vacuum brakes

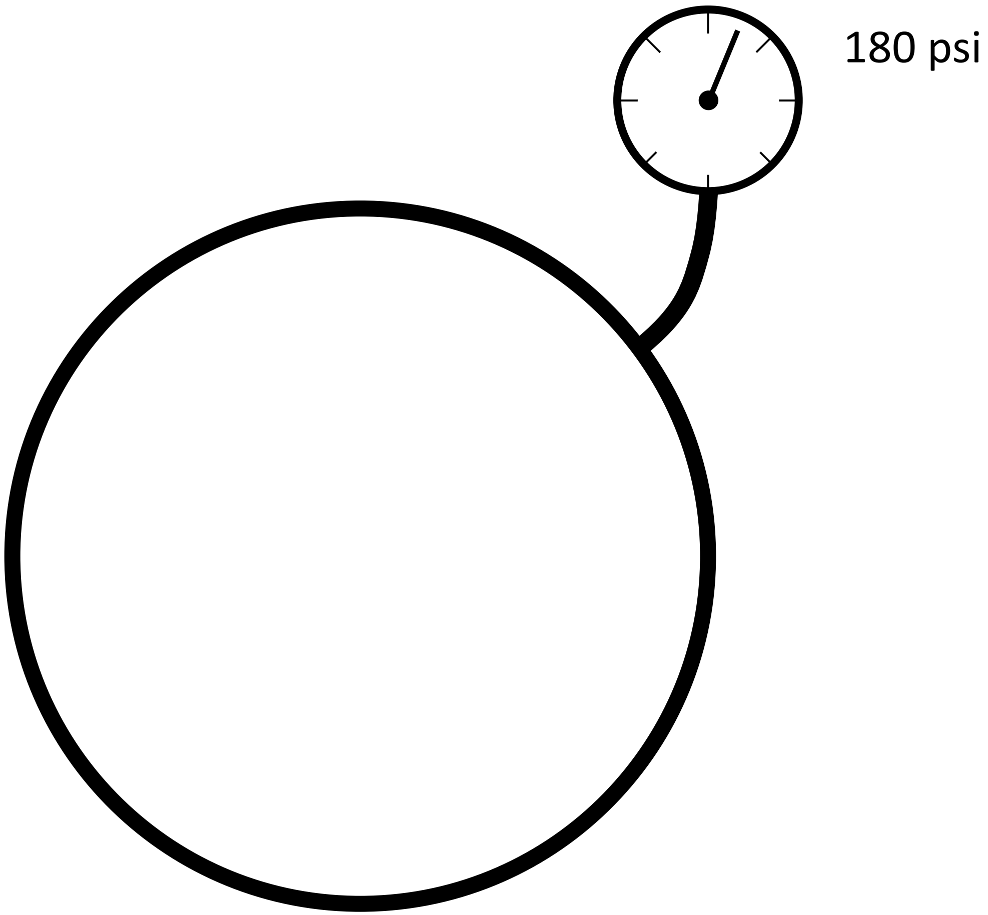
Or consider it another way. A "vacuum" is effectively nothing. Therefore, the vacuum brake system is actually a direct air brake using air at atmospheric pressure.



This will be explained further...

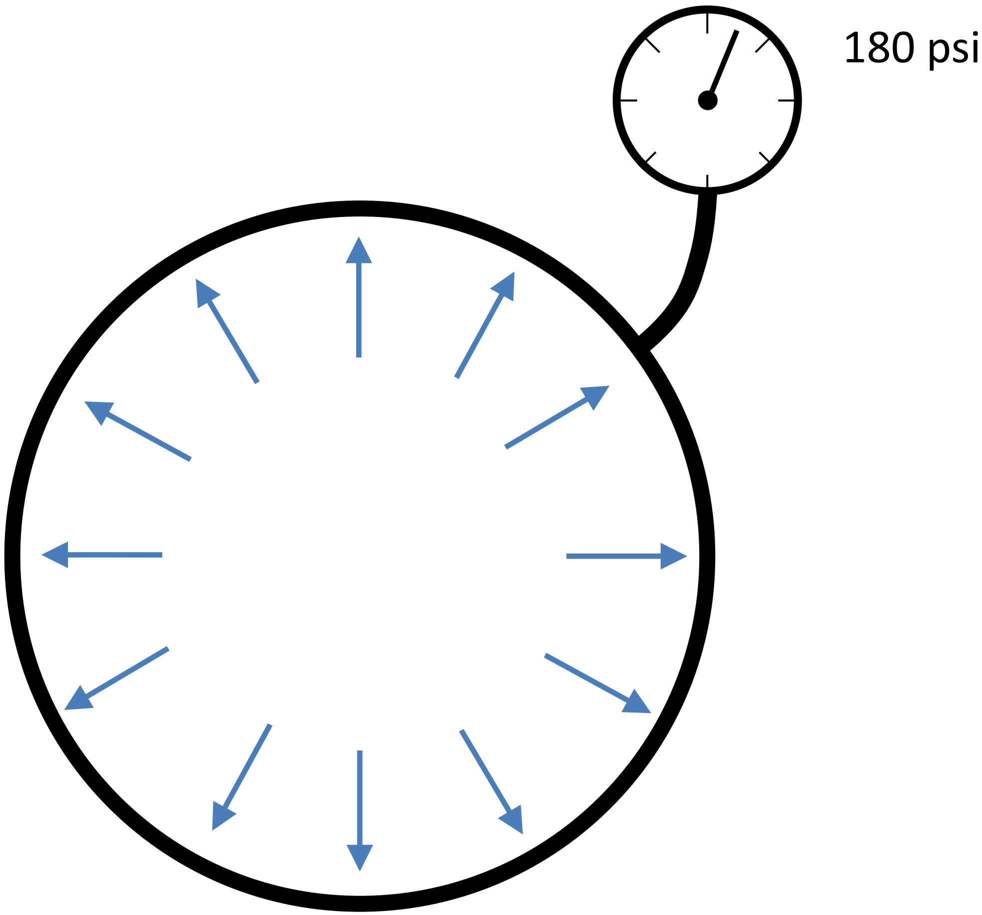
Vacuum brakes

Consider a boiler and its pressure gauge.



Vacuum brakes

The boiler is pressurised and the boiler pressure gauge reads 180 psi.



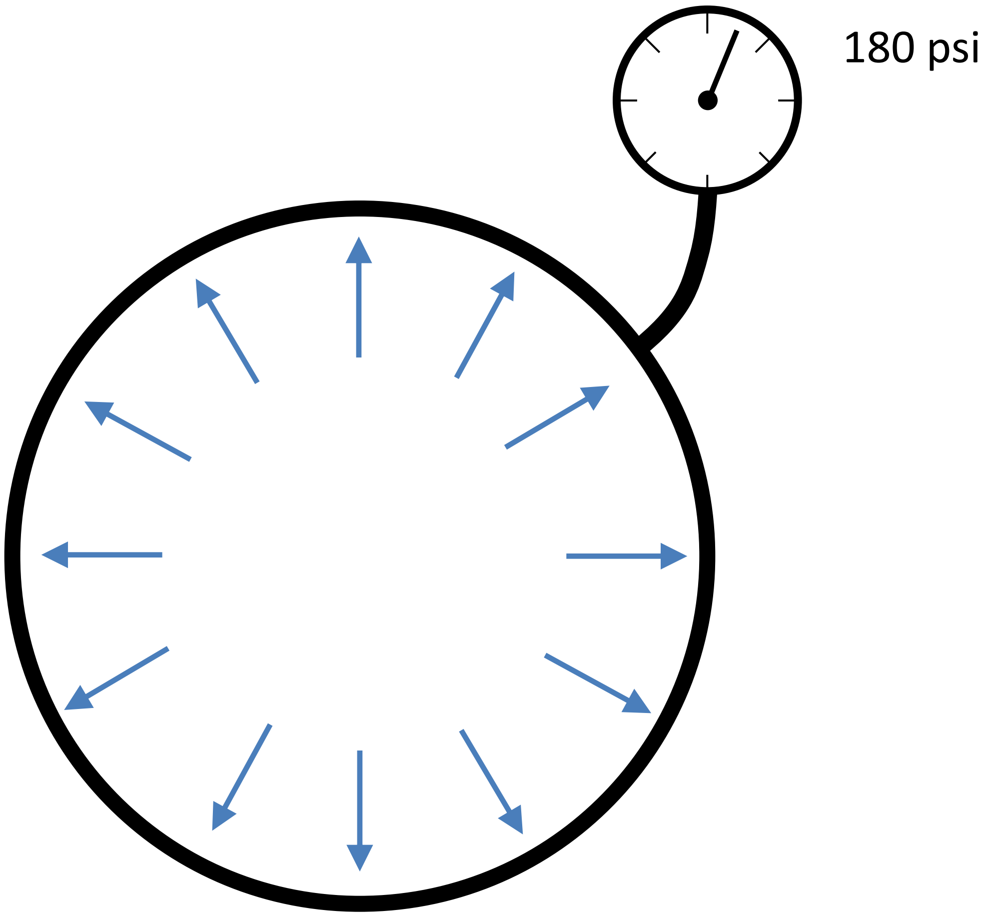
Vacuum brakes

<u>Question:</u> what is the actual pressure inside the boiler, is it...

a) Under 170 psi ?

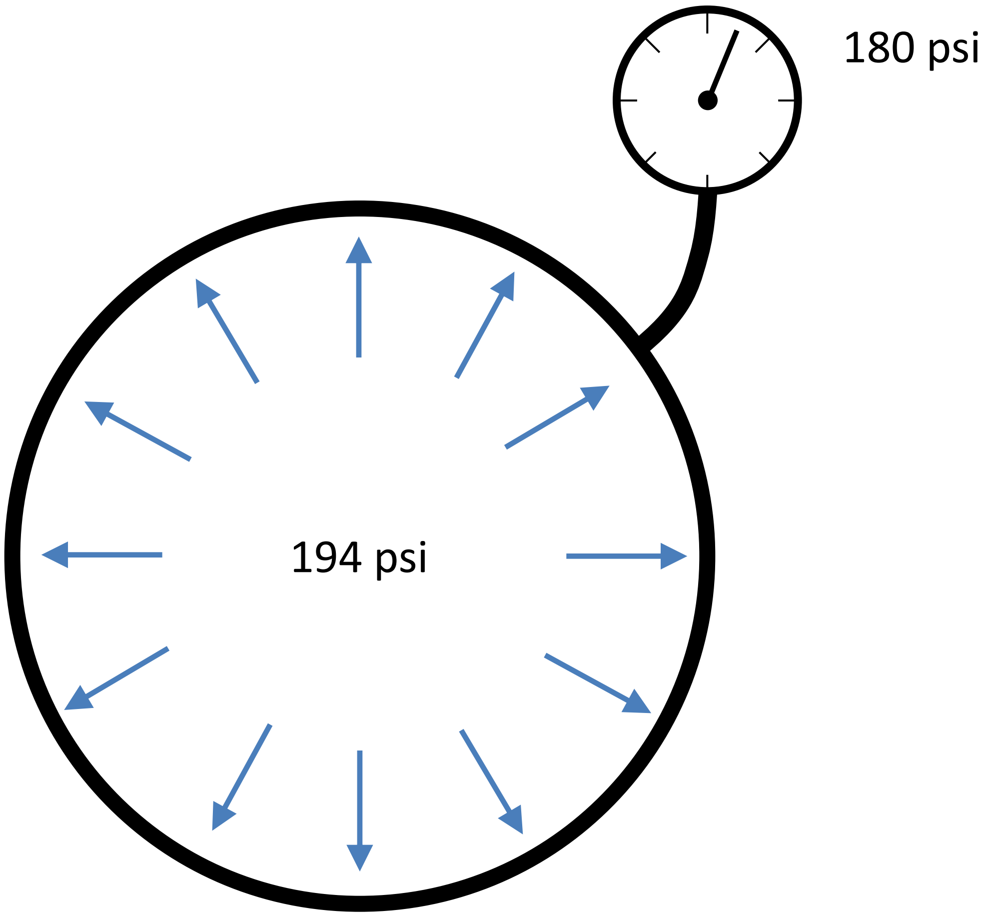
b) 175 – 185 psi ?

c) Over 190 psi ?



Vacuum brakes

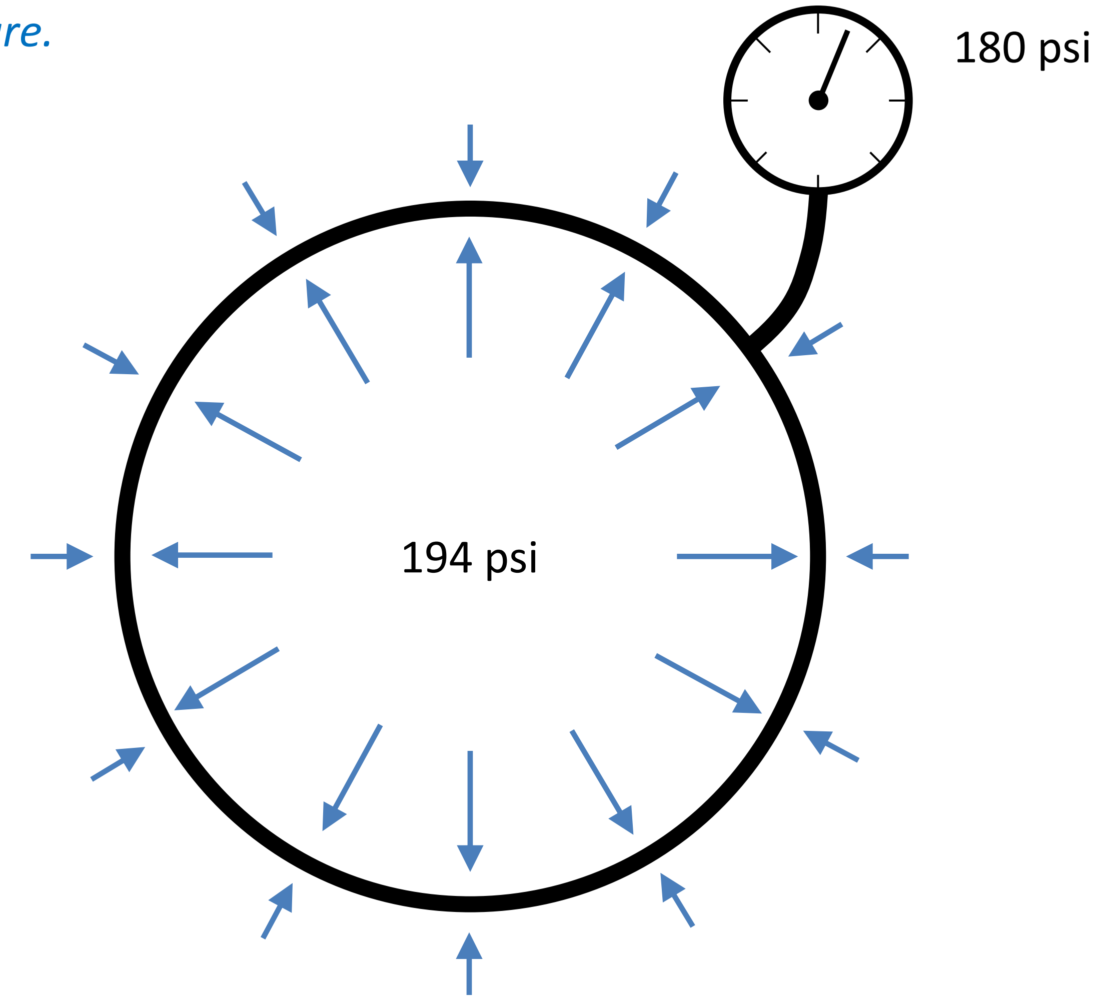
The answer is c). The pressure inside the boiler is actually 194 psi.



But why? ......

Vacuum brakes

The outside of the boiler is being crushed by atmospheric pressure.

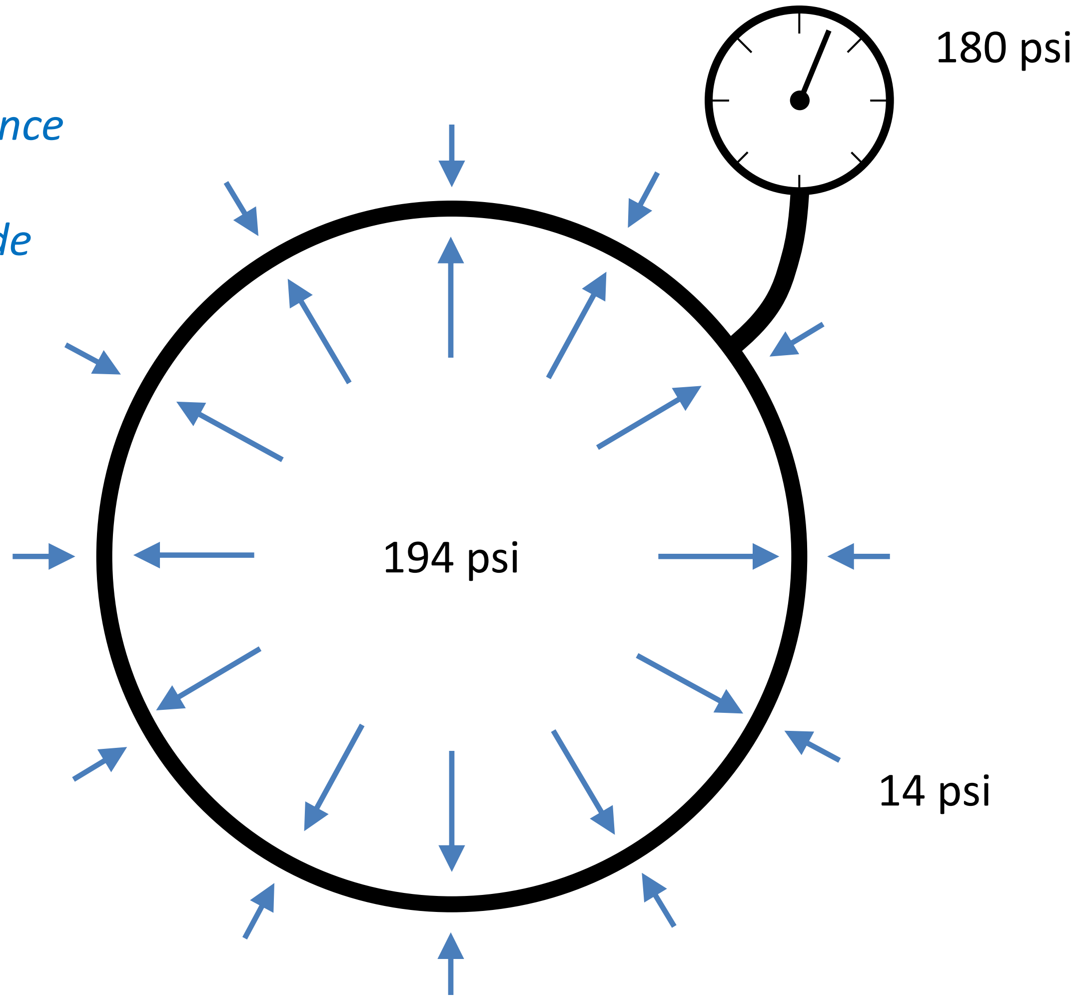


Vacuum brakes

An atmospheric pressure of 14 psi is crushing the outside of the boiler.

180 psi is the difference in pressure between the outside and inside of the boiler.

There was already 14 psi inside the boiler before it was pressurised (when the gauge read zero).



Vacuum brakes

Some useful notes:

180 psi is known as the gauge pressure, and in representing the pressure difference it correctly indicates the resultant pressure acting to try and burst the boiler.

194 psi is known as the absolute pressure.

Atmospheric pressure is typically 14.5 psi at sea level. For these notes it is taken as the round figure of 14 psi.

Let us now examine how this relates to vacuum brakes. There is a complication. Vacuum is not measured in psi. Vacuum is measured in inches...

Vacuum brakes

A complete vacuum is when the air pressure is zero.

	Pressure
Atmosphere	14 psi
Complete vacuum	0 psi

Vacuum brakes

A complete vacuum is measured as 30 inches...

	Pressure	Vacuum
Atmosphere	14 psi	0 in
Complete vacuum	0 psi	30 in

Note that vacuum is not negative pressure. The measurement of vacuum represents the reduction of air pressure.

Vacuum brakes

Locomotive ejectors do not achieve a complete vacuum. Those of the Ffestiniog Railway generate 21 inches of vacuum.

	Pressure	Vacuum
Atmosphere	14 psi	0 in
Complete vacuum	0 psi	30 in
Brake vacuum	*?*	21 in

<u>Question:</u> what is the air pressure at 21 inches of vacuum?

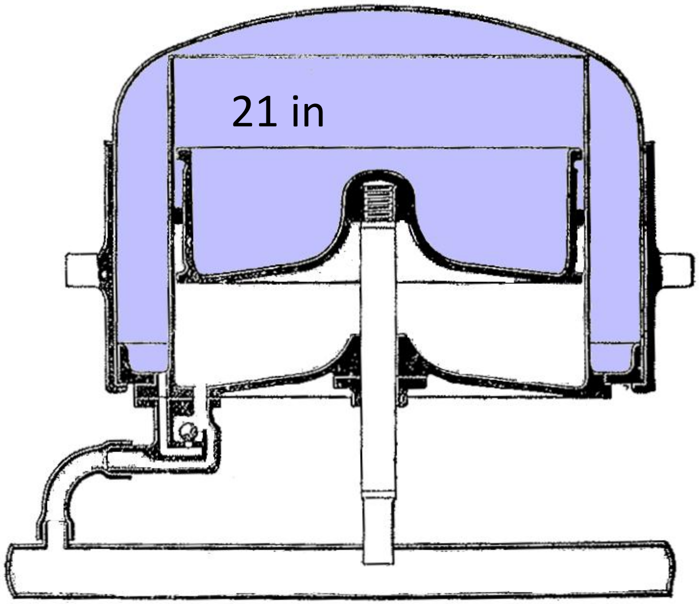
Vacuum brakes

Answer...

	Pressure	Vacuum
Atmosphere	14 psi	0 in
Complete vacuum	0 psi	30 in
Brake vacuum	4 psi	21 in

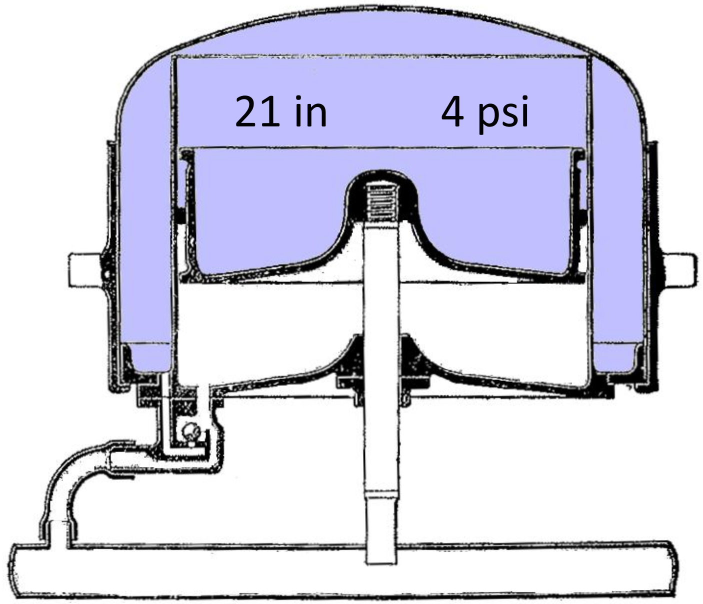
Vacuum brakes

This is the vacuum brake cylinder shown with 21 inches of vacuum above the piston.



Vacuum brakes

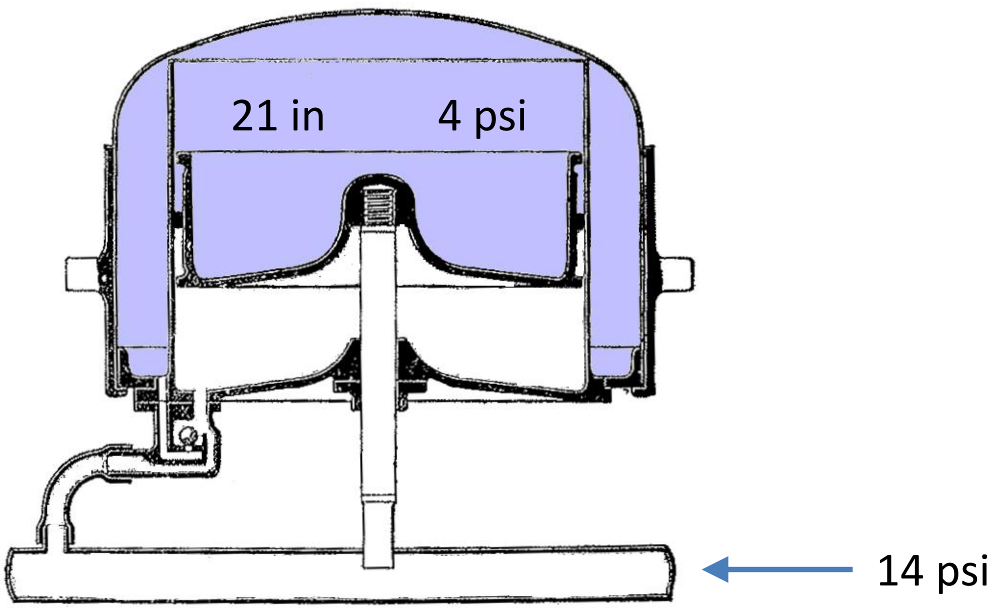
As shown previously, 21 inches of vacuum is actually 4 psi of air pressure.



Vacuum brakes

If train pipe vacuum is completely destroyed, atmospheric air at 14 psi is allowed into the brake pipe. This creates a pressure difference above and below the piston of 10 psi.

This 10 psi pressure difference, acting over the area of the piston provides the maximum brake force.

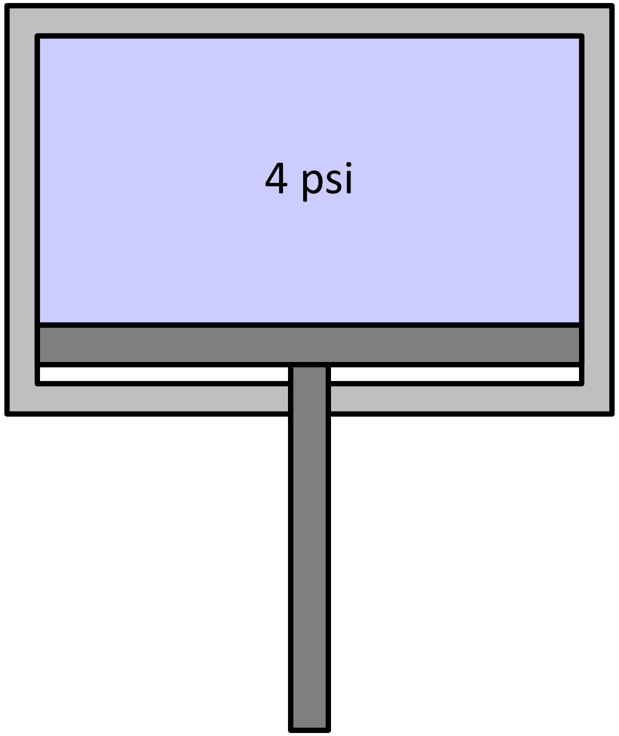


For reference, the pressure difference in air brake cylinders is around 50 psi. Therefore, the air brake system can use smaller cylinders to achieve the same brake force.

Vacuum brakes

Now we will look at an important operational aspect of the vacuum brake cylinder.

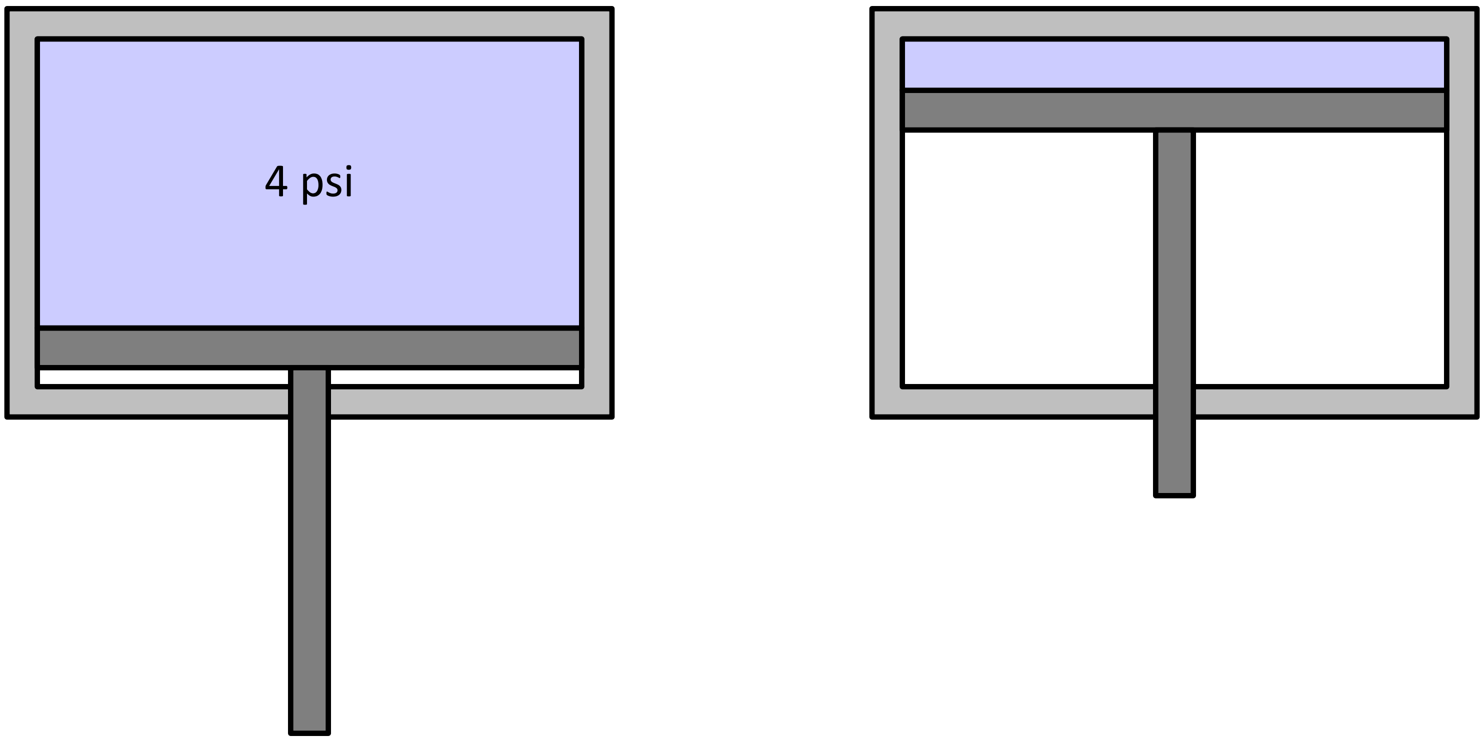
The diagram below represents a vacuum brake cylinder when the brake is released.



Vacuum brakes

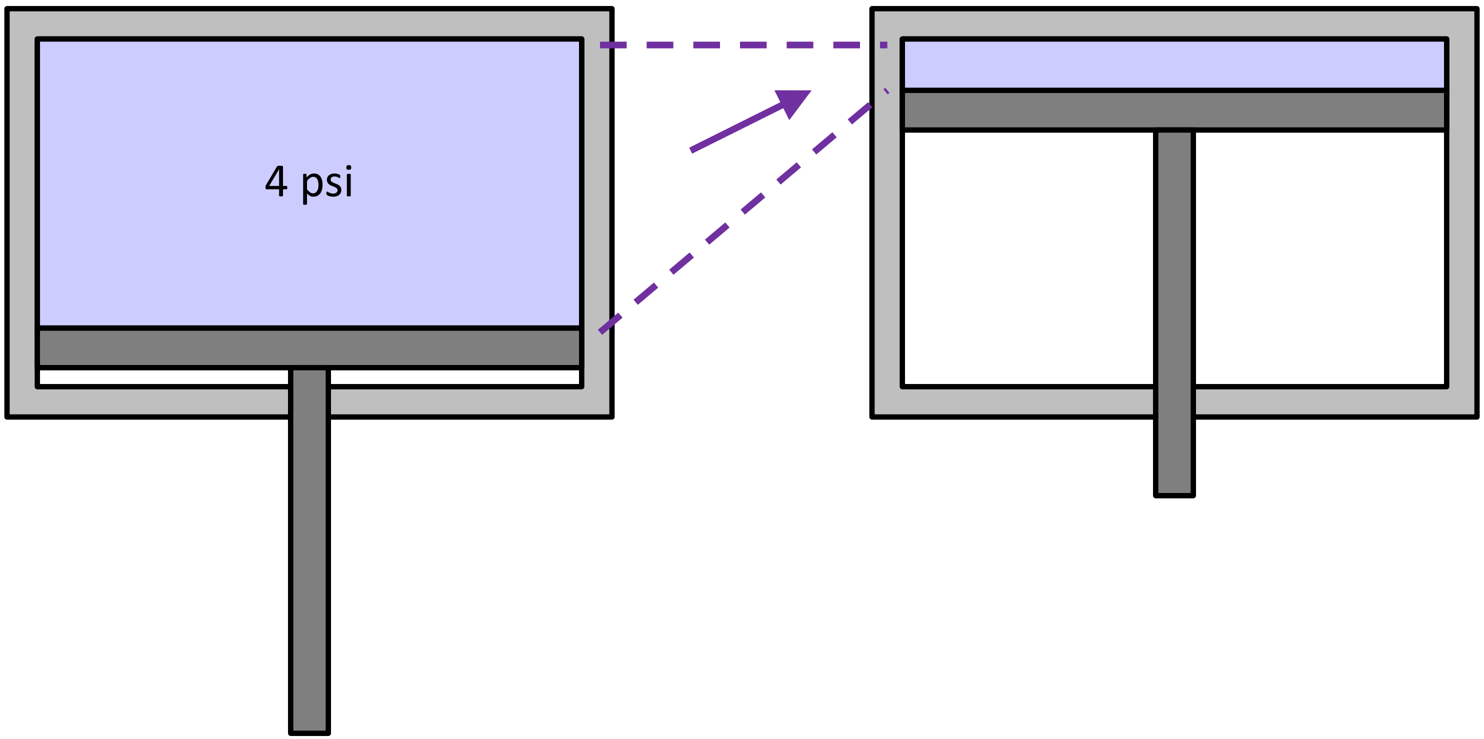
The diagram on the right represents the same cylinder when the brake is applied.

<u>Question:</u> Can you see the problem with this?

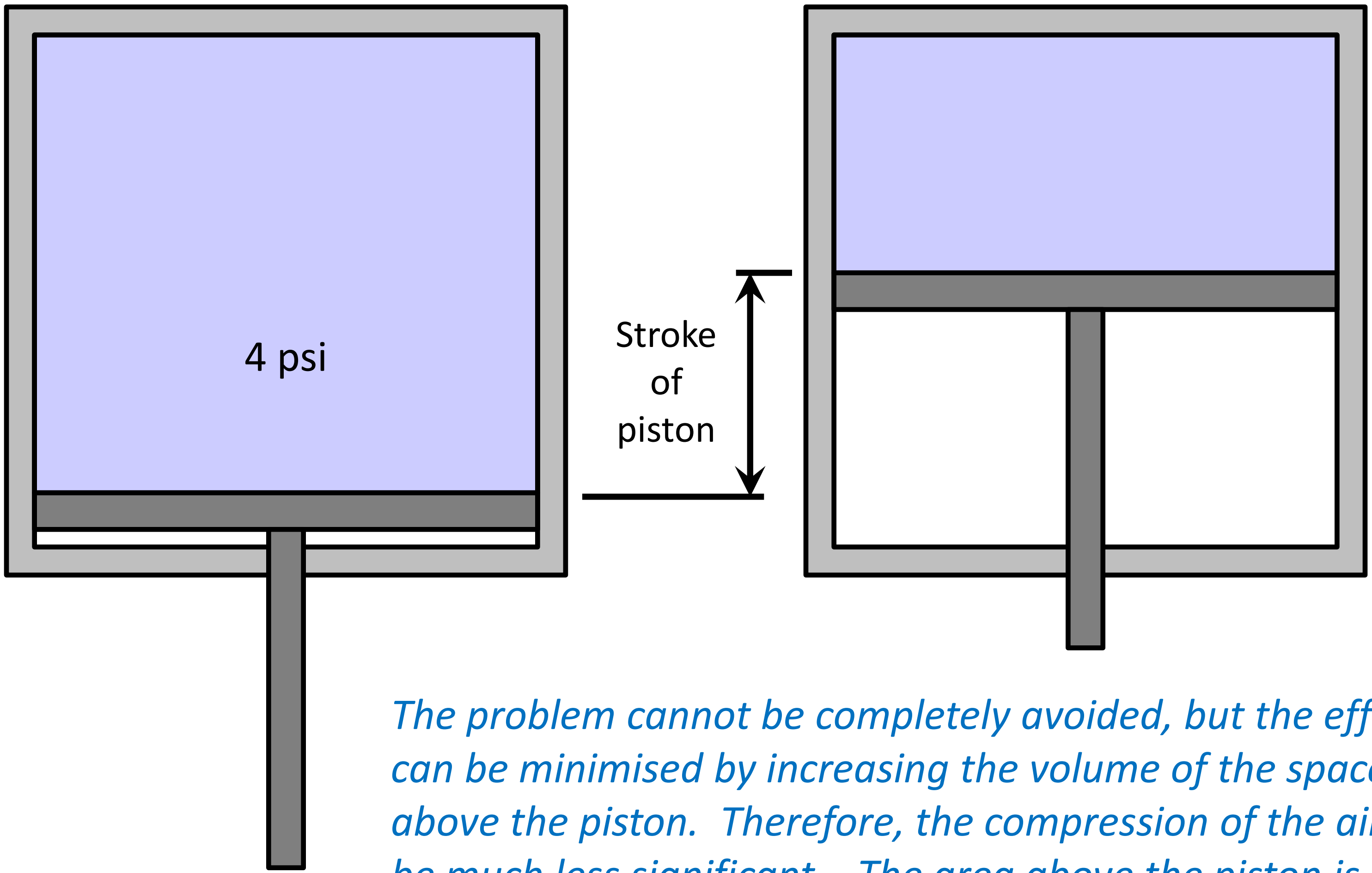


Vacuum brakes

<u>Answer:</u> The air at 4 psi is being compressed into a smaller space as the piston moves up the cylinder. As a result, its pressure will increase . The pressure difference across the piston will consequently reduce, which in turn will reduce the brake force.

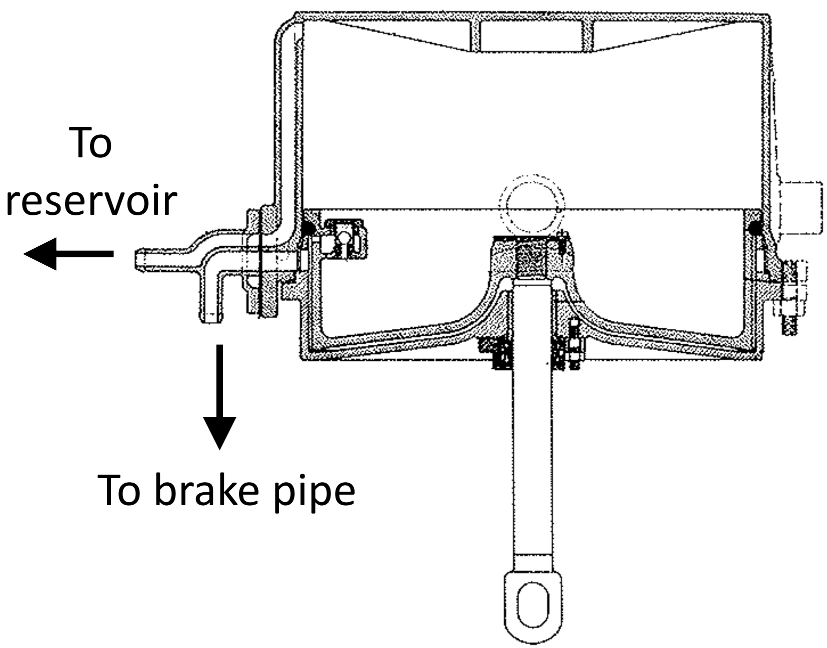


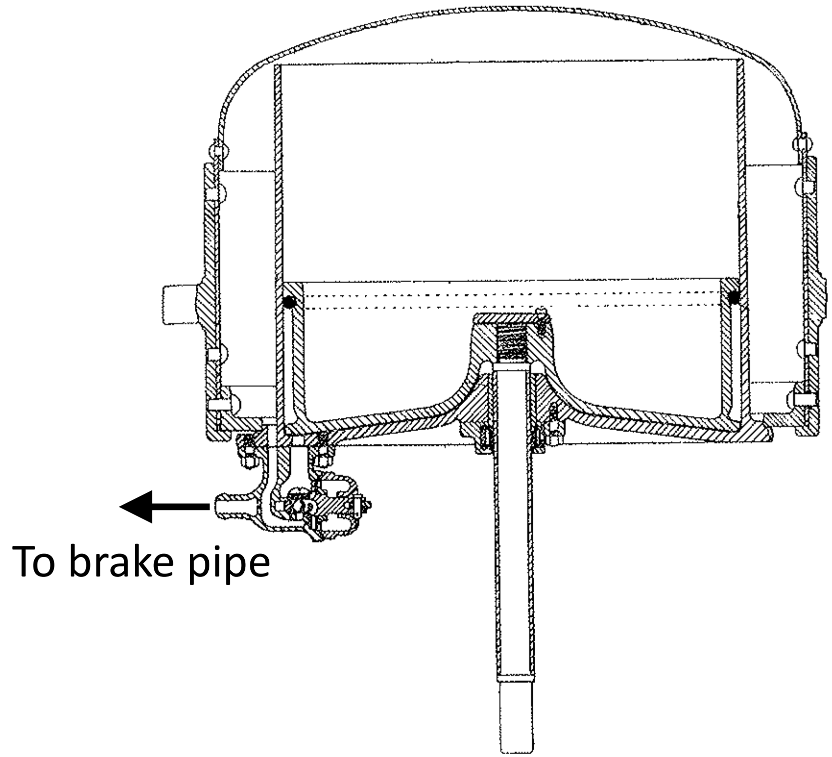
Vacuum brakes



The problem cannot be completely avoided, but the effect can be minimised by increasing the volume of the space above the piston. Therefore, the compression of the air will be much less significant. The area above the piston is referred to as the ***vacuum chamber****.*

Vacuum brakes



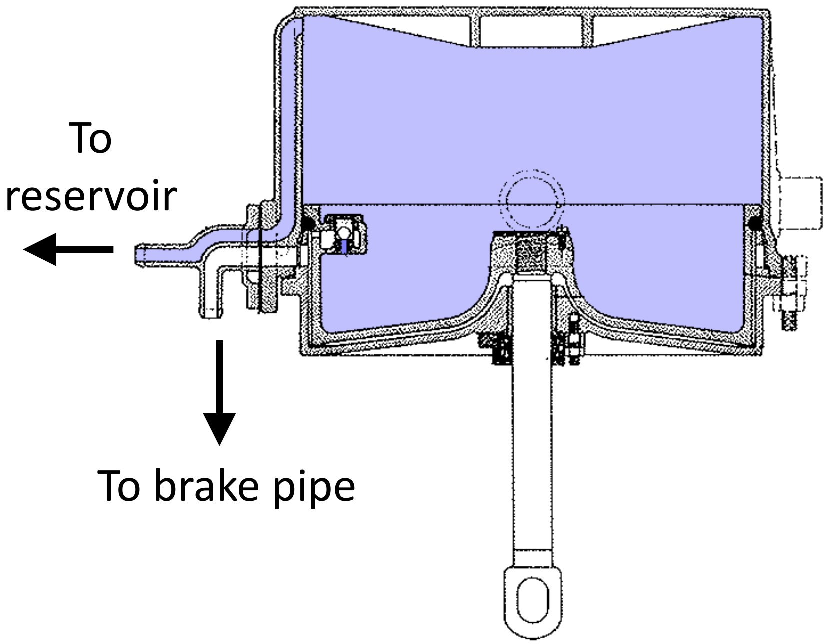


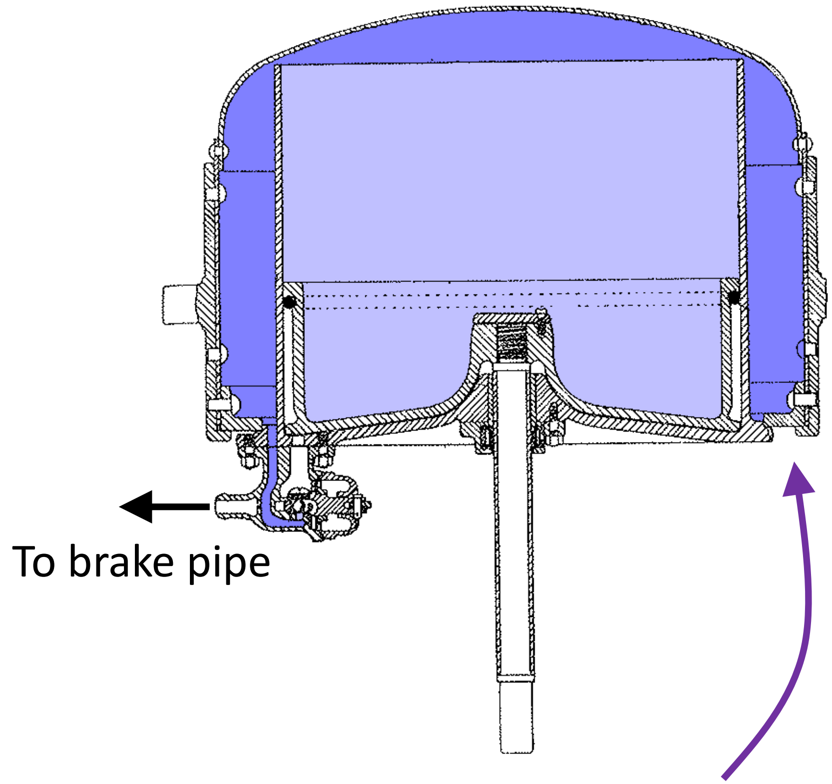
There are two types of vacuum chamber.

The cylinder shown above left is connected to a separate reservoir to increase the size of its vacuum chamber.

The cylinder shown above right contains its own annular reservoir.

Vacuum brakes





Although the vacuum chamber on the cylinder shown above right appears small, it is actually quite a large volume because it surrounds the outer edge of the working cylinder.

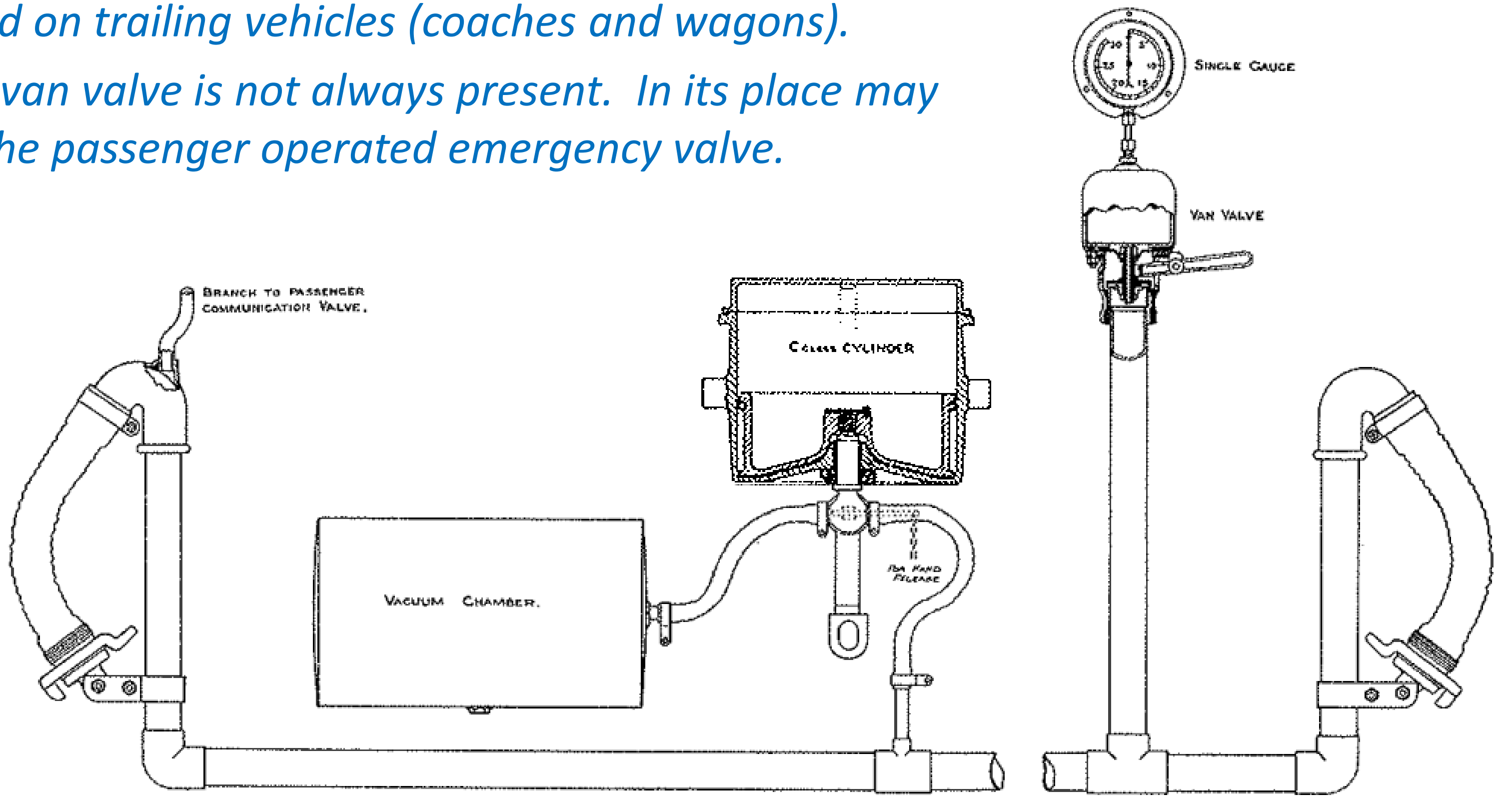
Vacuum brakes

The system

Vacuum brakes

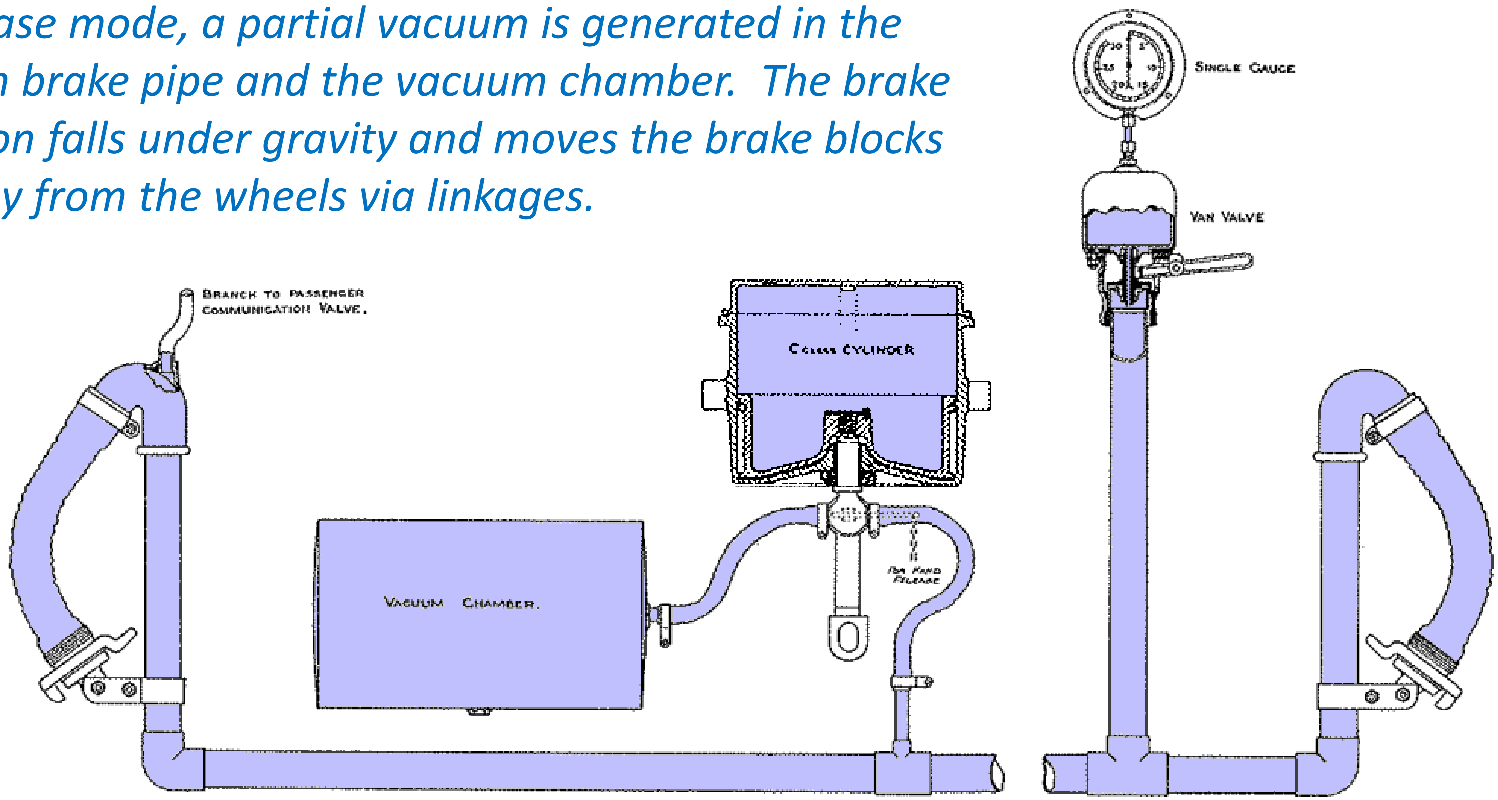
This diagram shows the complete system as typically fitted on trailing vehicles (coaches and wagons).

The van valve is not always present. In its place may be the passenger operated emergency valve.



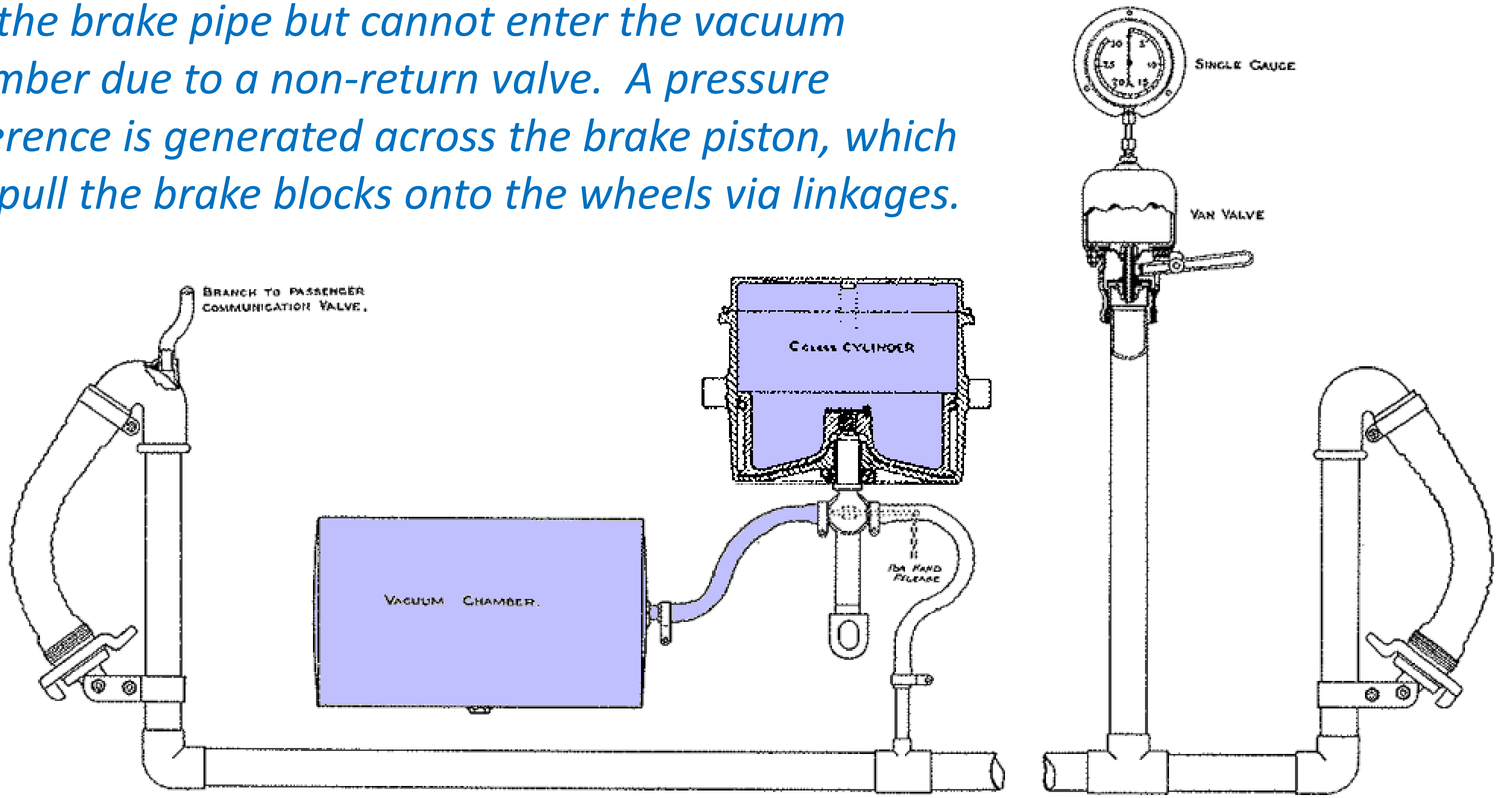
Vacuum brakes

When the brake system is activated, and is in its release mode, a partial vacuum is generated in the train brake pipe and the vacuum chamber. The brake piston falls under gravity and moves the brake blocks away from the wheels via linkages.

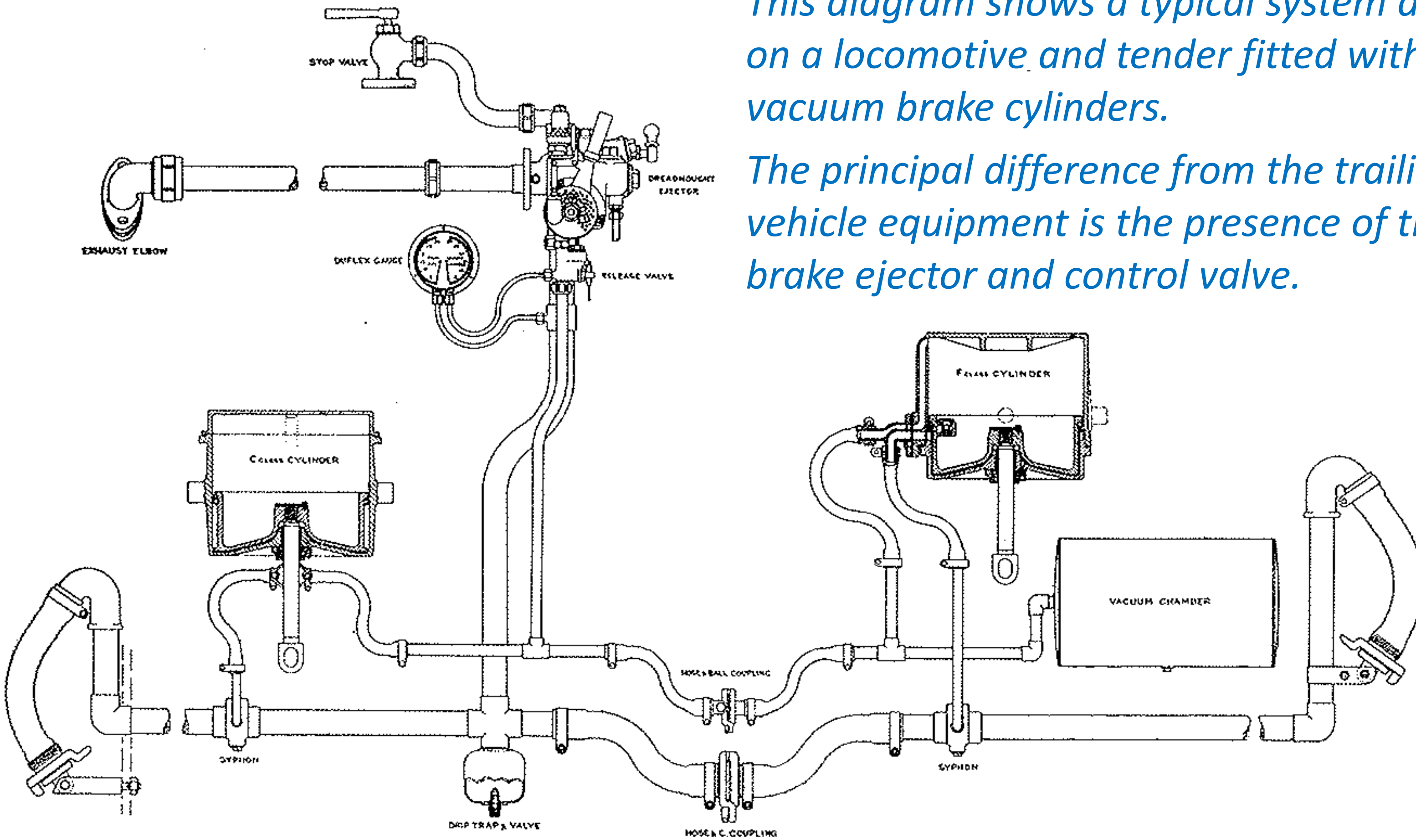


Vacuum brakes

When the brake is applied, atmospheric air pressure fills the brake pipe but cannot enter the vacuum chamber due to a non-return valve. A pressure difference is generated across the brake piston, which will pull the brake blocks onto the wheels via linkages.



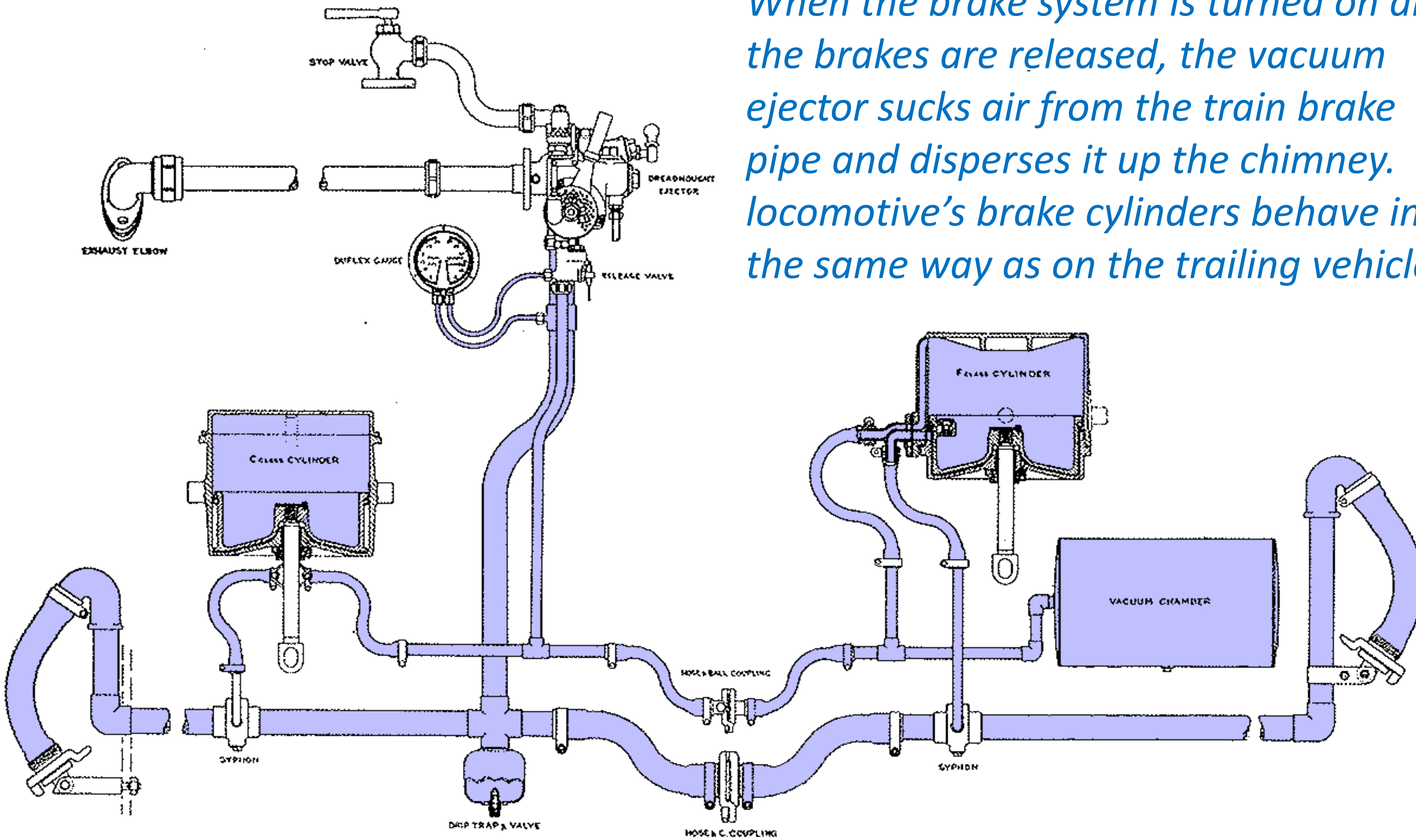
Vacuum brakes



This diagram shows a typical system as on a locomotive and tender fitted with vacuum brake cylinders.

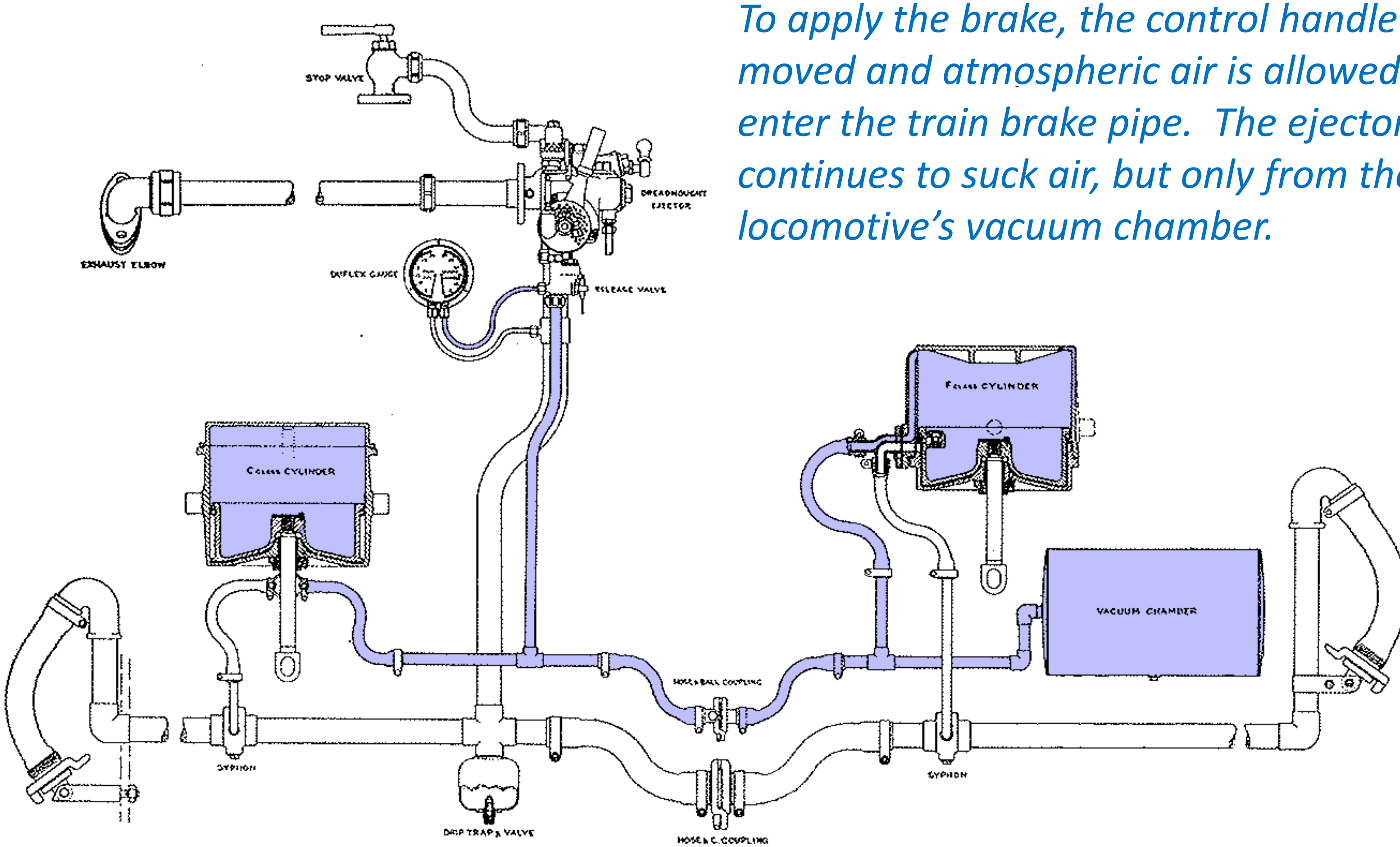
The principal difference from the trailing vehicle equipment is the presence of the brake ejector and control valve.

Vacuum brakes



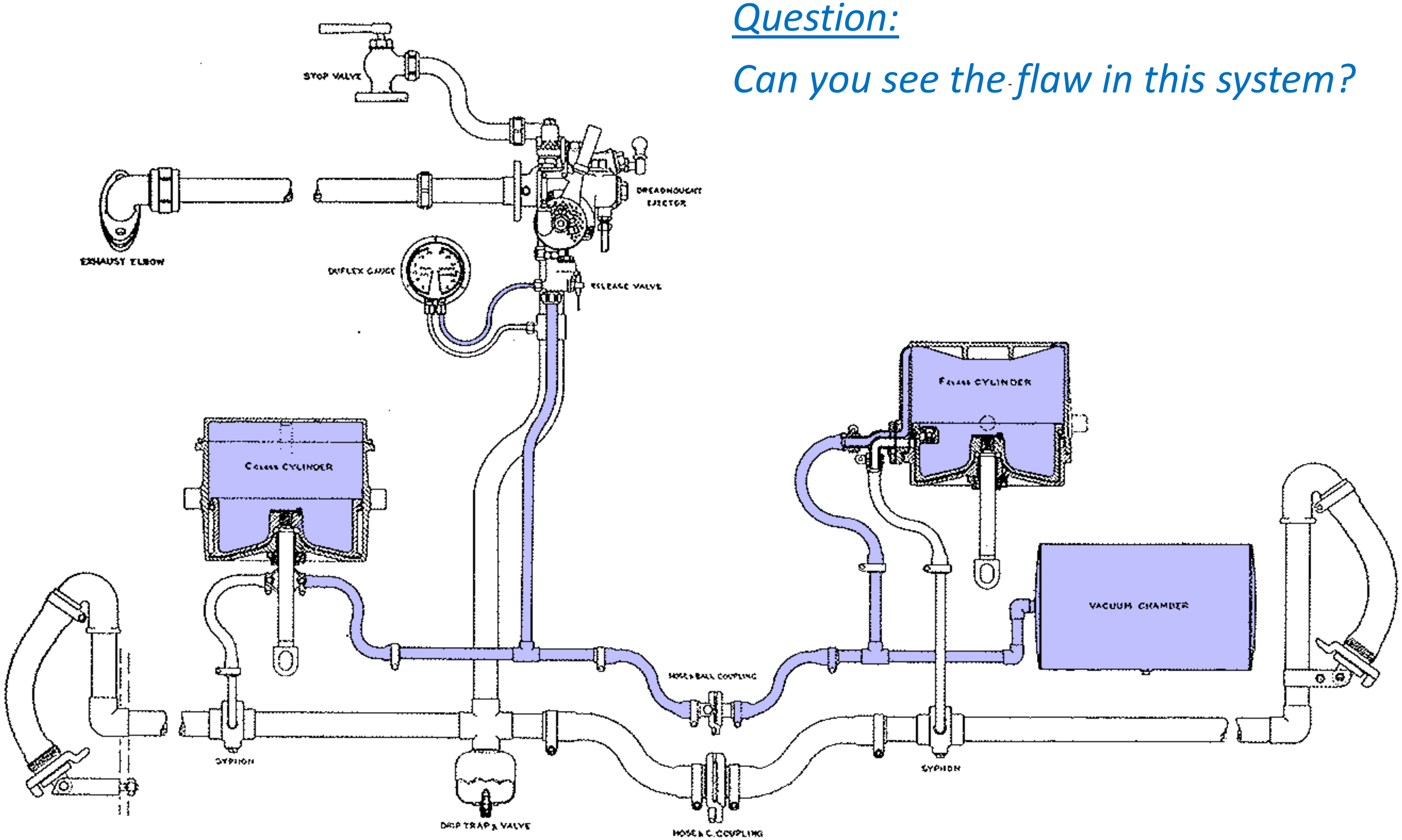
When the brake system is turned on and the brakes are released, the vacuum ejector sucks air from the train brake pipe and disperses it up the chimney. The locomotive's brake cylinders behave in the same way as on the trailing vehicles.

Vacuum brakes



To apply the brake, the control handle is moved and atmospheric air is allowed to enter the train brake pipe. The ejector continues to suck air, but only from the locomotive's vacuum chamber.

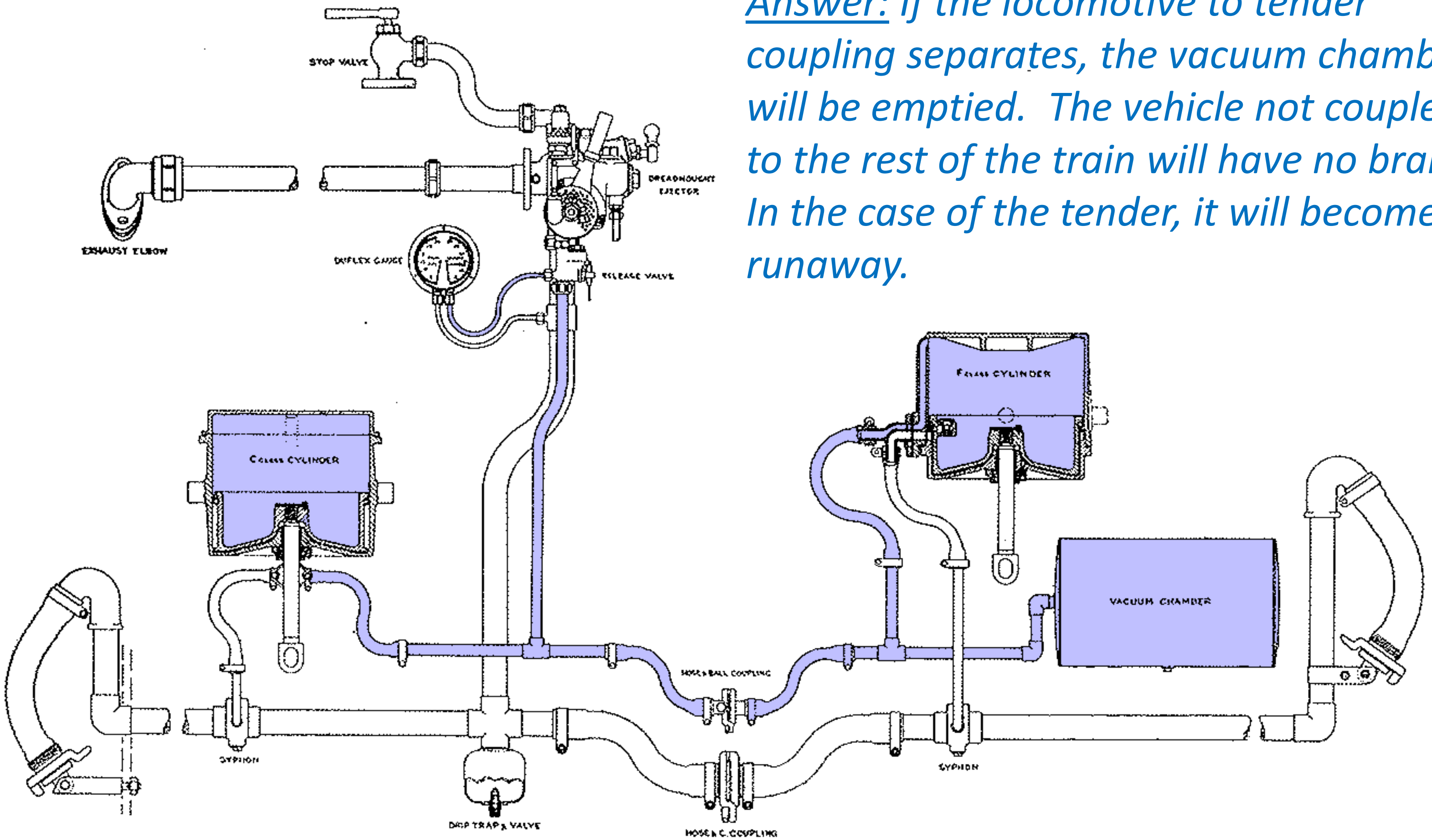
Vacuum brakes



__Question:__

Can you see the flaw in this system?

Vacuum brakes



<u>Answer:</u> If the locomotive to tender coupling separates, the vacuum chamber will be emptied. The vehicle not coupled to the rest of the train will have no brake. In the case of the tender, it will become a runaway.

Vacuum brakes

In terms of continuous brakes, the locomotive and its tender are considered as one vehicle because they are permanently coupled.

Therefore, if you are working on a locomotive restoration, give due consideration to the integrity of the locomotive to tender coupling.

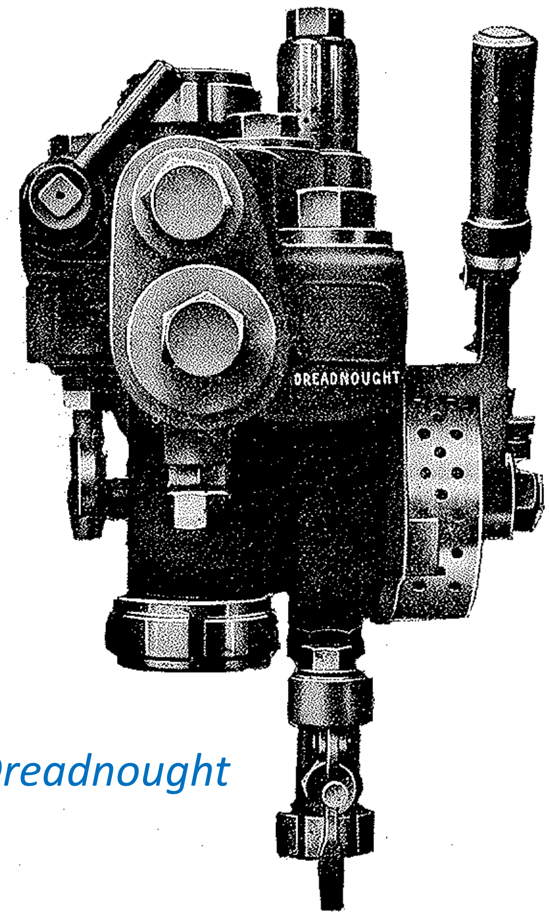
Vacuum brakes

Brake control valves

Vacuum brakes

These two types of brake controller are used extensively on the Ffestiniog Railway.

<u>Question:</u> What is the fundamental difference between them?



Dreadnought

DMU valve

Vacuum brakes

Answer: the Dreadnought has a continuous operation whereas the DMU valve has a lap position.

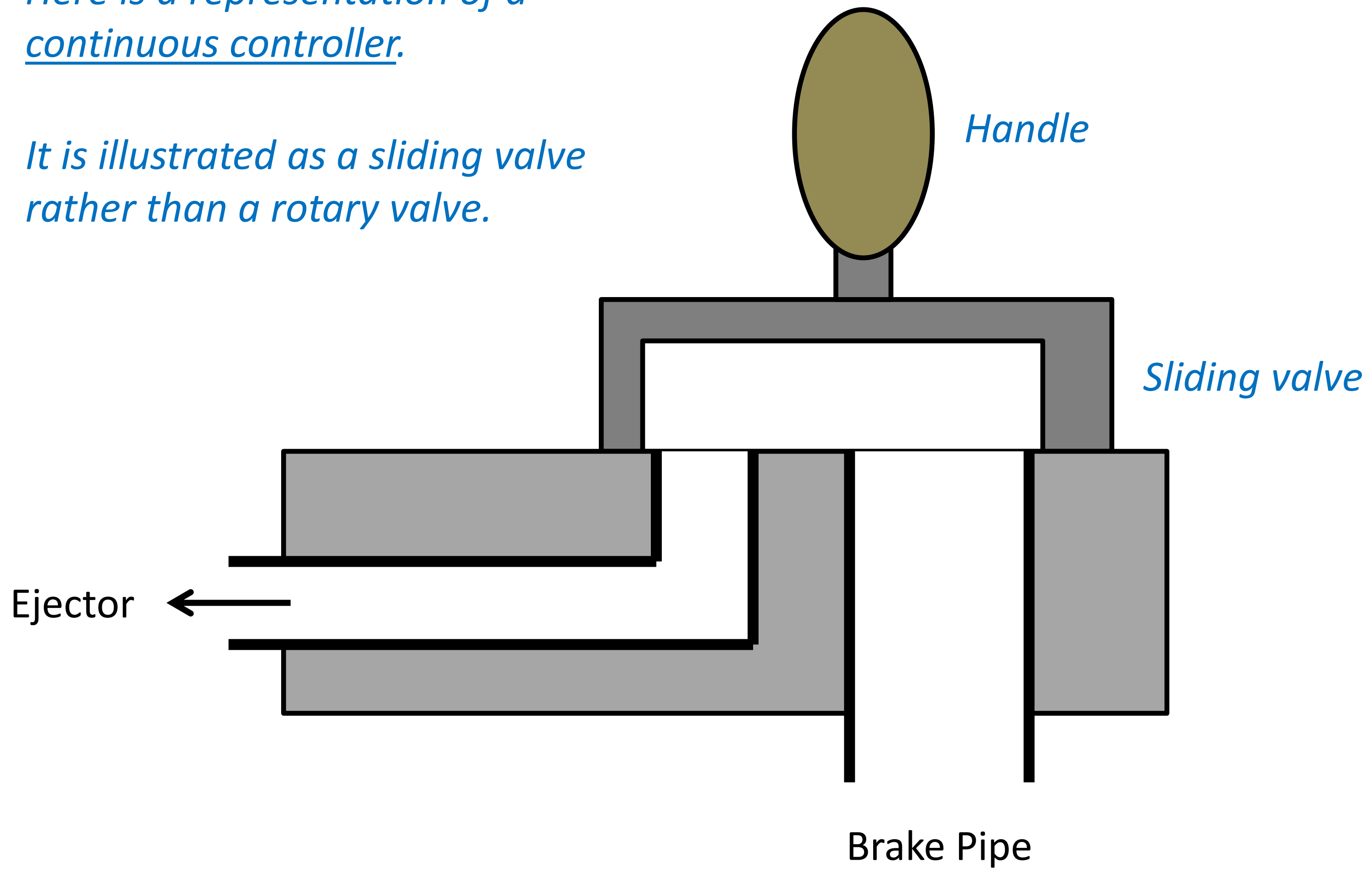
Another difference is that the Dreadnought contains the ejector in the same fitting as the controller, whilst the DMU valve requires a separate exhauster.

The next few slides will look at the difference between a continuous controller (like the Dreadnought) and a lap position controller (like the DMU valve).

Vacuum brakes

Here is a representation of a <u>continuous controller</u>.

It is illustrated as a sliding valve rather than a rotary valve.

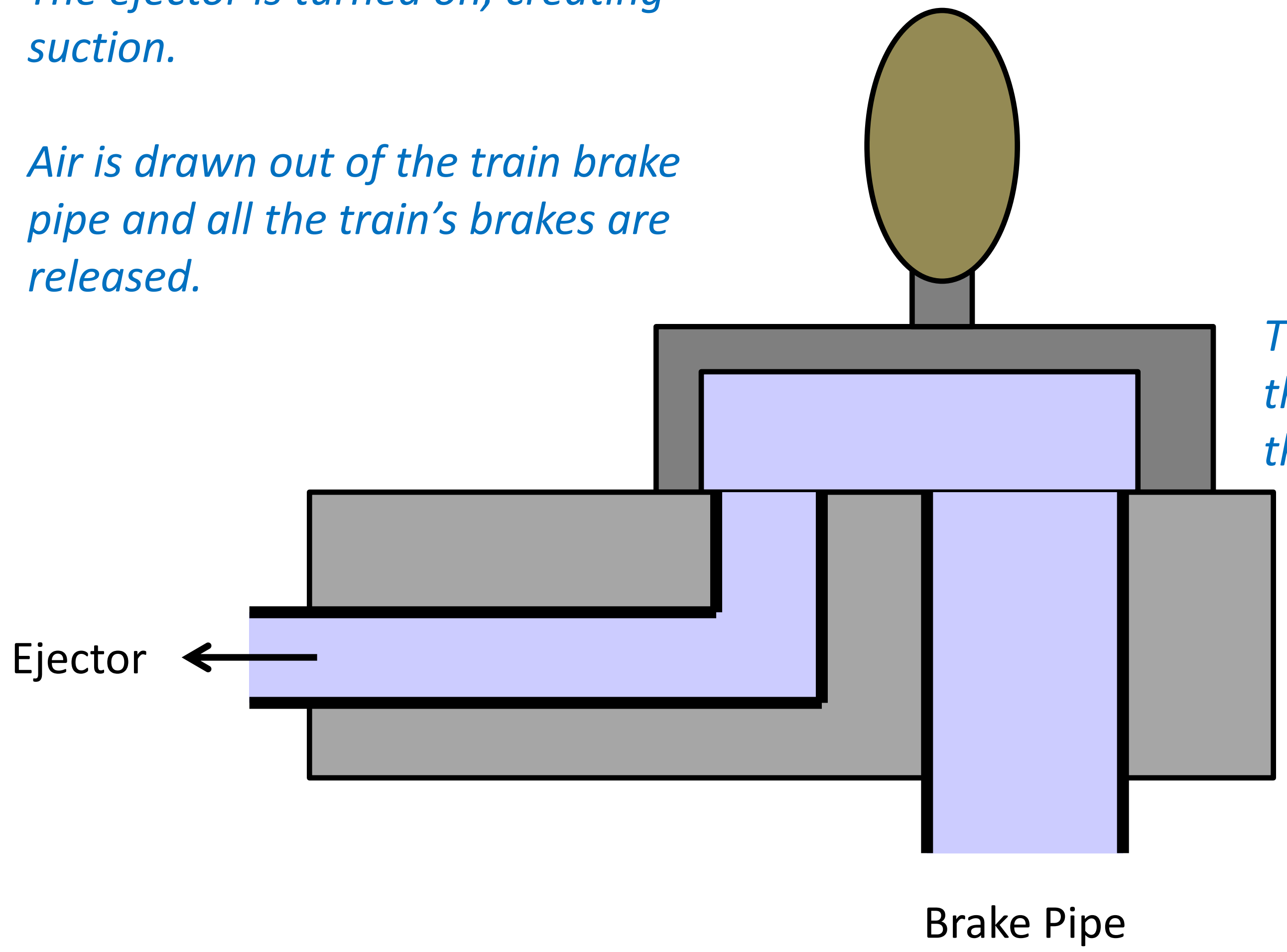


Vacuum brakes

The ejector is turned on, creating suction.

Air is drawn out of the train brake pipe and all the train's brakes are released.

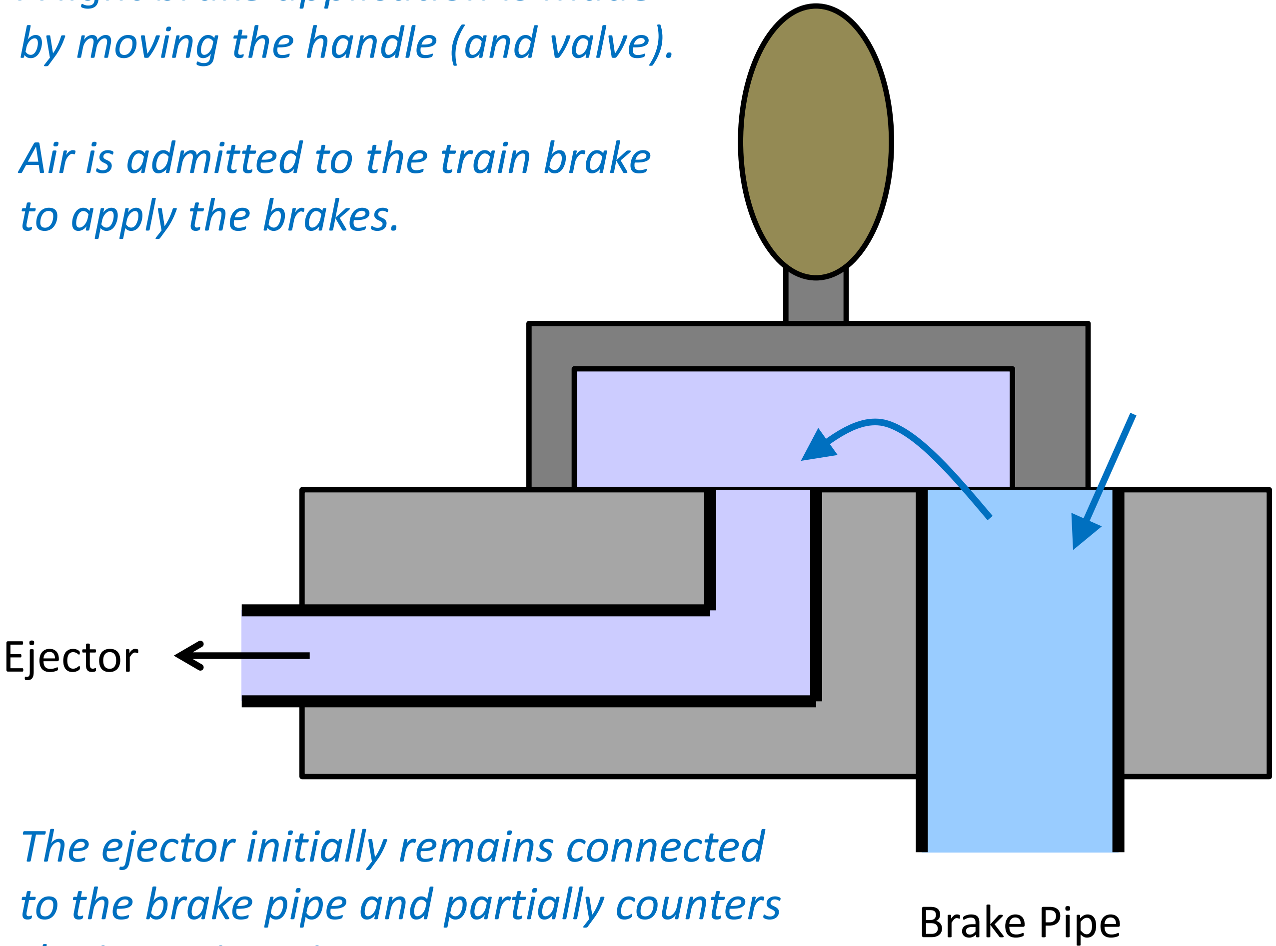
The valve is held on the sliding face by the vacuum.



Vacuum brakes

A light brake application is made by moving the handle (and valve).

Air is admitted to the train brake to apply the brakes.

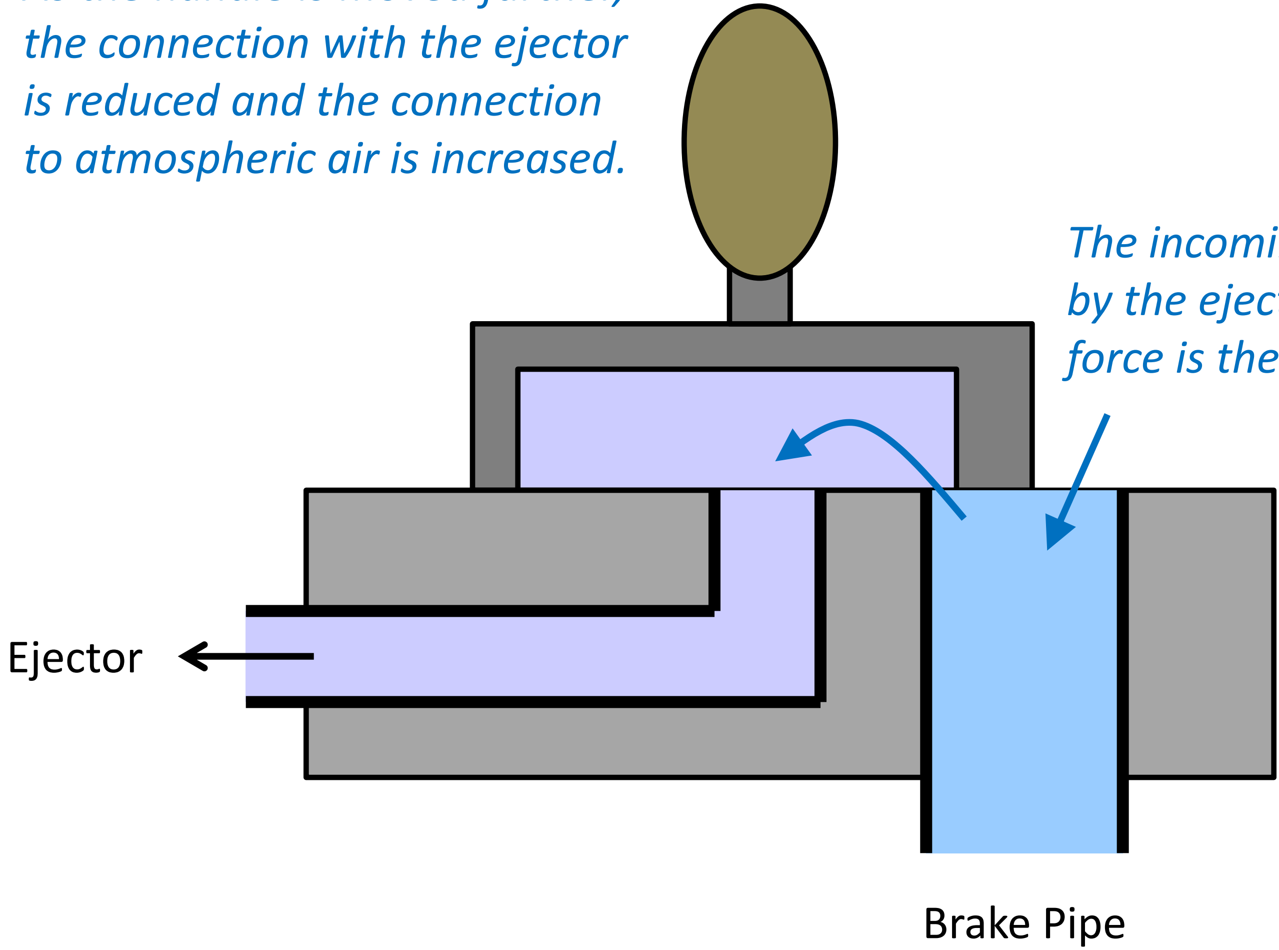


The ejector initially remains connected to the brake pipe and partially counters the incoming air.

Vacuum brakes

As the handle is moved further, the connection with the ejector is reduced and the connection to atmospheric air is increased.

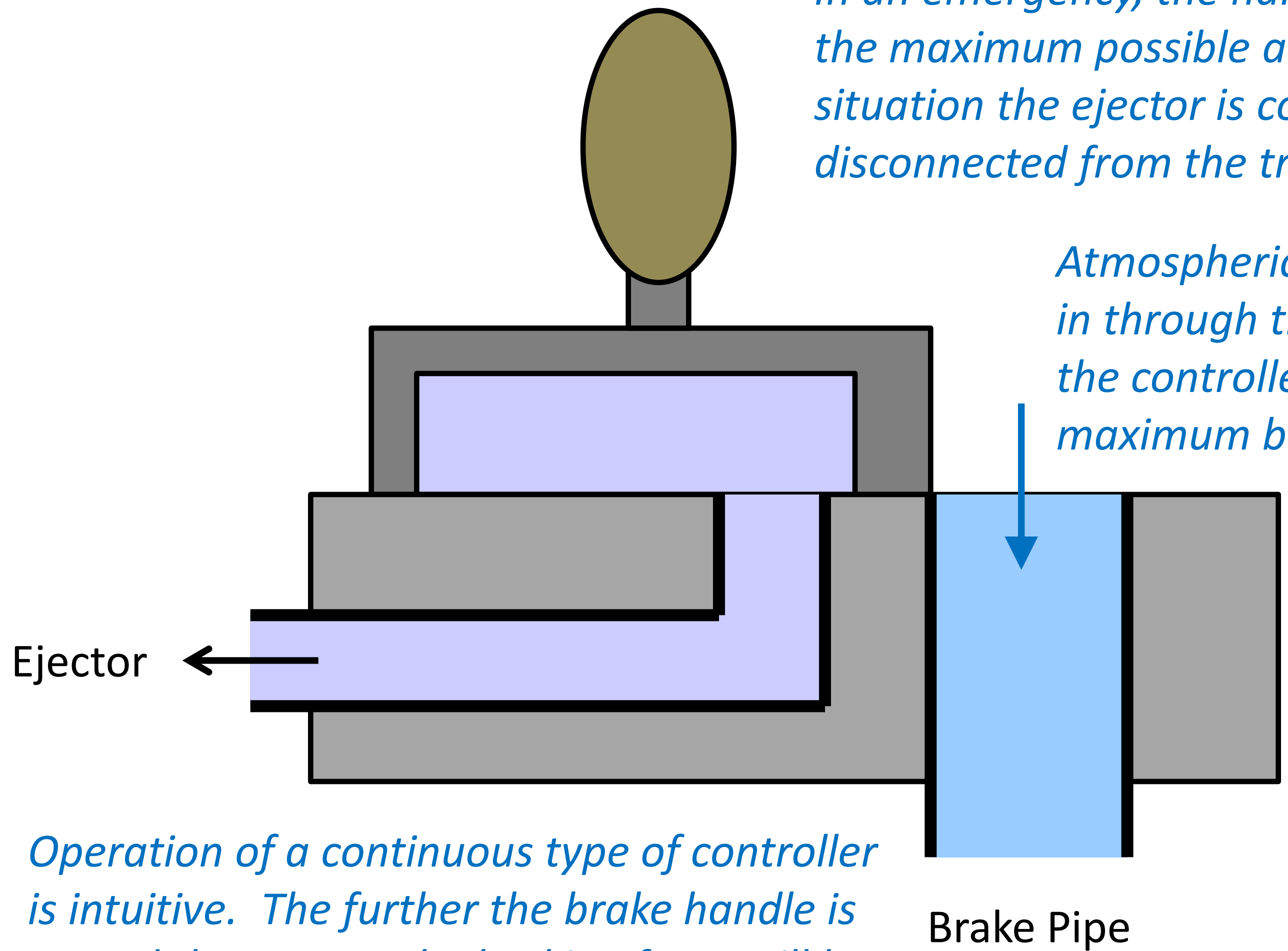
The incoming air is less hindered by the ejector and the brake force is therefore increased.



Vacuum brakes

In an emergency, the handle is moved by the maximum possible amount. In this situation the ejector is completely disconnected from the train brake pipe.

Atmospheric air pressure rushes in through the large opening in the controller and applies the maximum brake force.

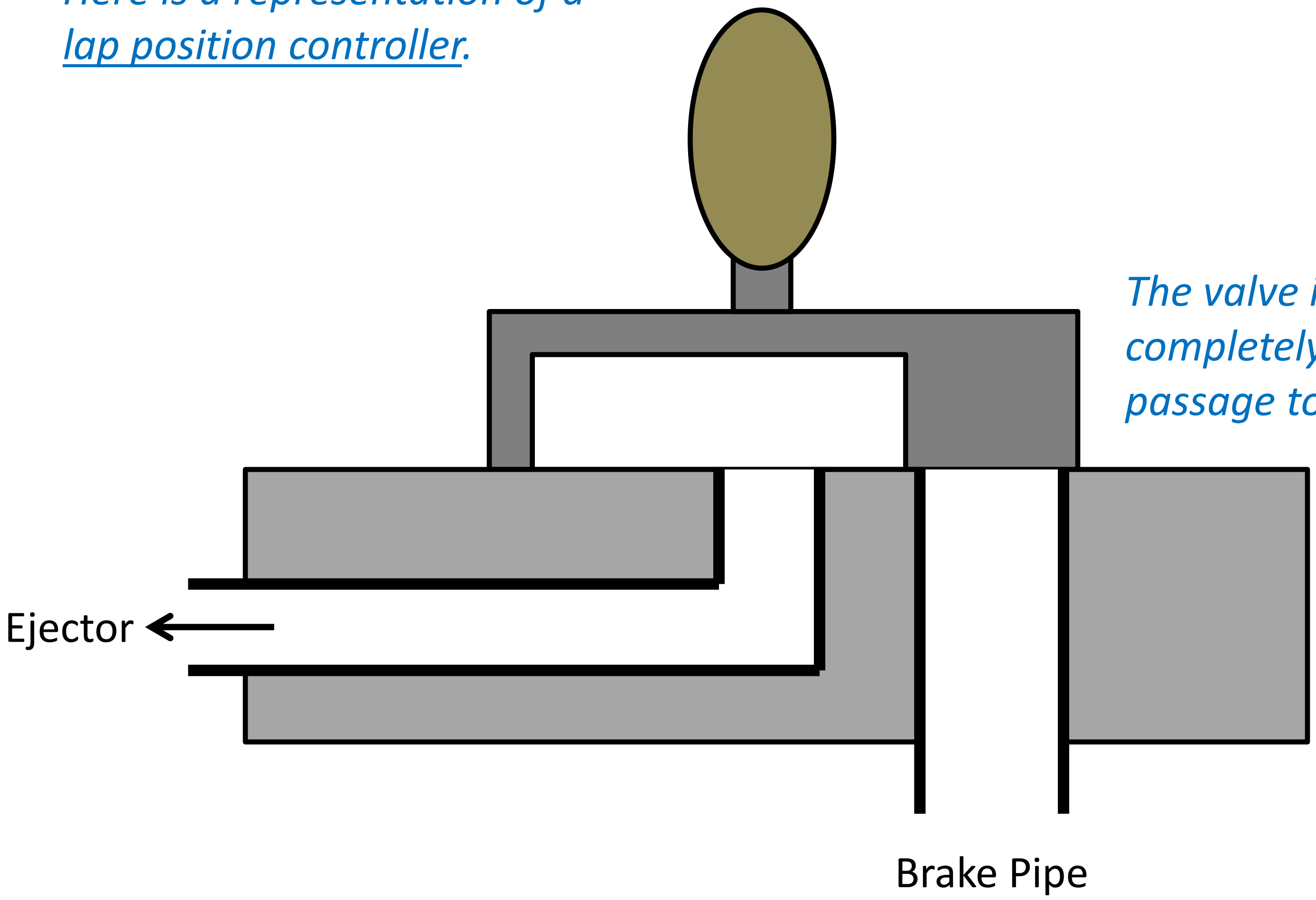


Operation of a continuous type of controller is intuitive. The further the brake handle is moved the greater the braking force will be.

Vacuum brakes

Here is a representation of a [lap position controller](#).

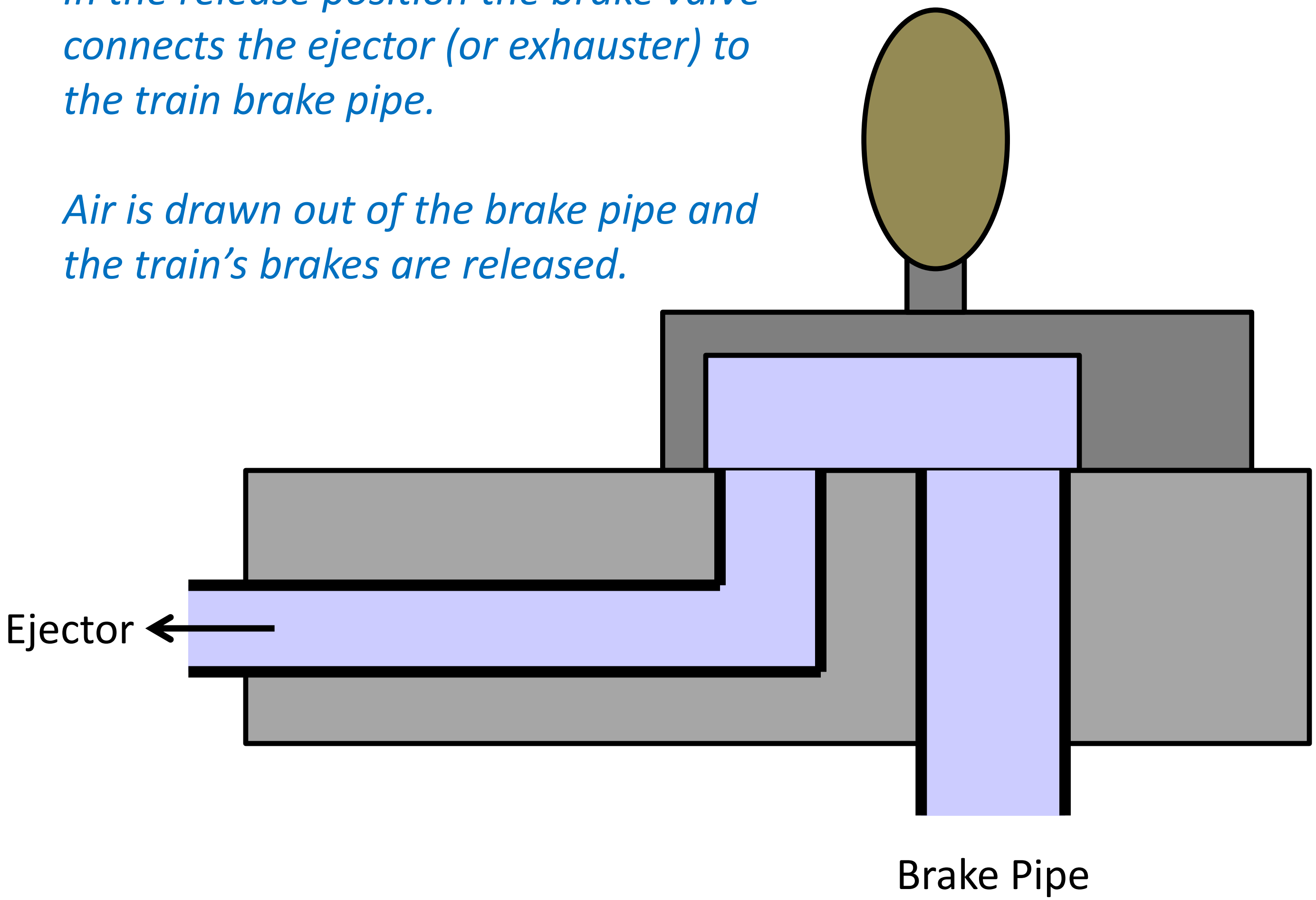
The valve is capable of completely covering the passage to the brake pipe.



Vacuum brakes

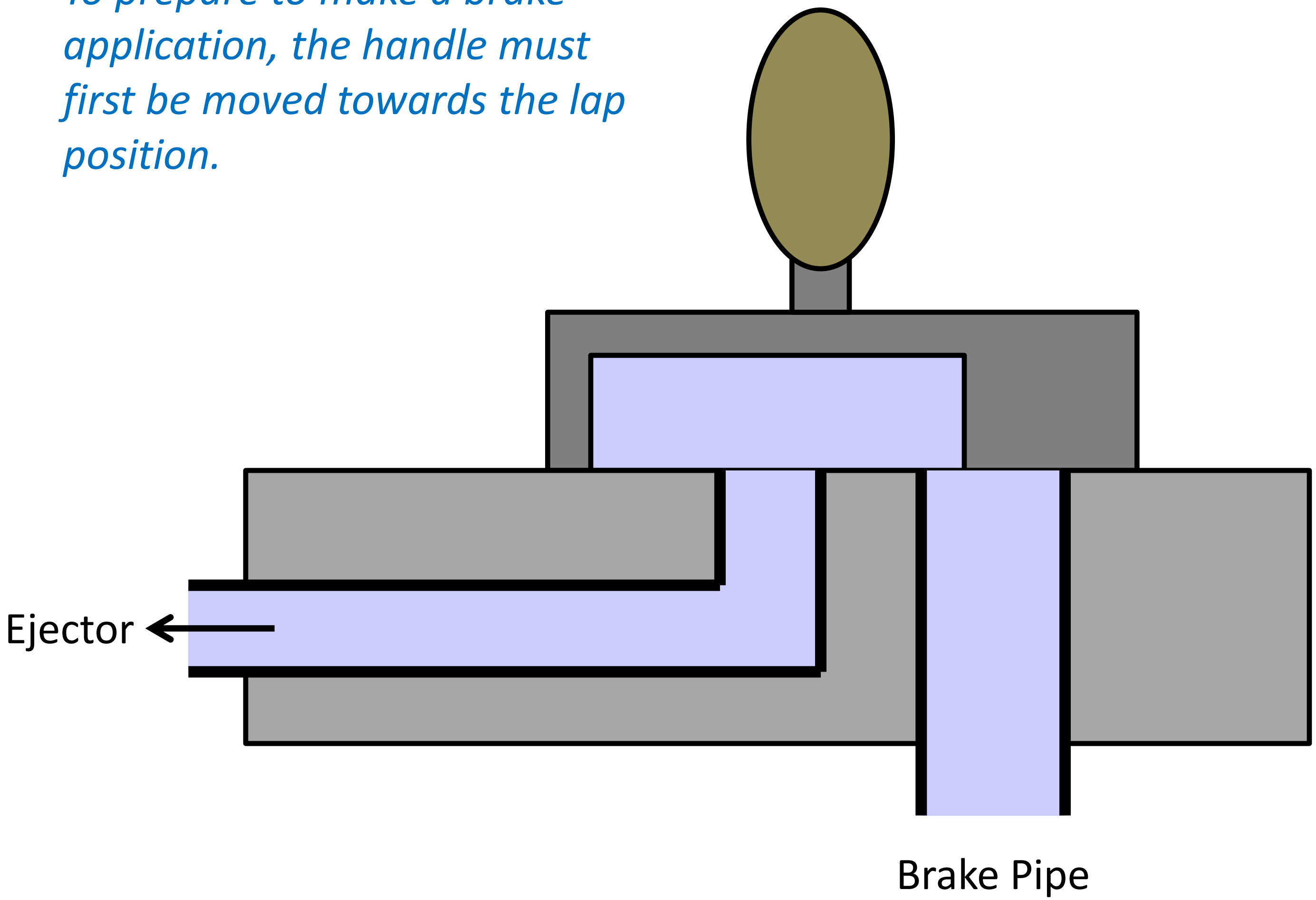
In the release position the brake valve connects the ejector (or exhauster) to the train brake pipe.

Air is drawn out of the brake pipe and the train's brakes are released.



Vacuum brakes

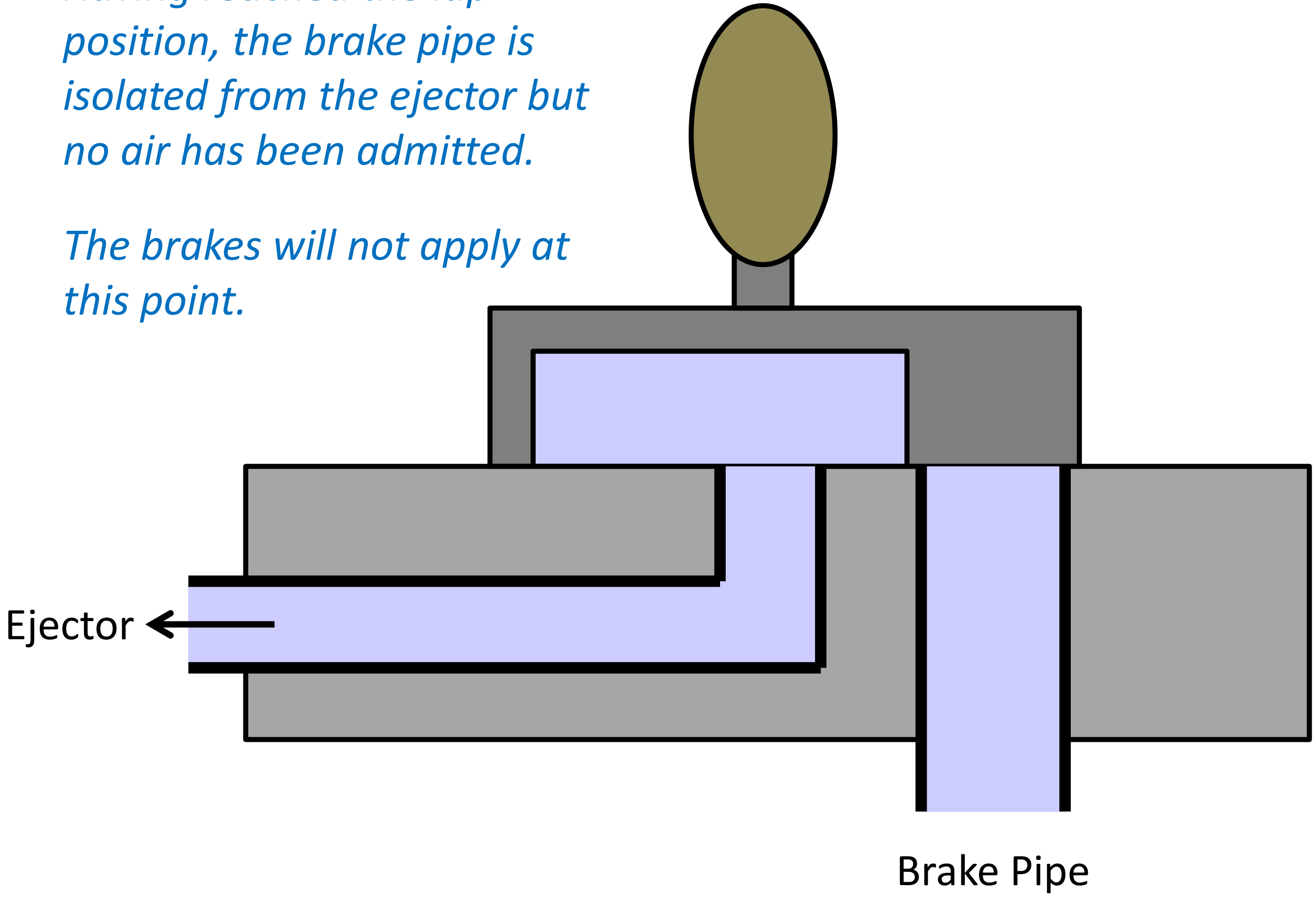
To prepare to make a brake application, the handle must first be moved towards the lap position.



Vacuum brakes

Having reached the lap position, the brake pipe is isolated from the ejector but no air has been admitted.

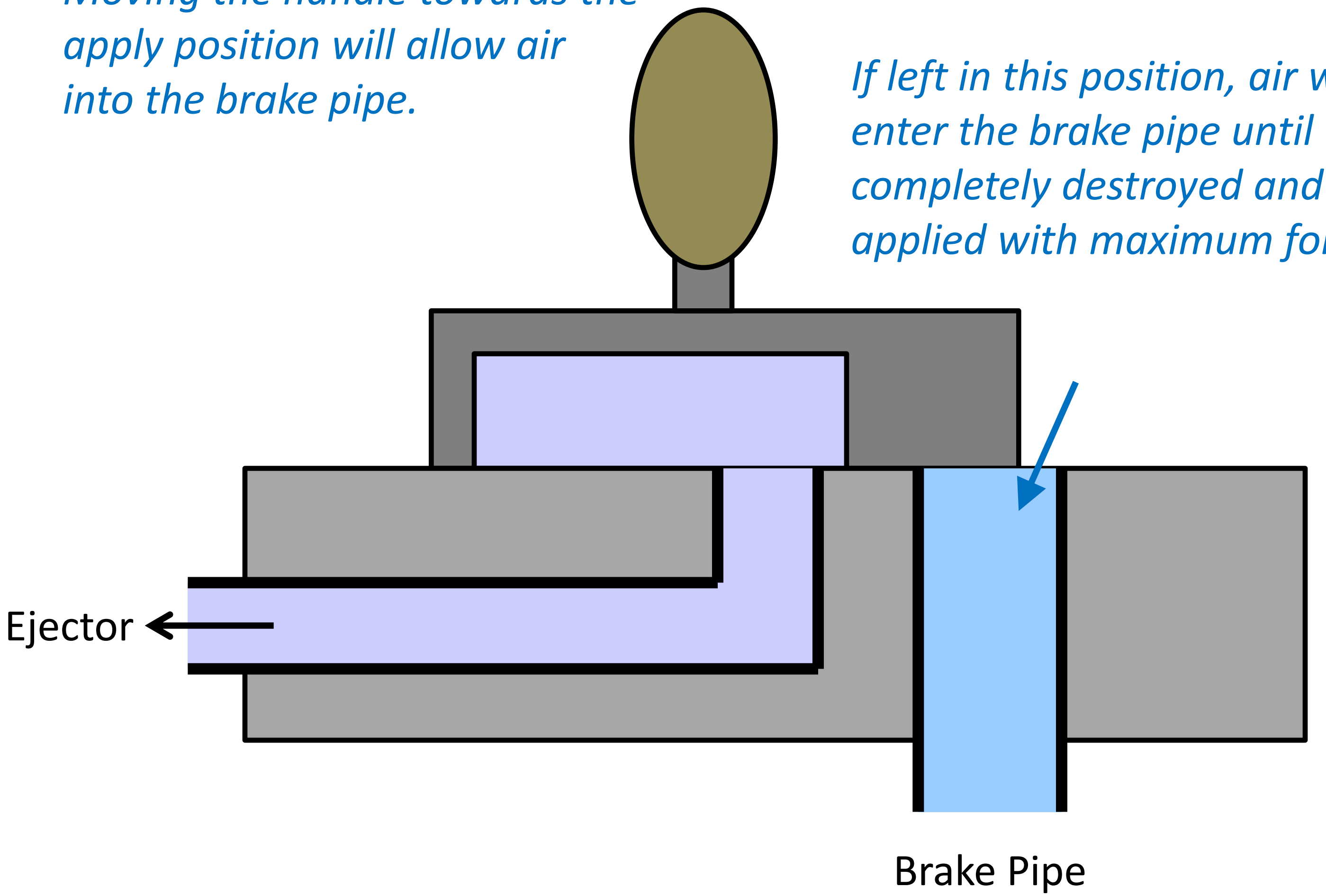
The brakes will not apply at this point.



Vacuum brakes

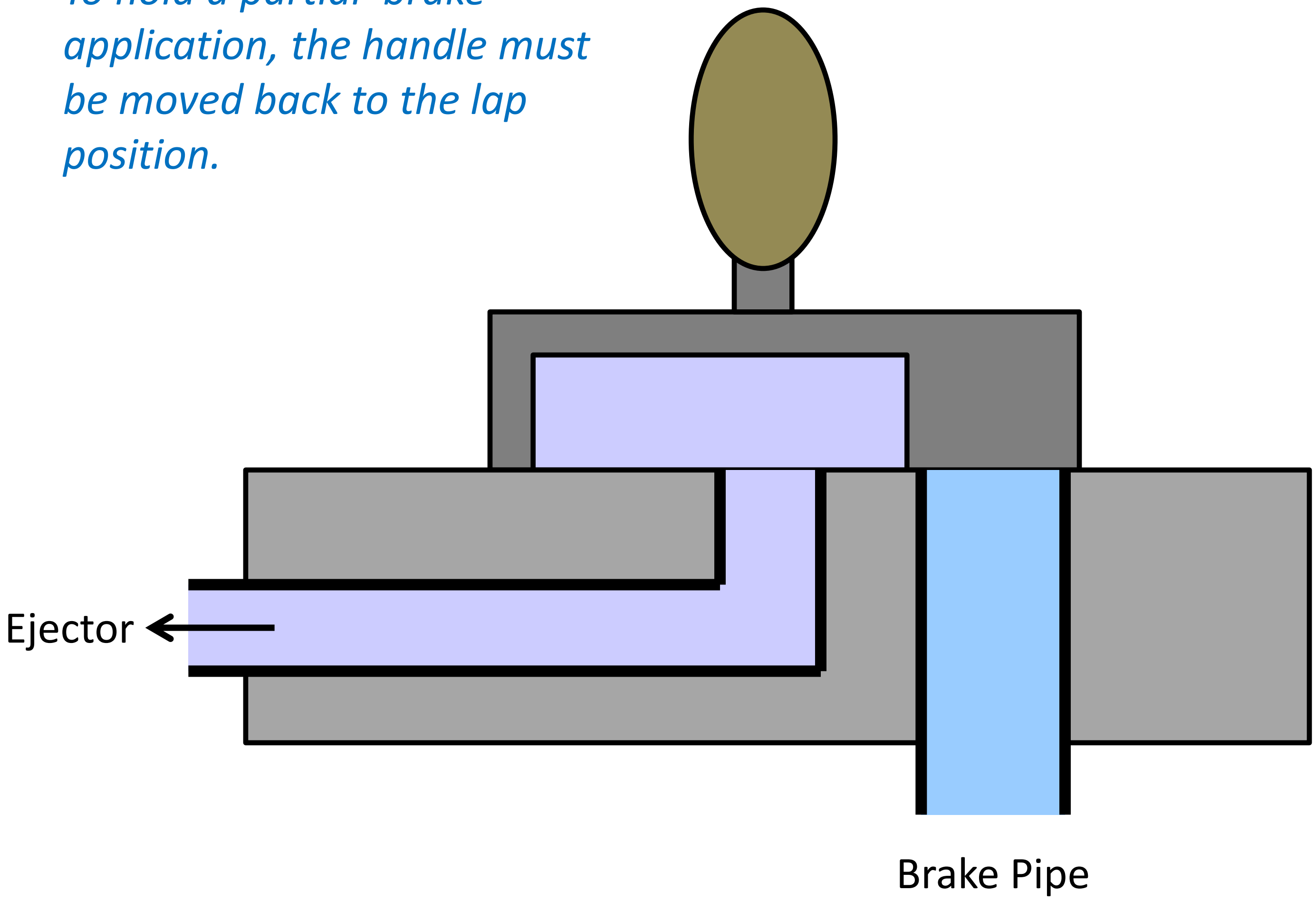
Moving the handle towards the apply position will allow air into the brake pipe.

If left in this position, air will continue to enter the brake pipe until the vacuum is completely destroyed and the brakes applied with maximum force.



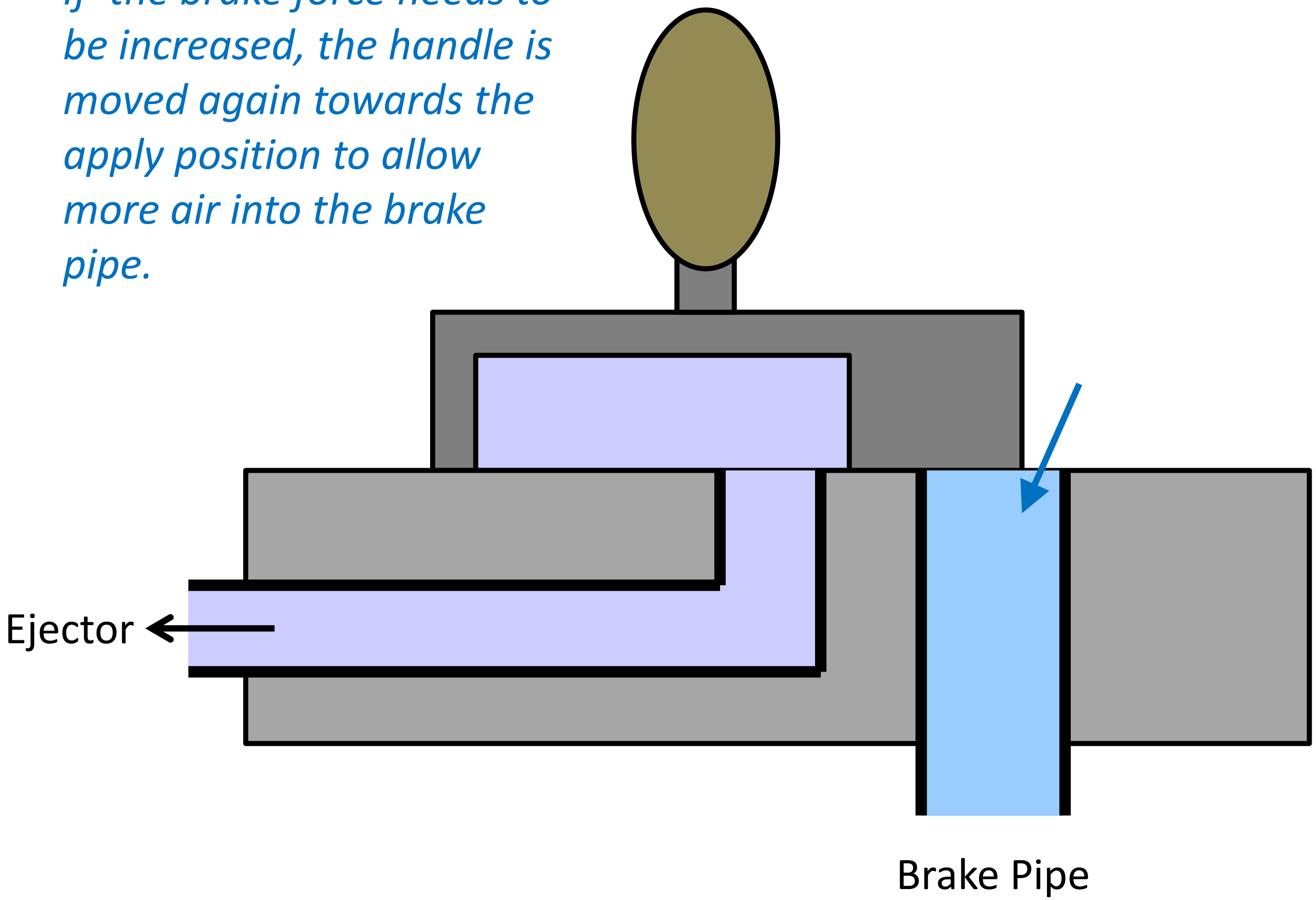
Vacuum brakes

To hold a partial brake application, the handle must be moved back to the lap position.



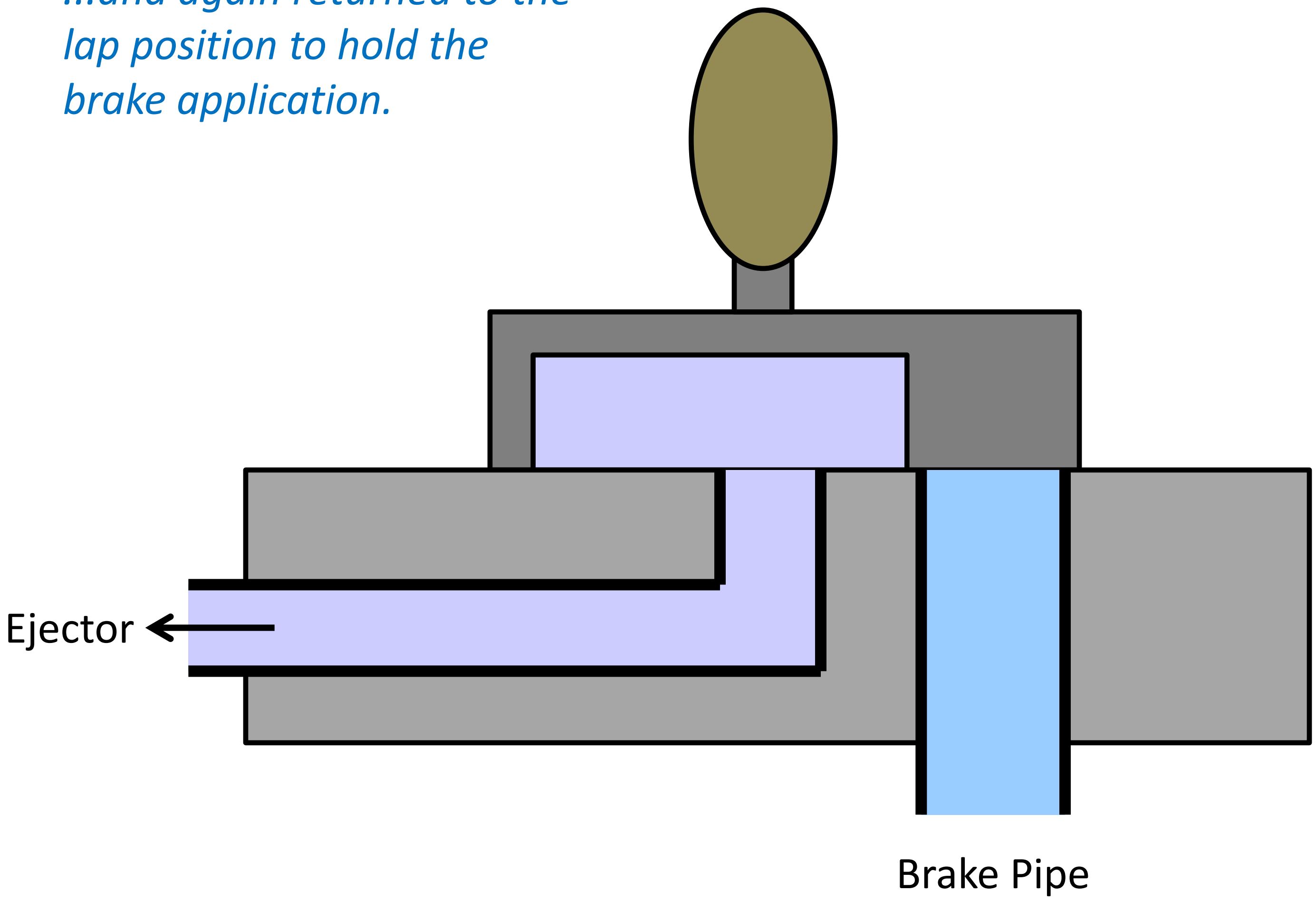
Vacuum brakes

If the brake force needs to be increased, the handle is moved again towards the apply position to allow more air into the brake pipe.



Vacuum brakes

...and again returned to the lap position to hold the brake application.

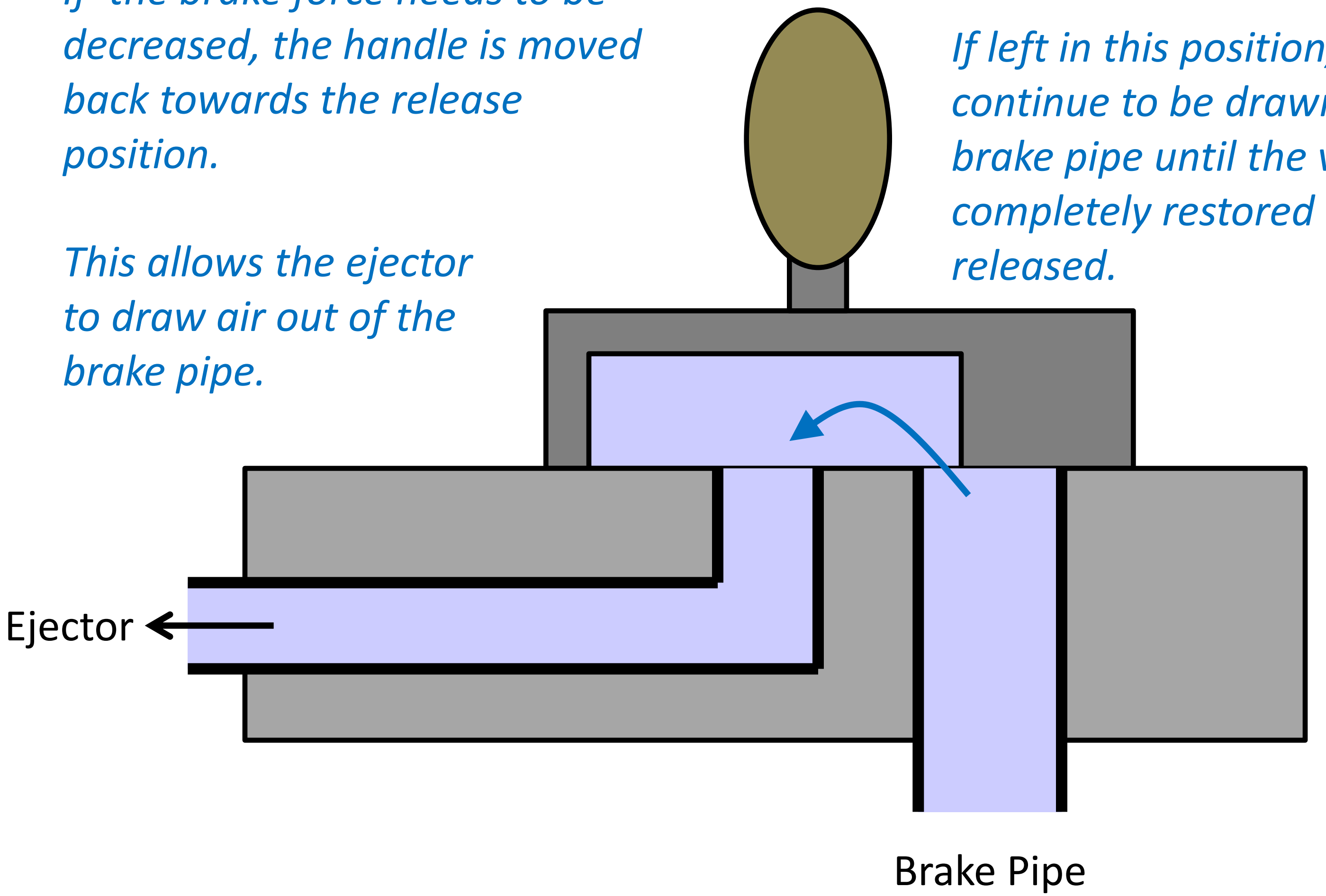


Vacuum brakes

If the brake force needs to be decreased, the handle is moved back towards the release position.

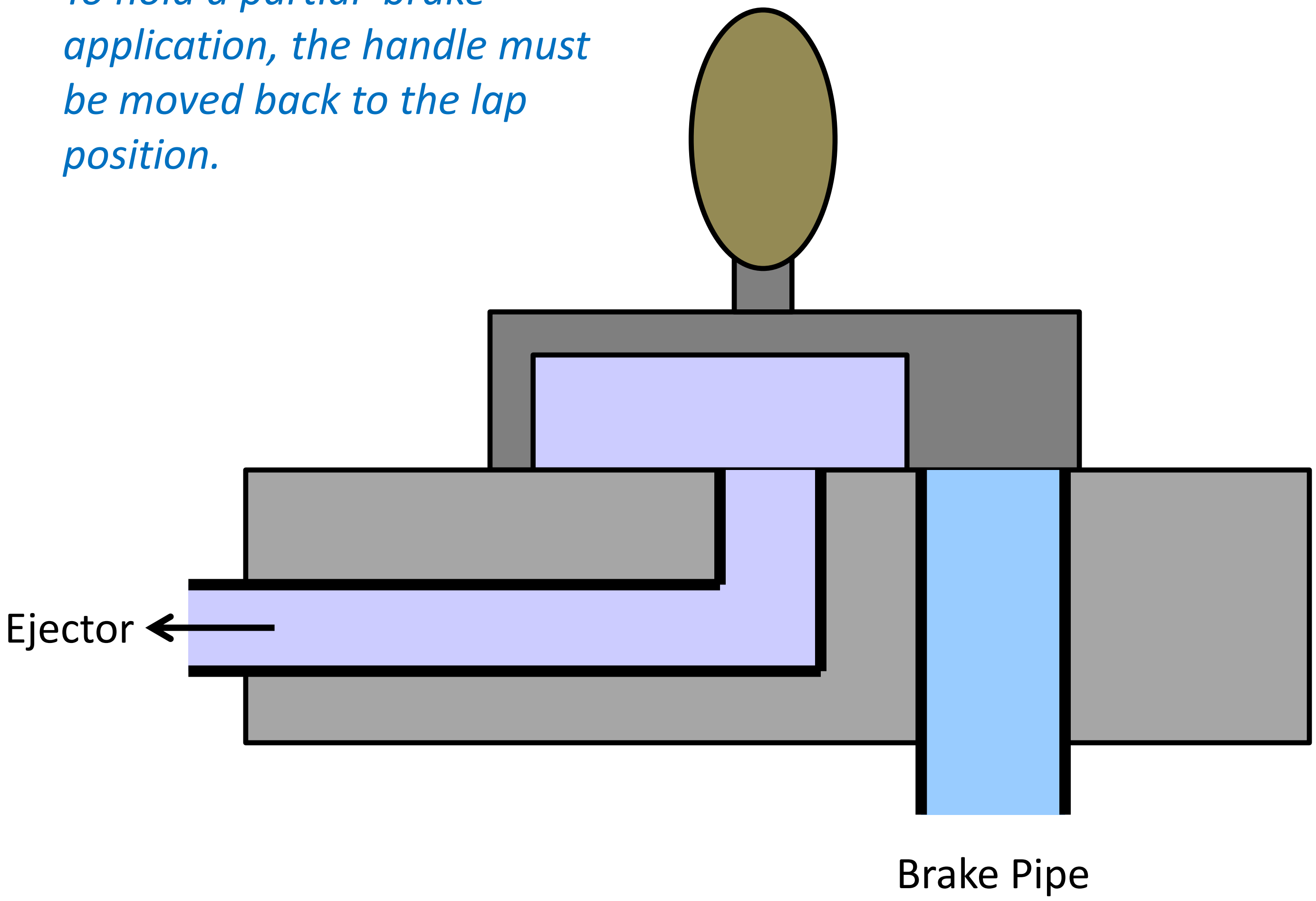
This allows the ejector to draw air out of the brake pipe.

If left in this position, air will continue to be drawn out of the brake pipe until the vacuum is completely restored and the brakes released.



Vacuum brakes

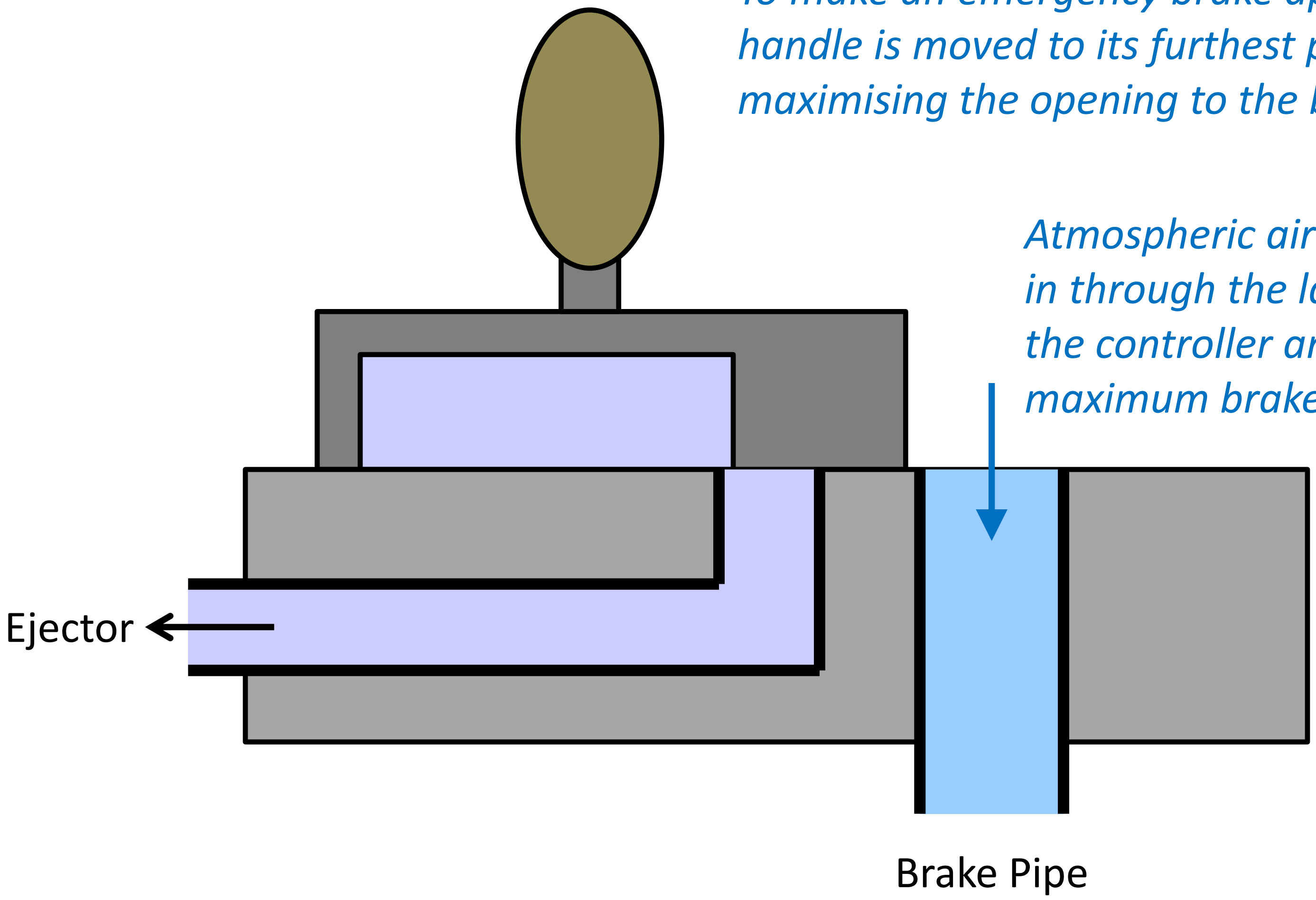
To hold a partial brake application, the handle must be moved back to the lap position.



Vacuum brakes

To make an emergency brake application, the handle is moved to its furthest position, thus maximising the opening to the brake pipe.

Atmospheric air pressure rushes in through the large opening in the controller and applies the maximum brake force.



Vacuum brakes

Important note:

Whilst the brake controller is in the lap position, a small amount of air will enter the brake pipe as leakage at all the joints in the system. These leaks cannot be countered by the ejector, which is now disconnected from the brake pipe. Therefore, a gradual increase in brake force may be experienced whilst in the lap position.

The controller must not be left in the lap position when the train brakes have been released. This is because air could leak into the vacuum chambers of the trailing vehicles, resulting in reduced brake effectiveness. The ejector must remain connected to the train brake pipe up until a brake application is required, so that the vacuum chambers are all fully charged.

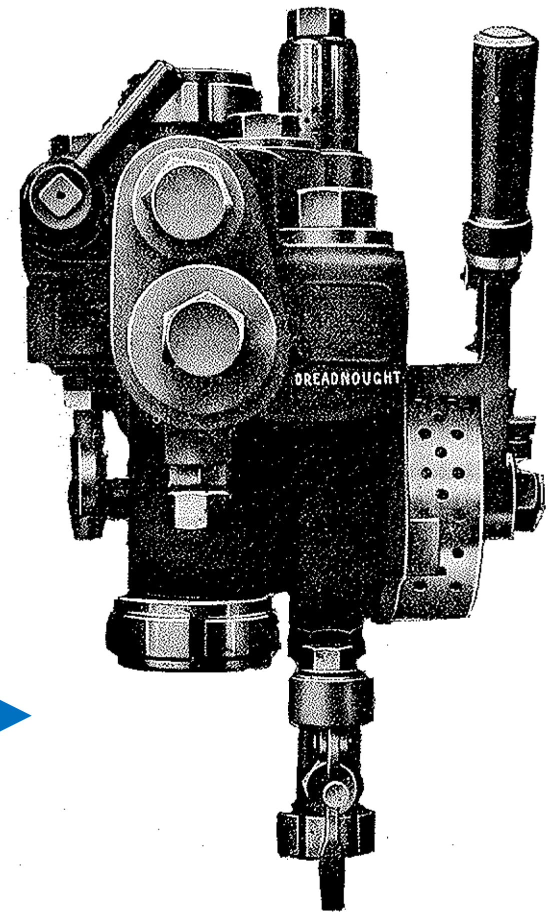
Vacuum brakes

The next section of slides will examine the actual internal configuration of the vacuum brake controllers and ejectors used on the Ffestiniog and Welsh Highland Railways.

The dreadnought is typical on the Ffestiniog Railway steam locomotives.

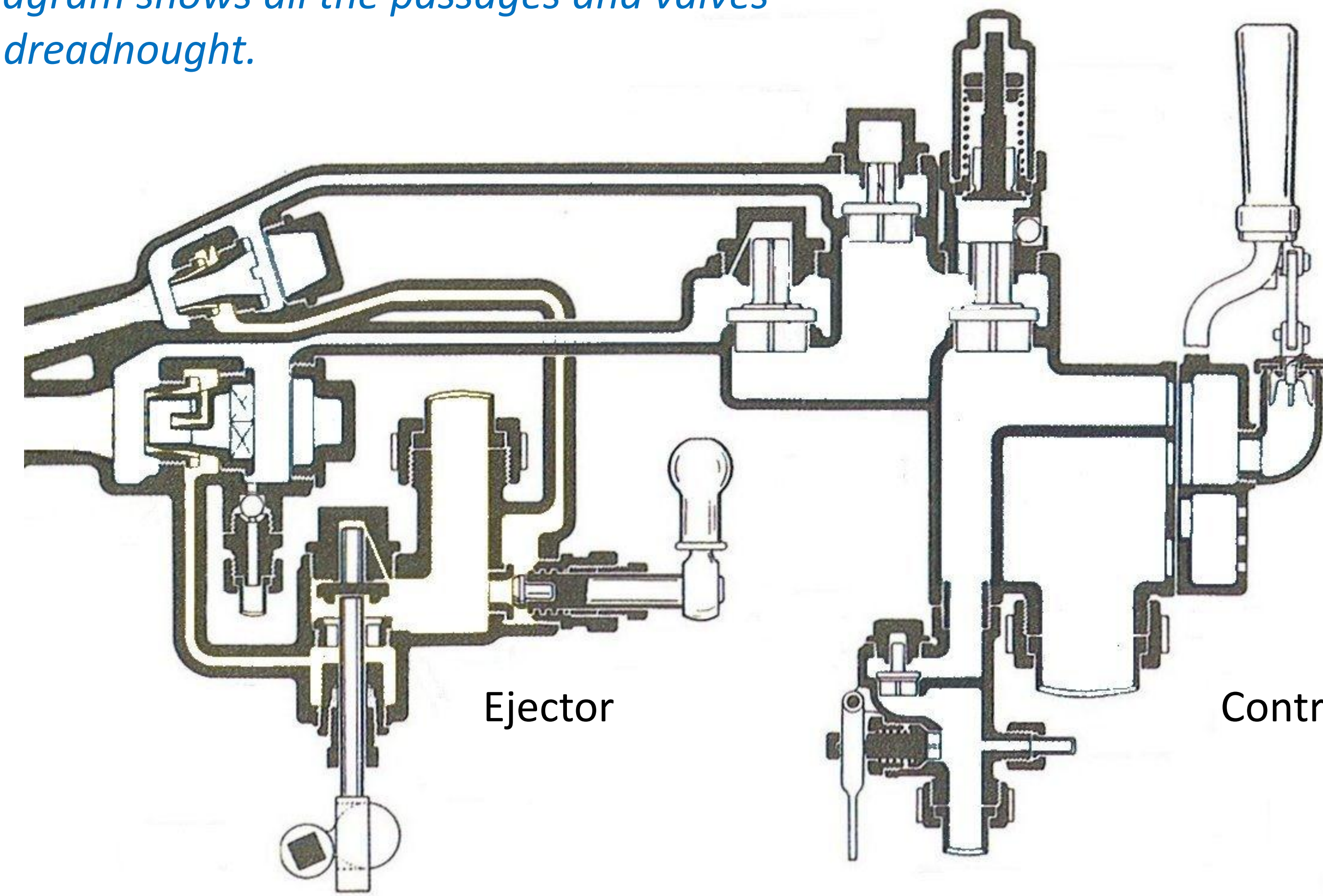
The SJ brake controller is typical on the Welsh Highland Railway locomotives.

The dreadnought is examined first, being essentially as described by the previous description of a continuous controller.



Vacuum brakes

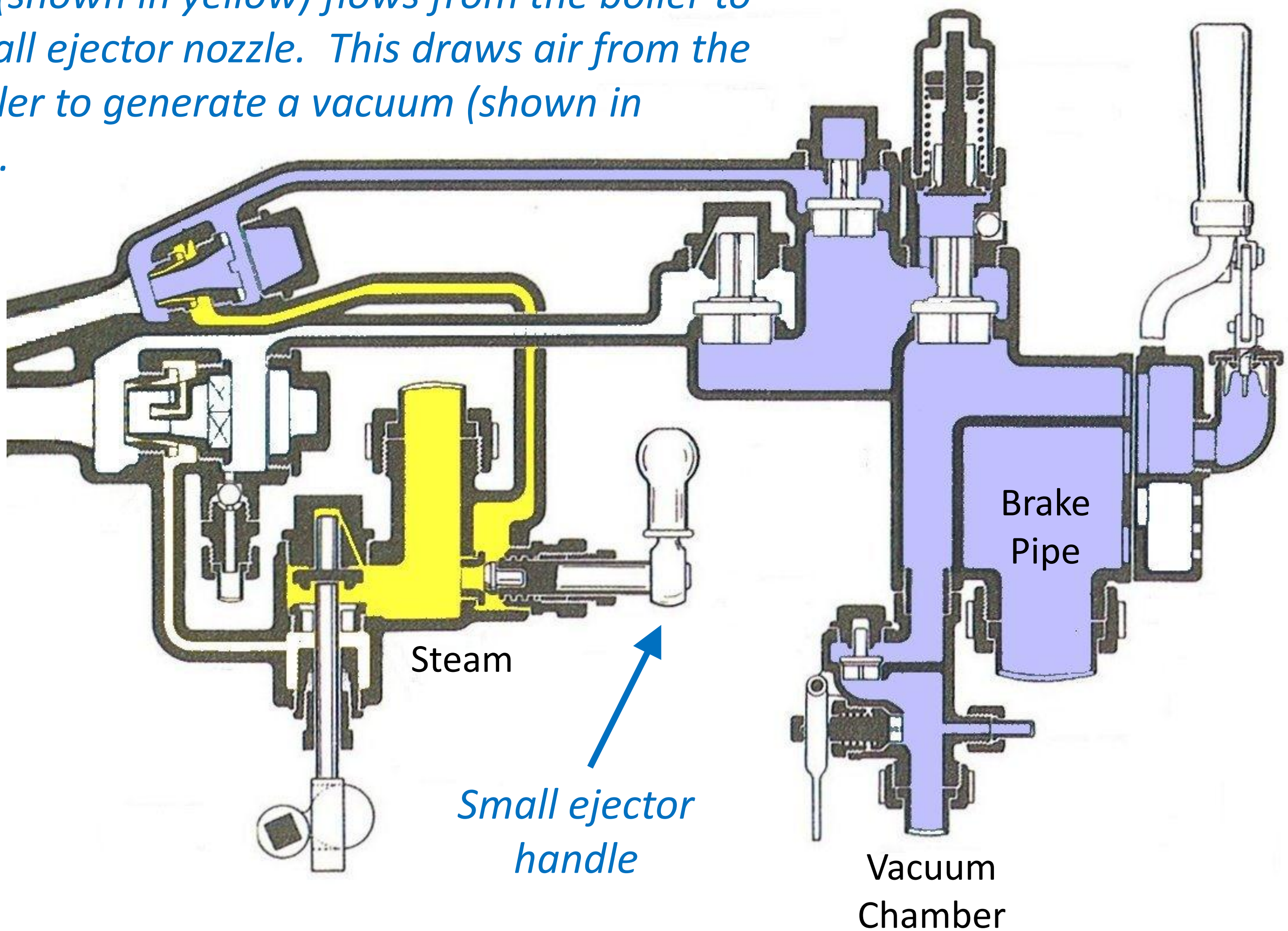
This diagram shows all the passages and valves of the dreadnought.



Let's turn on the small ejector...

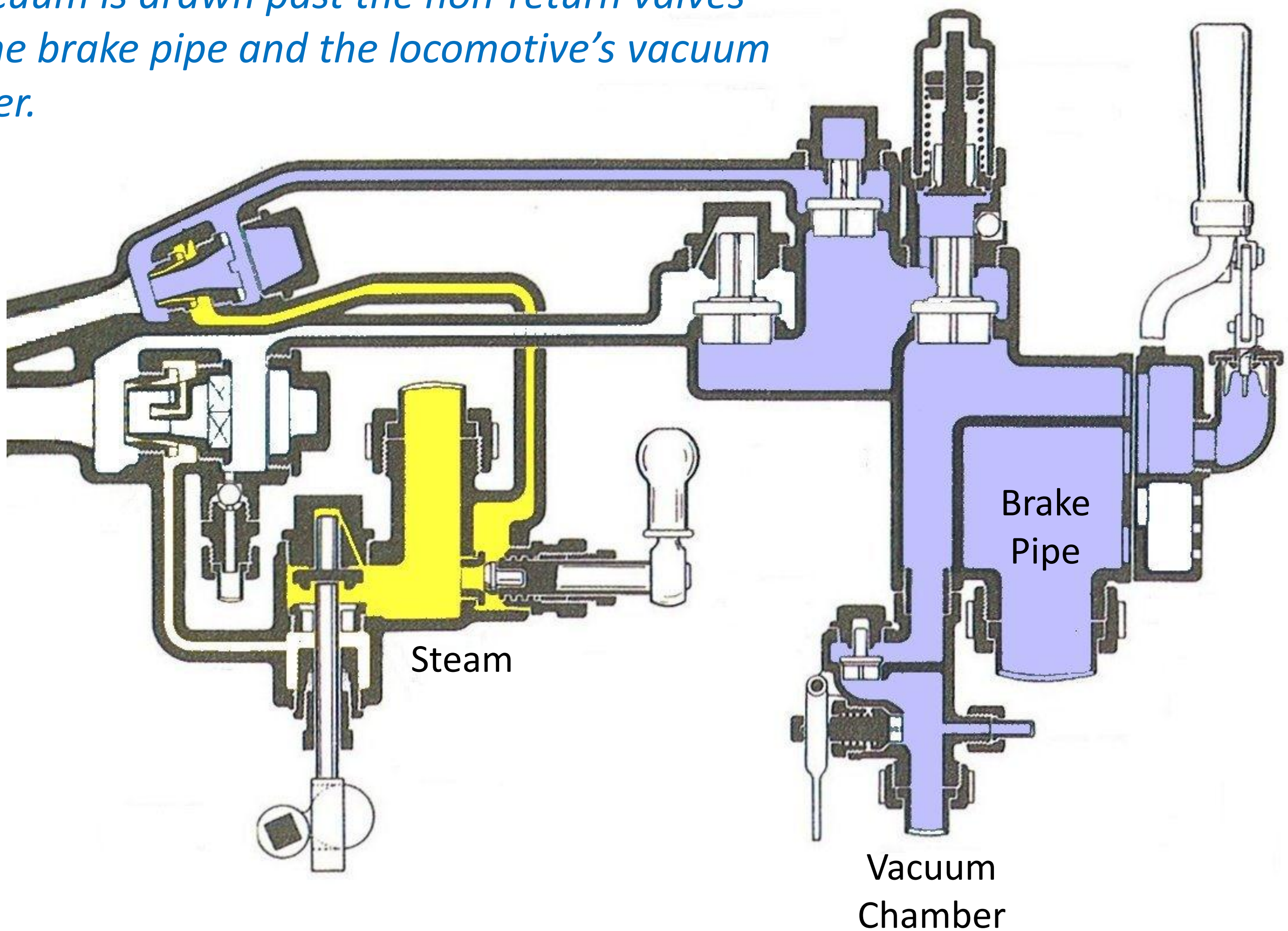
Vacuum brakes

Steam (shown in yellow) flows from the boiler to the small ejector nozzle. This draws air from the controller to generate a vacuum (shown in purple).



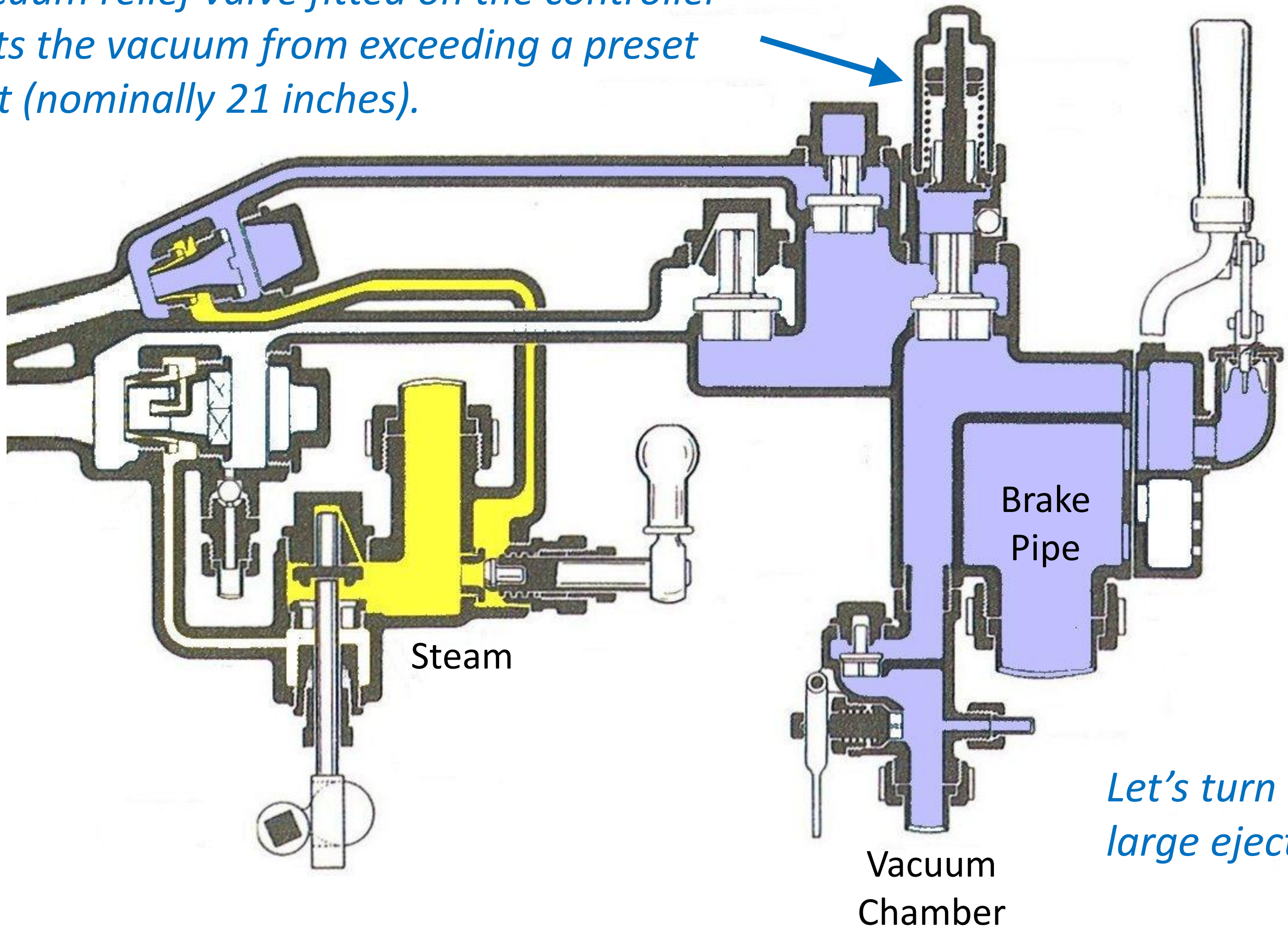
Vacuum brakes

The vacuum is drawn past the non-return valves from the brake pipe and the locomotive's vacuum chamber.



Vacuum brakes

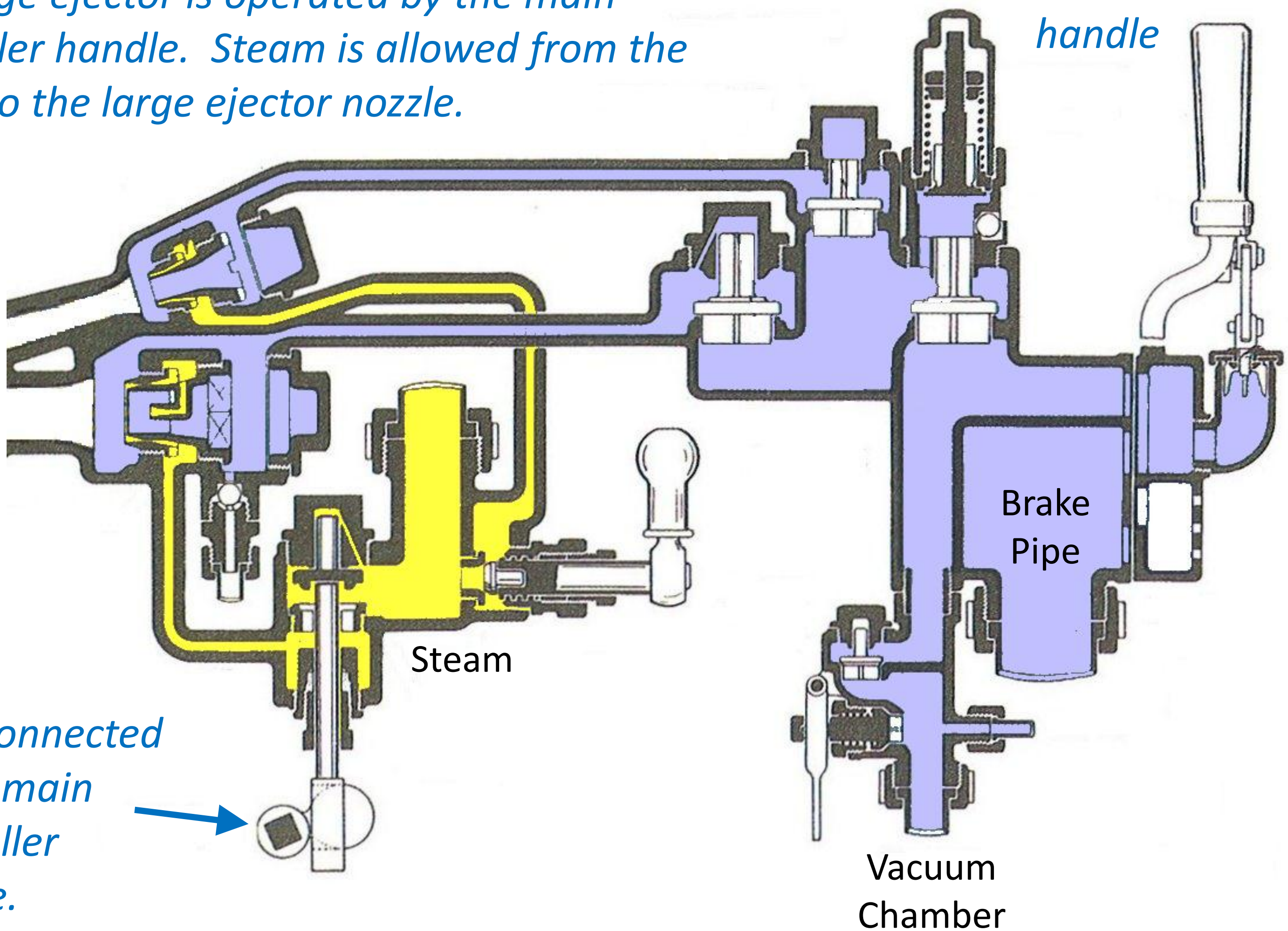
The vacuum relief valve fitted on the controller prevents the vacuum from exceeding a preset amount (nominally 21 inches).



Let's turn on the large ejector...

Vacuum brakes

The large ejector is operated by the main controller handle. Steam is allowed from the boiler to the large ejector nozzle.

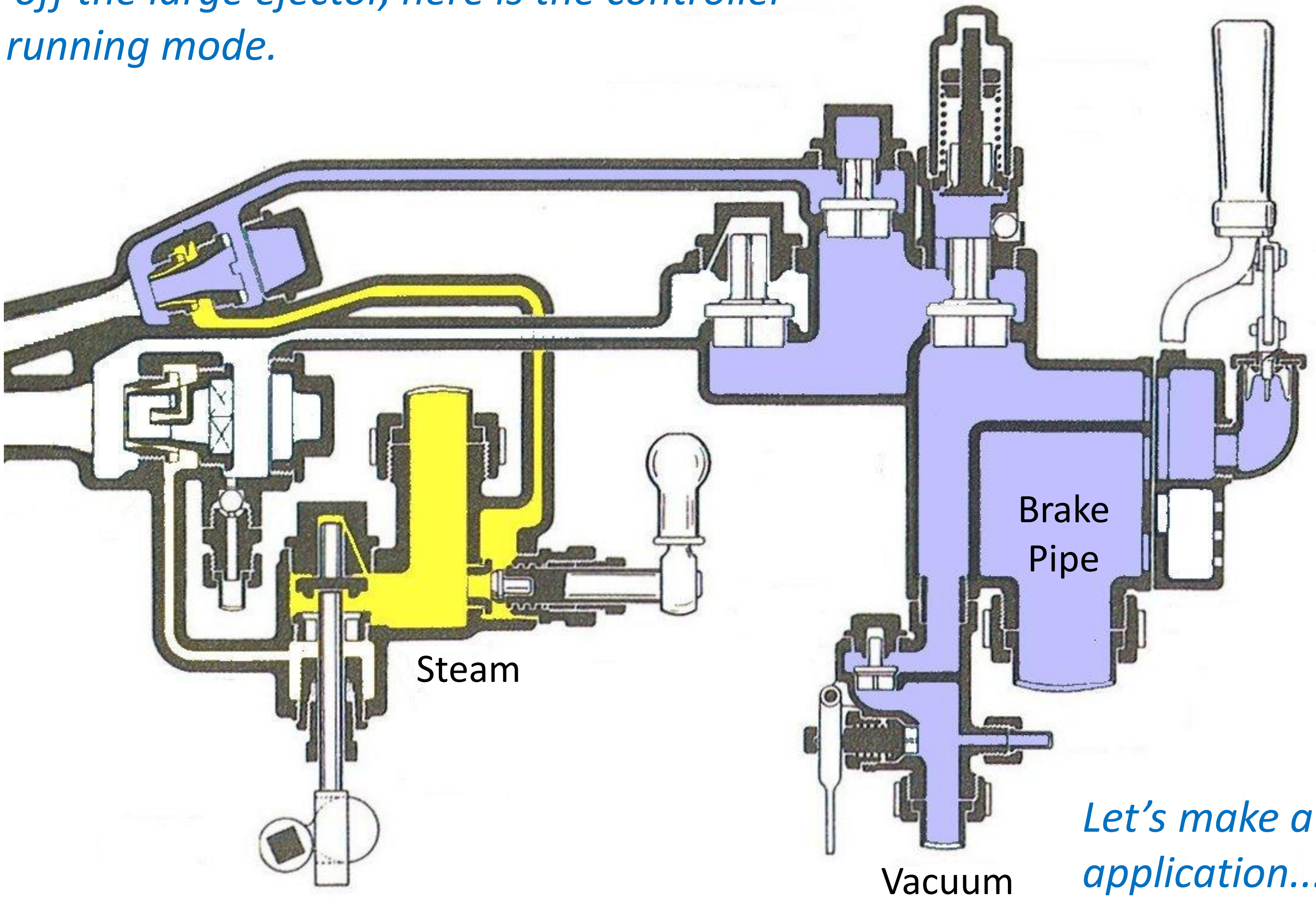


Main controller handle

Cam connected to the main controller handle.

Vacuum brakes

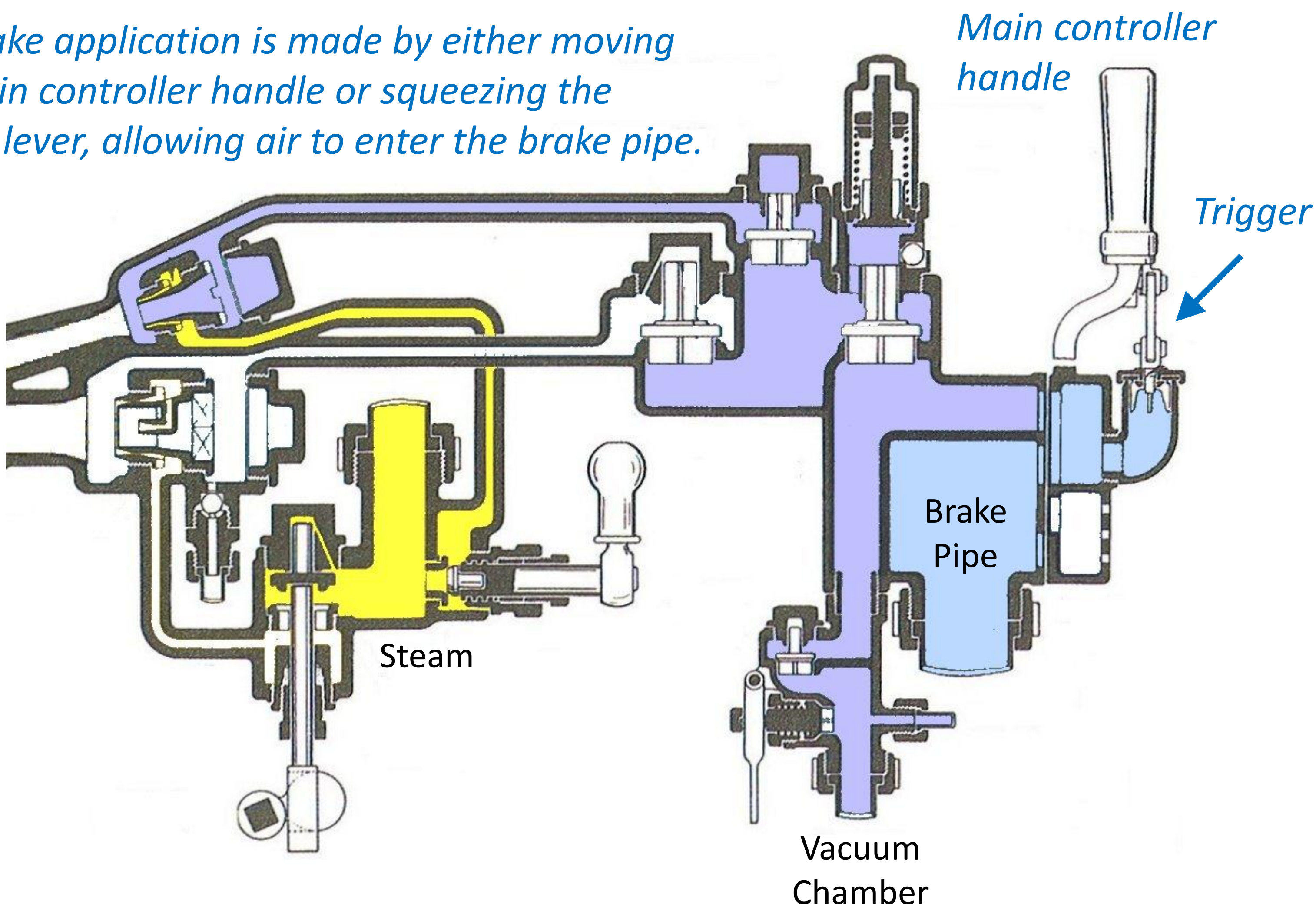
Turning off the large ejector, here is the controller back in running mode.



Let's make a brake application...

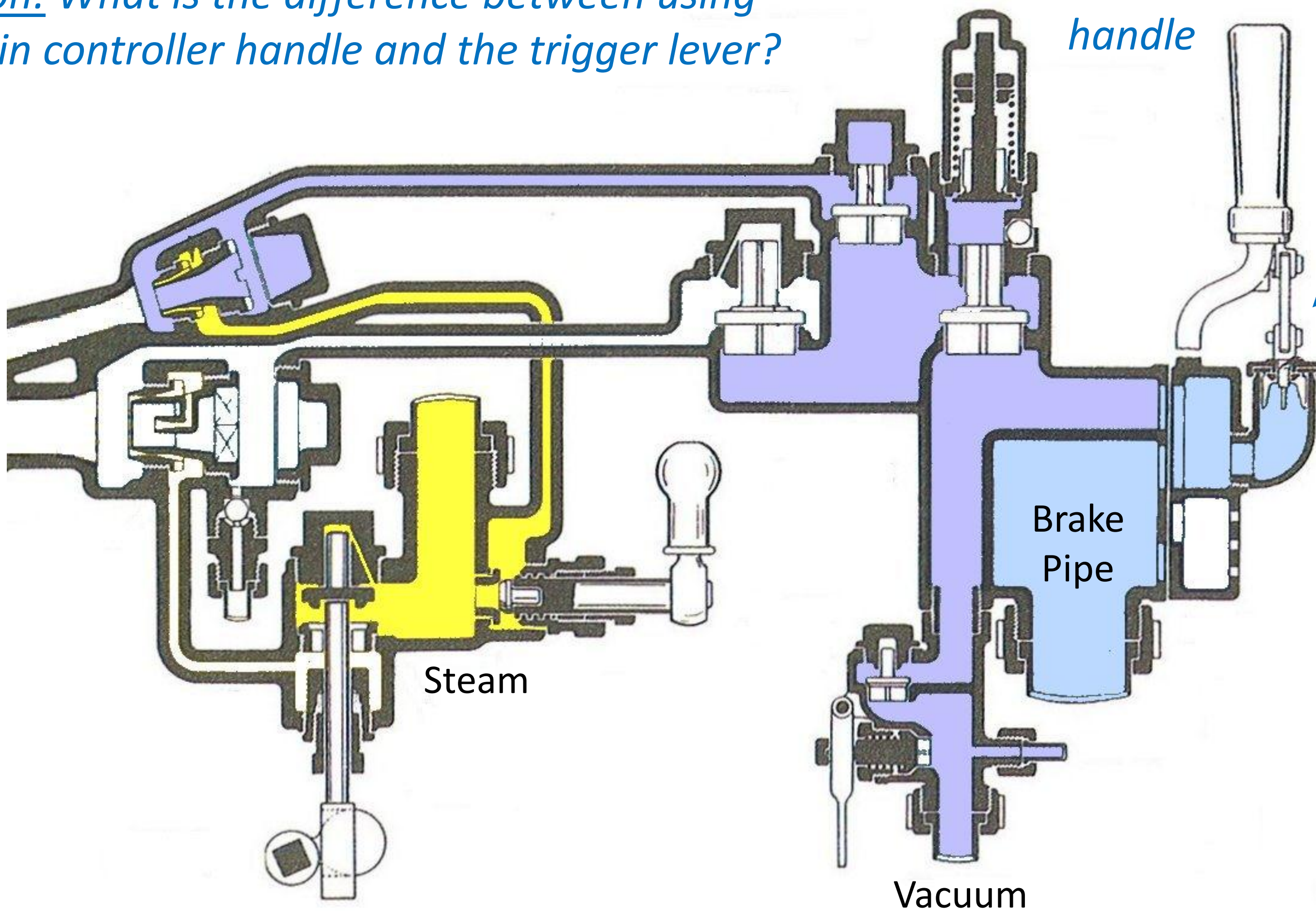
Vacuum brakes

The brake application is made by either moving the main controller handle or squeezing the trigger lever, allowing air to enter the brake pipe.



Vacuum brakes

<u>Question:</u> What is the difference between using the main controller handle and the trigger lever?



Vacuum brakes

Answer:

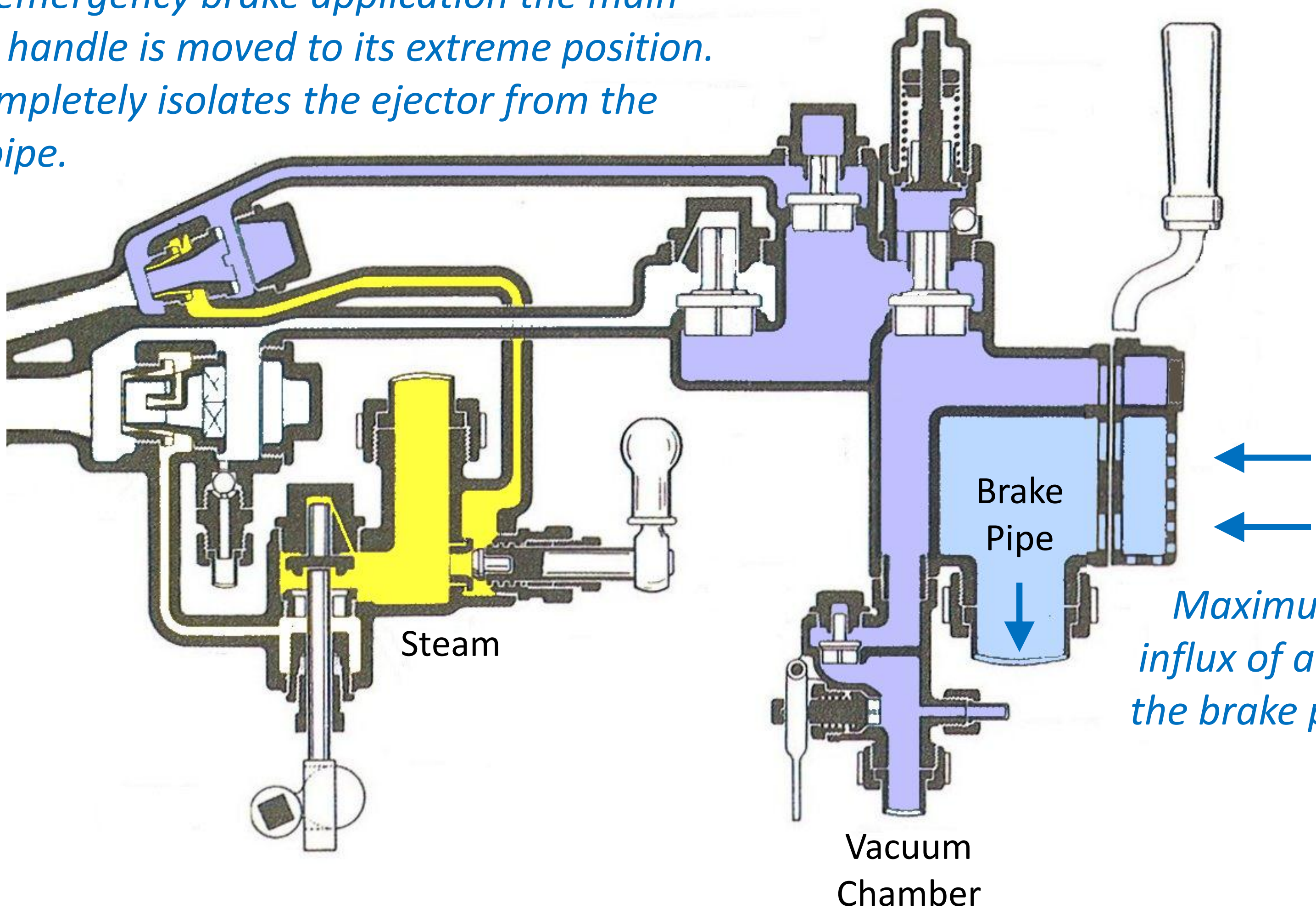
Moving the main controller handle will start to cut off the connection between the ejector and the brake pipe.

Squeezing the trigger allows only a small amount of air to enter the controller through the poppet valve, whilst the ejector will continue to draw air from the brake pipe.

Hence, the trigger provides finer control of the air entering the brake pipe during light applications. However, it is unable to let enough air into the brake pipe for a harsh brake application.

Vacuum brakes

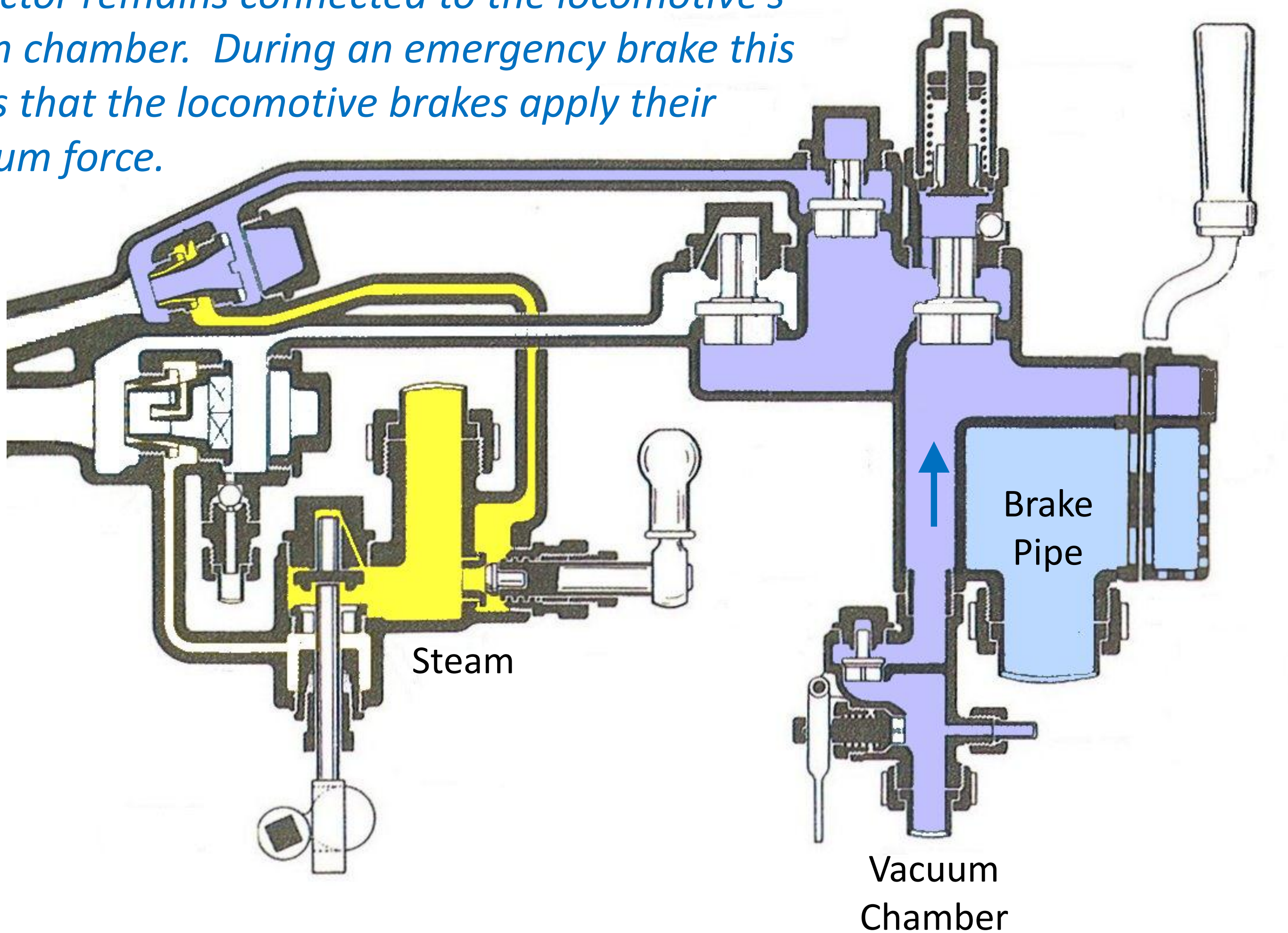
For an emergency brake application the main control handle is moved to its extreme position. This completely isolates the ejector from the brake pipe.



Maximum influx of air to the brake pipe.

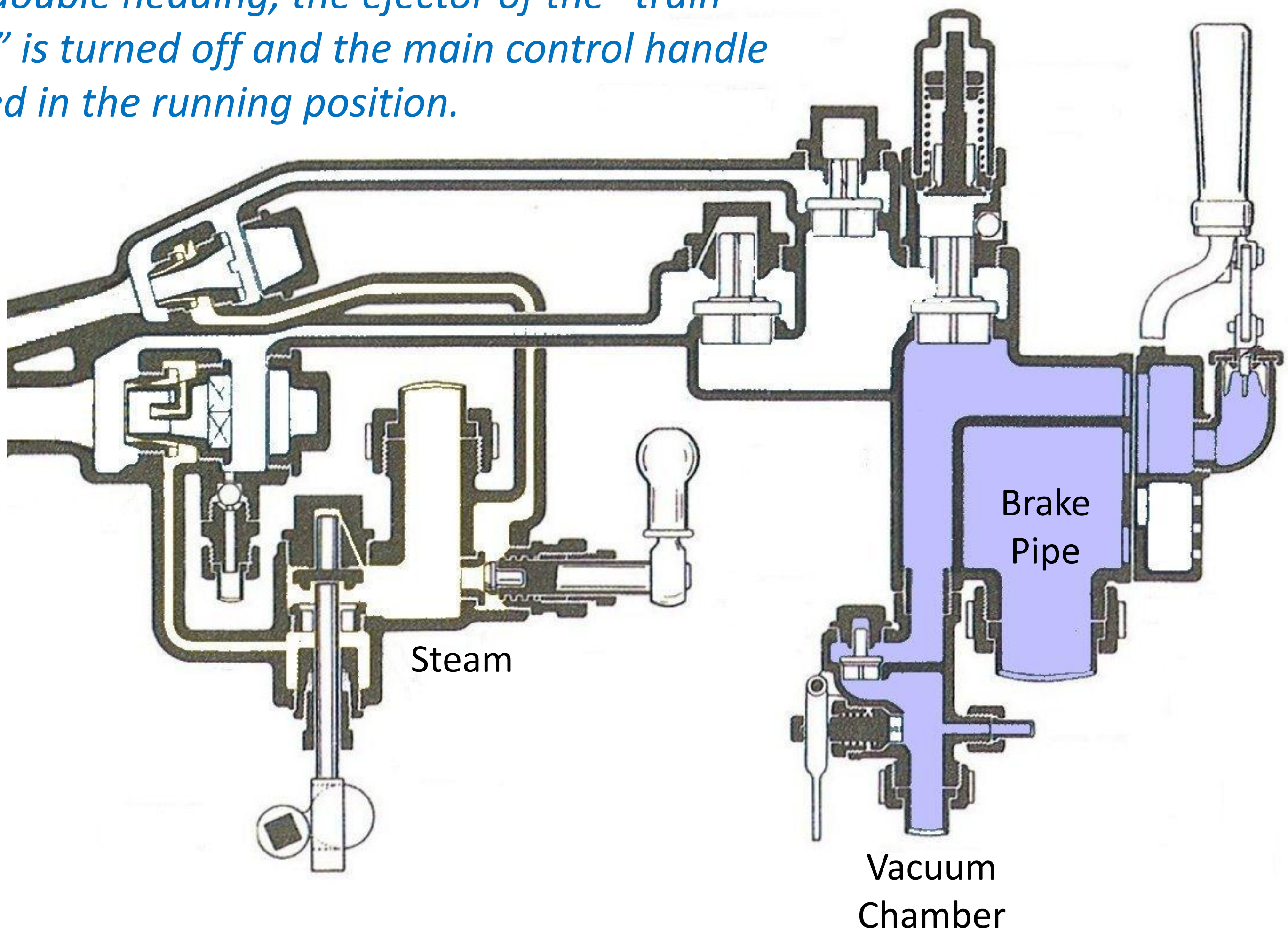
Vacuum brakes

The ejector remains connected to the locomotive's vacuum chamber. During an emergency brake this ensures that the locomotive brakes apply their maximum force.



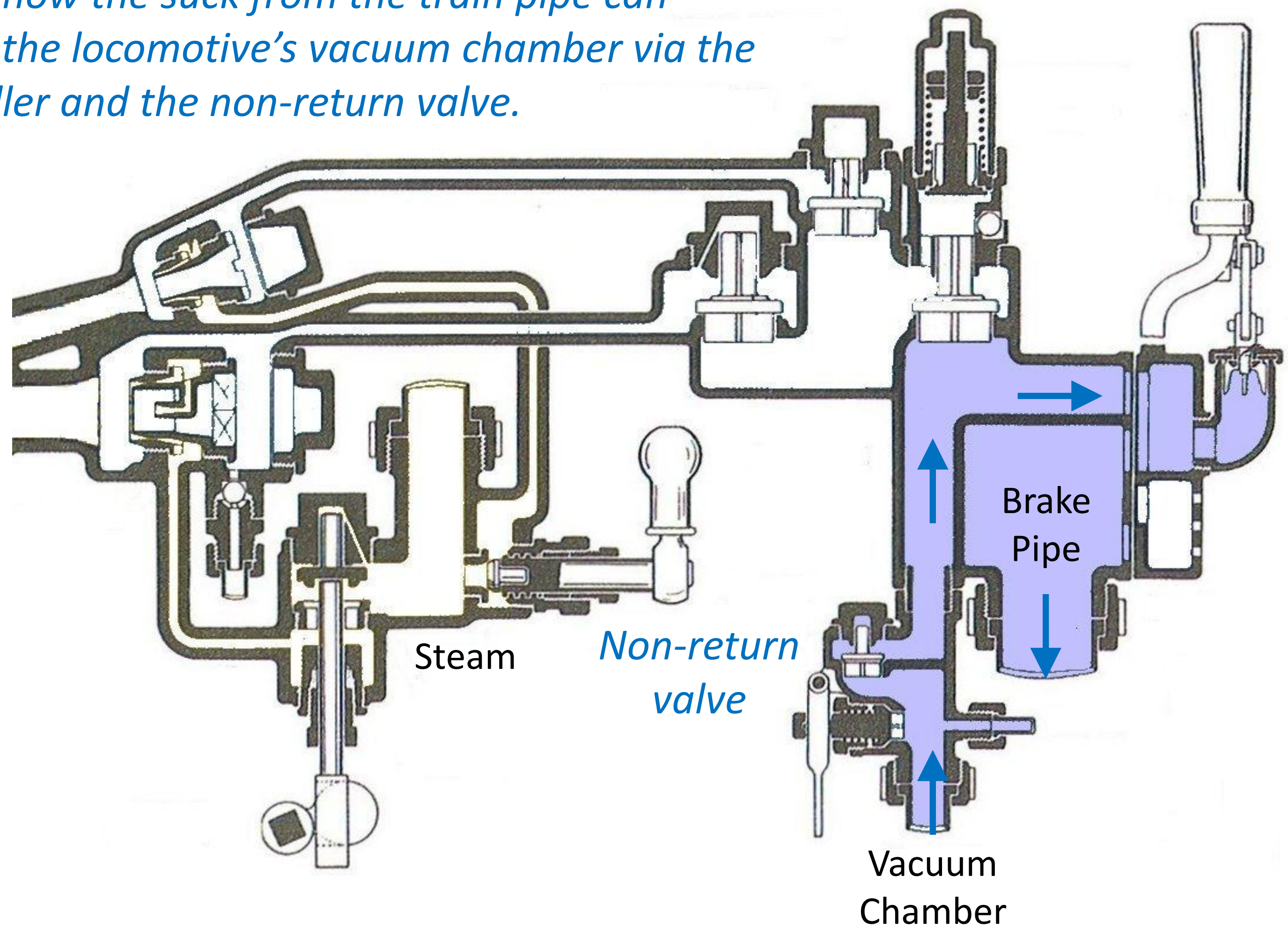
Vacuum brakes

When double heading, the ejector of the "train engine" is turned off and the main control handle is placed in the running position.



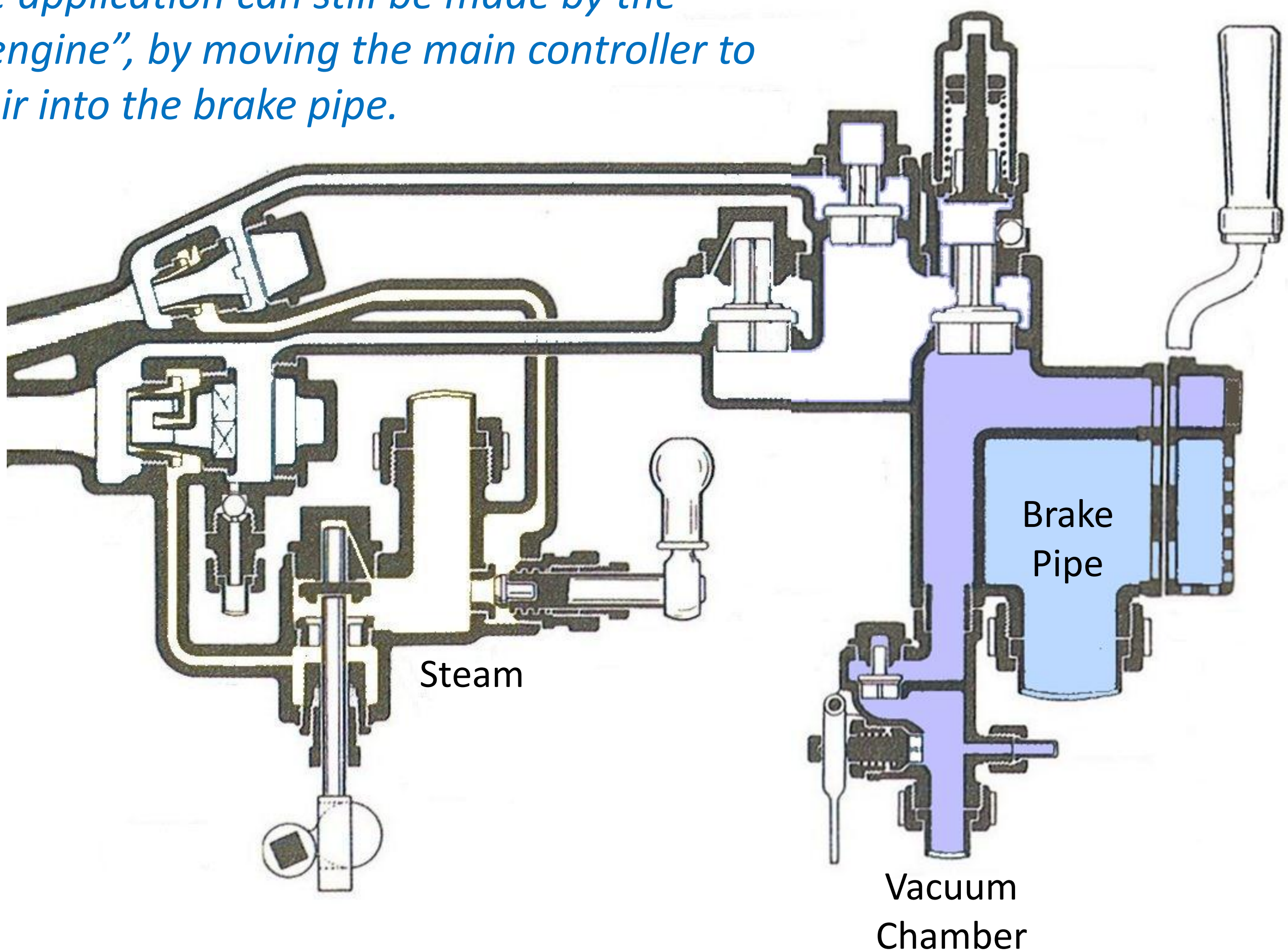
Vacuum brakes

Notice how the suck from the train pipe can access the locomotive's vacuum chamber via the controller and the non-return valve.



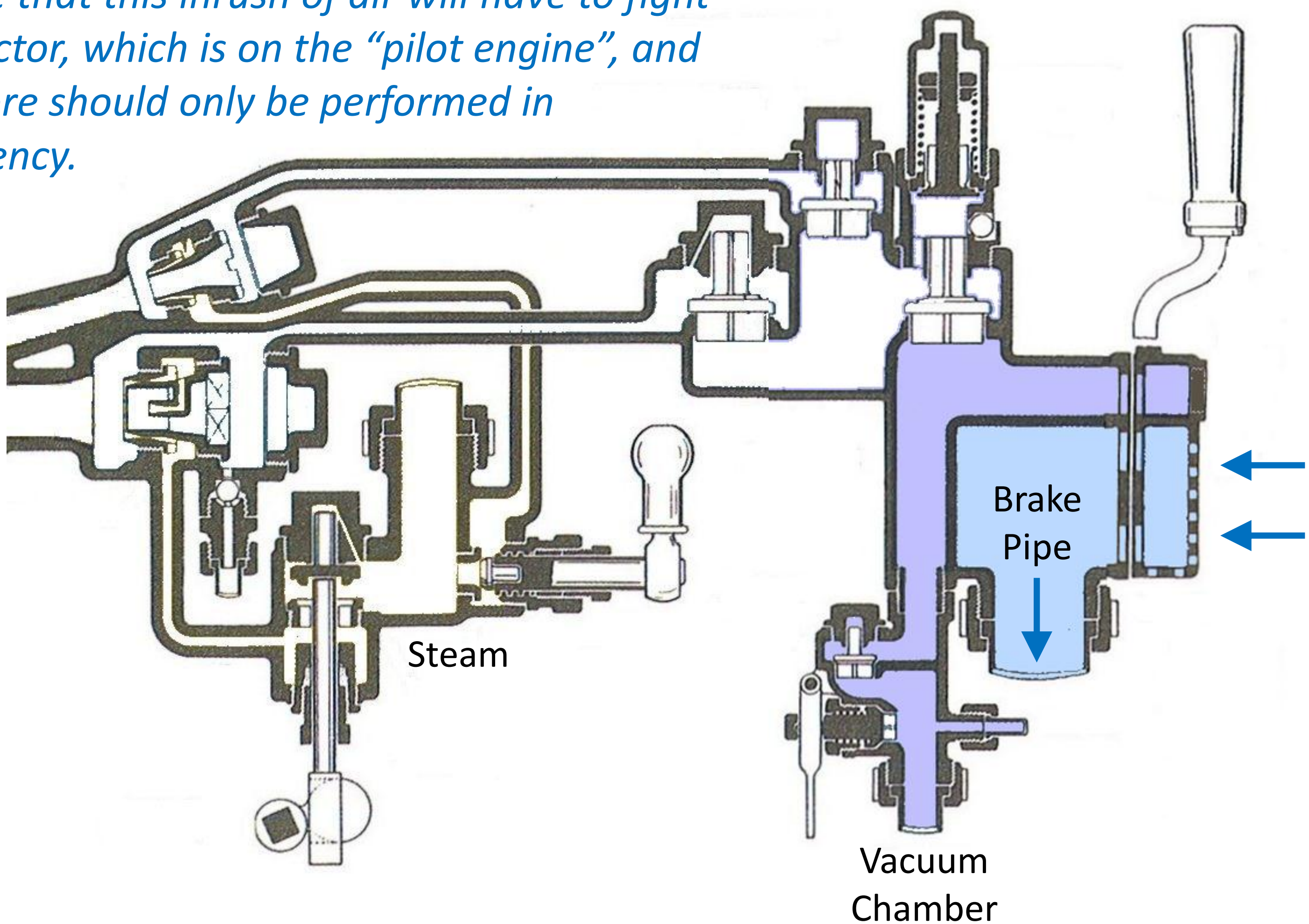
Vacuum brakes

A brake application can still be made by the "train engine", by moving the main controller to allow air into the brake pipe.



Vacuum brakes

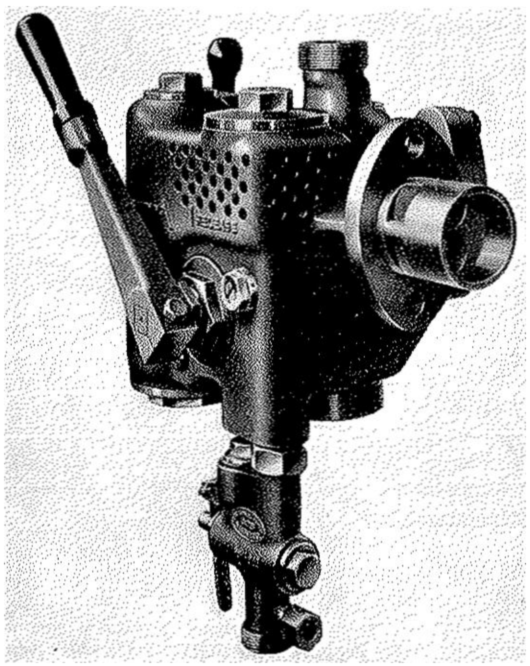
Beware that this inrush of air will have to fight the ejector, which is on the "pilot engine", and therefore should only be performed in emergency.



Vacuum brakes

Now we will examine the SJ controller.

The version on the left is fitted on K1; the version on the right is fitted on the NGG16s.

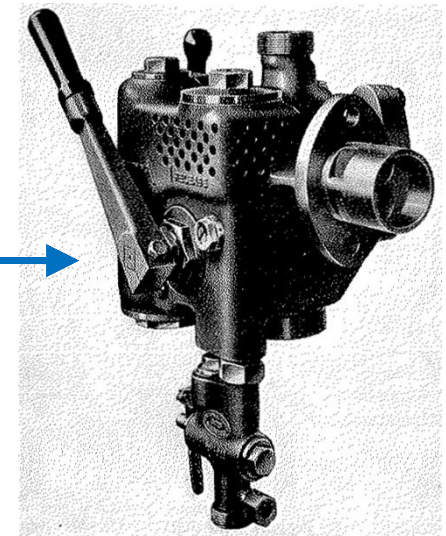


Question: what are the differences?

Vacuum brakes

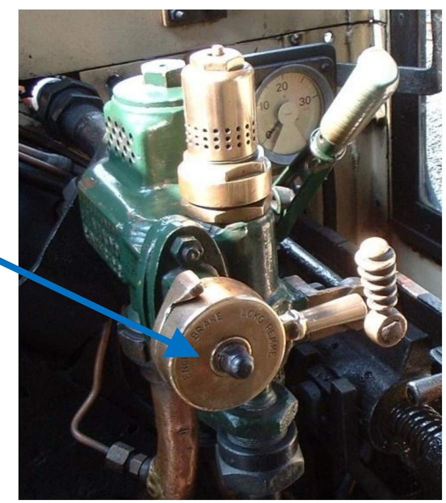
Answer:

The standard type of SJ controller as fitted on K1 incorporates the ejector as part of the same fitting.



The modified version on the NGG16s comprises only the controller mechanism, there being a separate ejector housing on the side of the boiler.

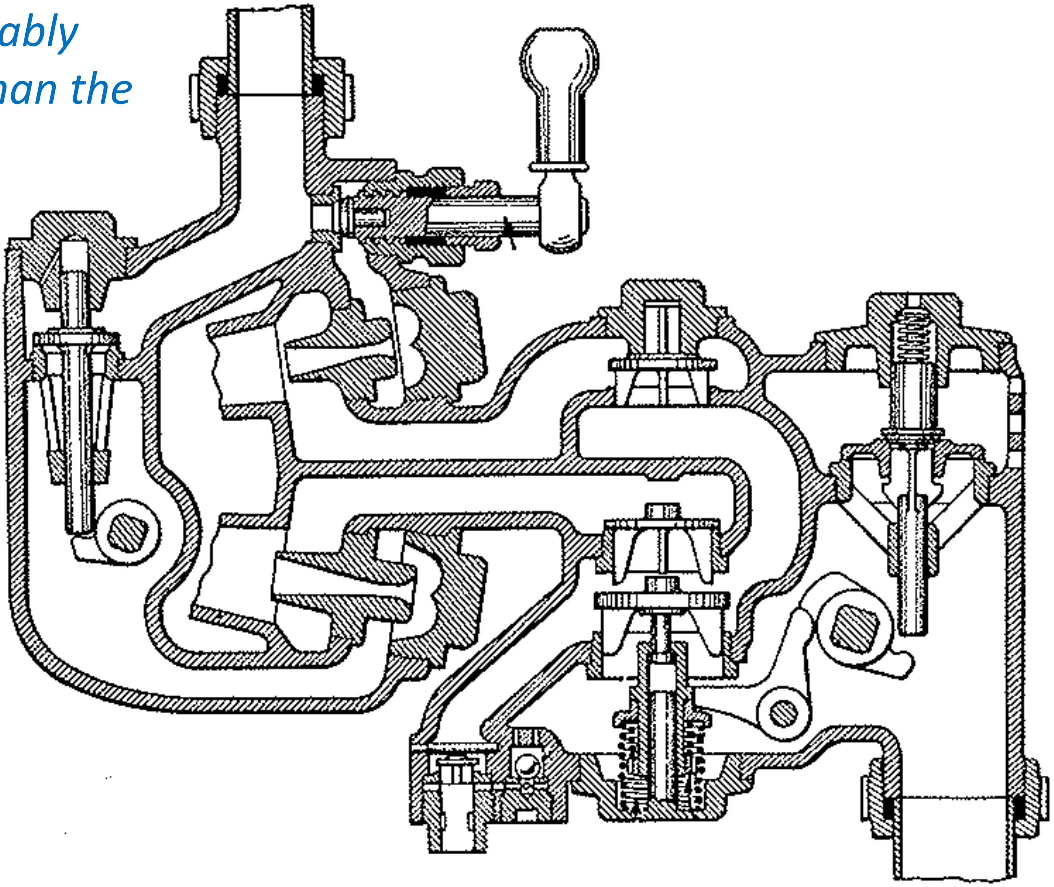
Further, the NGG16 controller incorporates a locomotive parking brake valve, which will be discussed later.



The essential controller mechanism is the same in both of these controllers.

Vacuum brakes

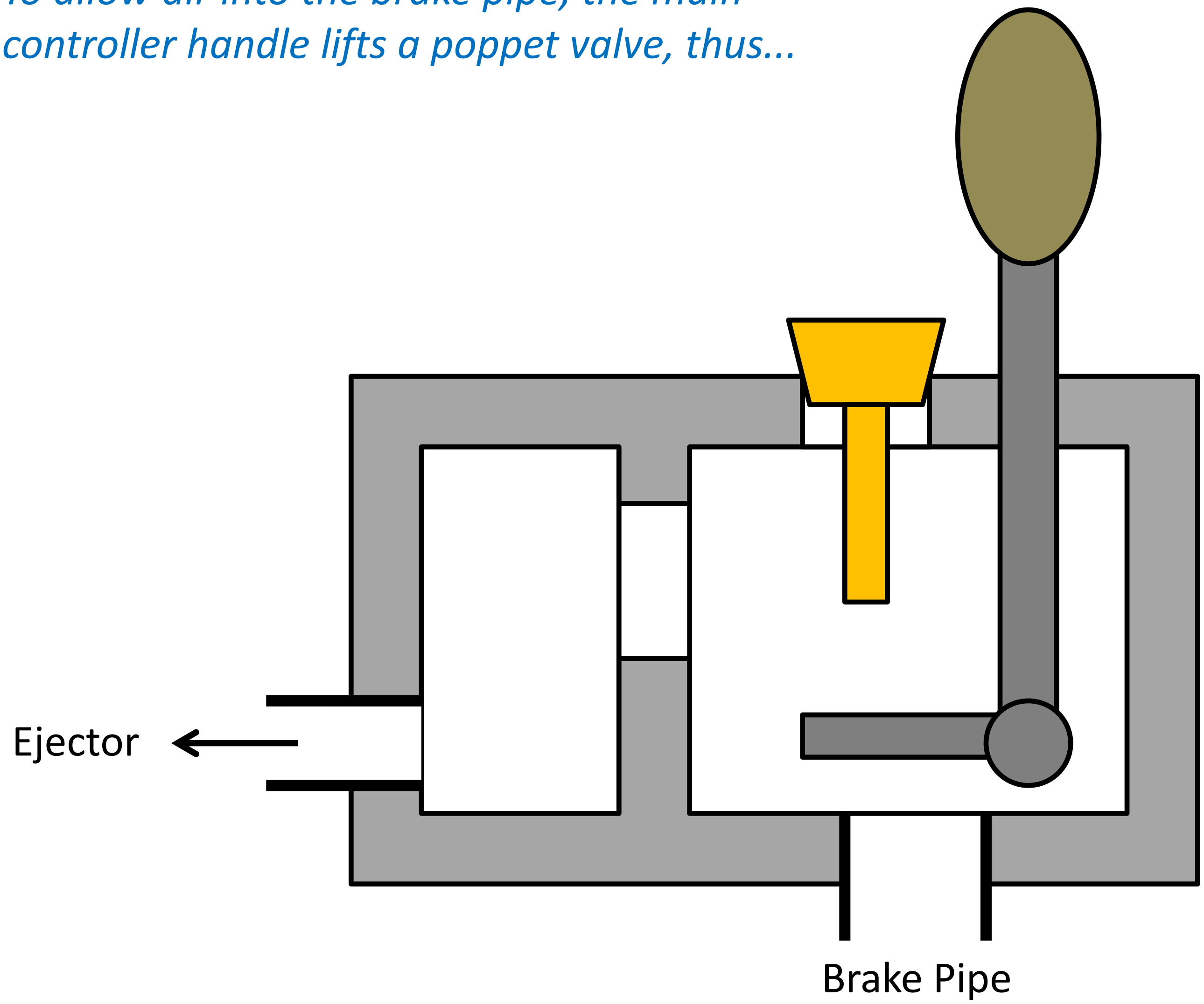
The SJ controller, shown here, is considerably more complex than the dreadnought.



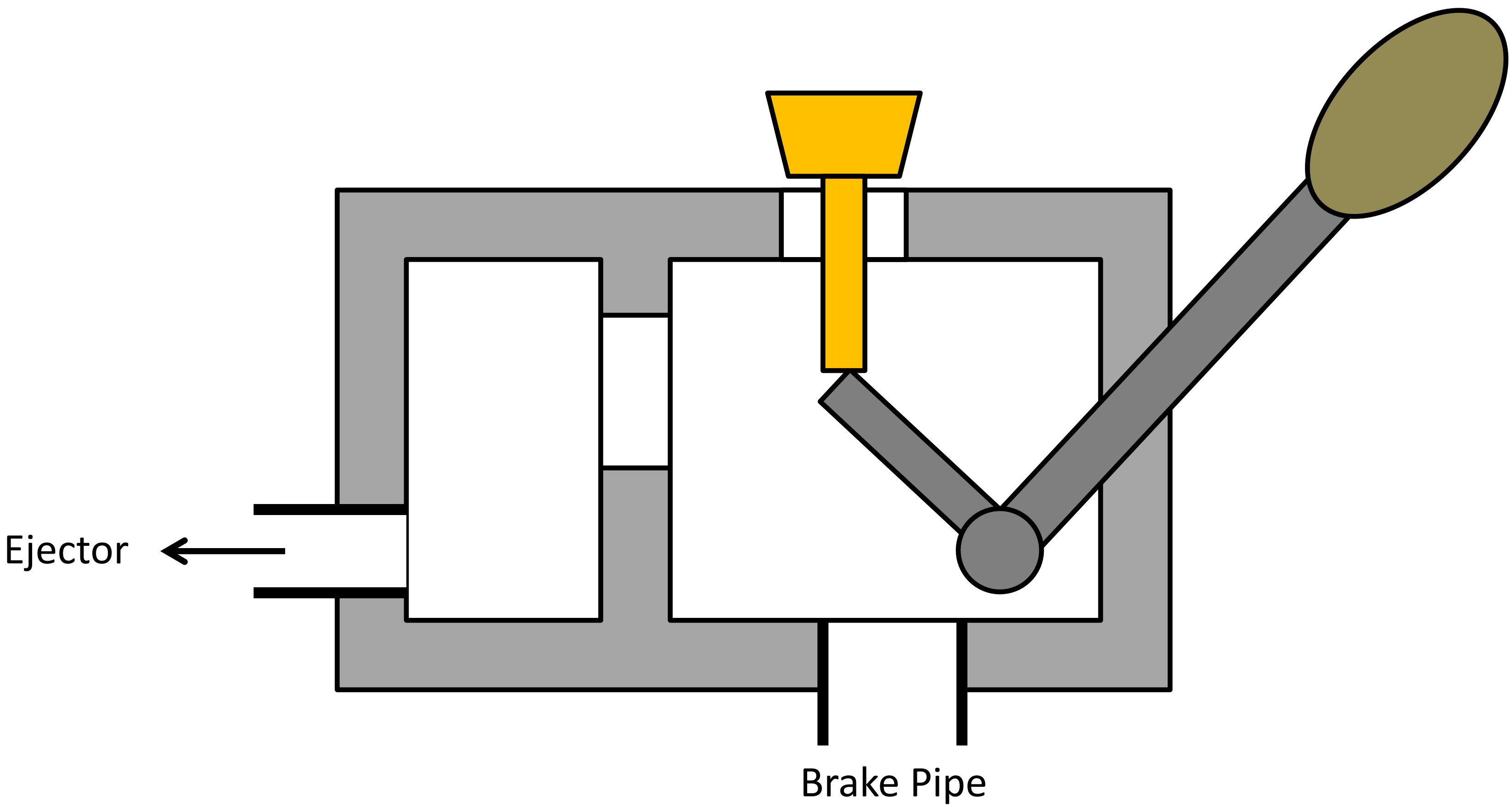
Therefore, we will start with a simpler diagram...

Vacuum brakes

To allow air into the brake pipe, the main controller handle lifts a poppet valve, thus...



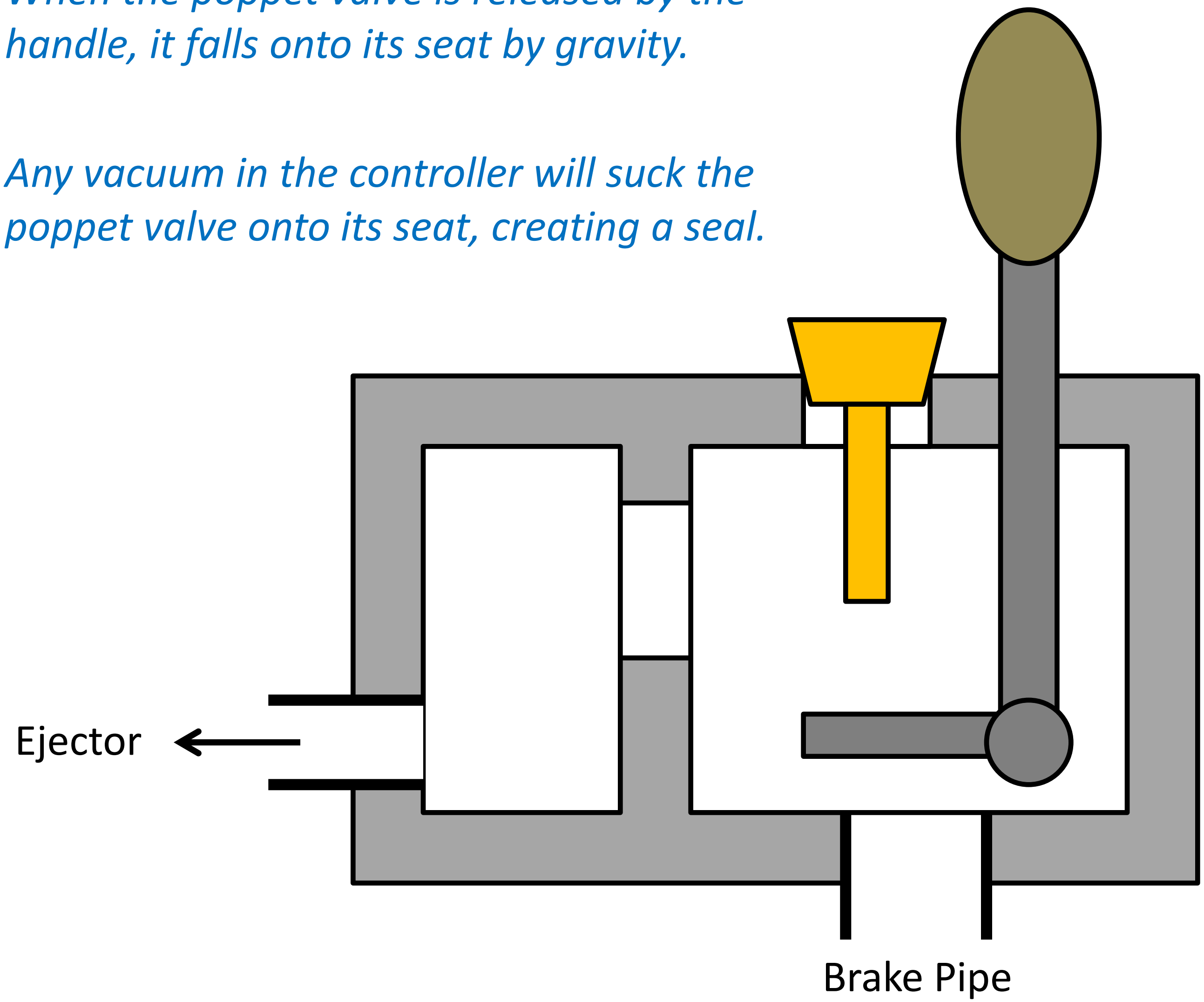
Vacuum brakes



Vacuum brakes

When the poppet valve is released by the handle, it falls onto its seat by gravity.

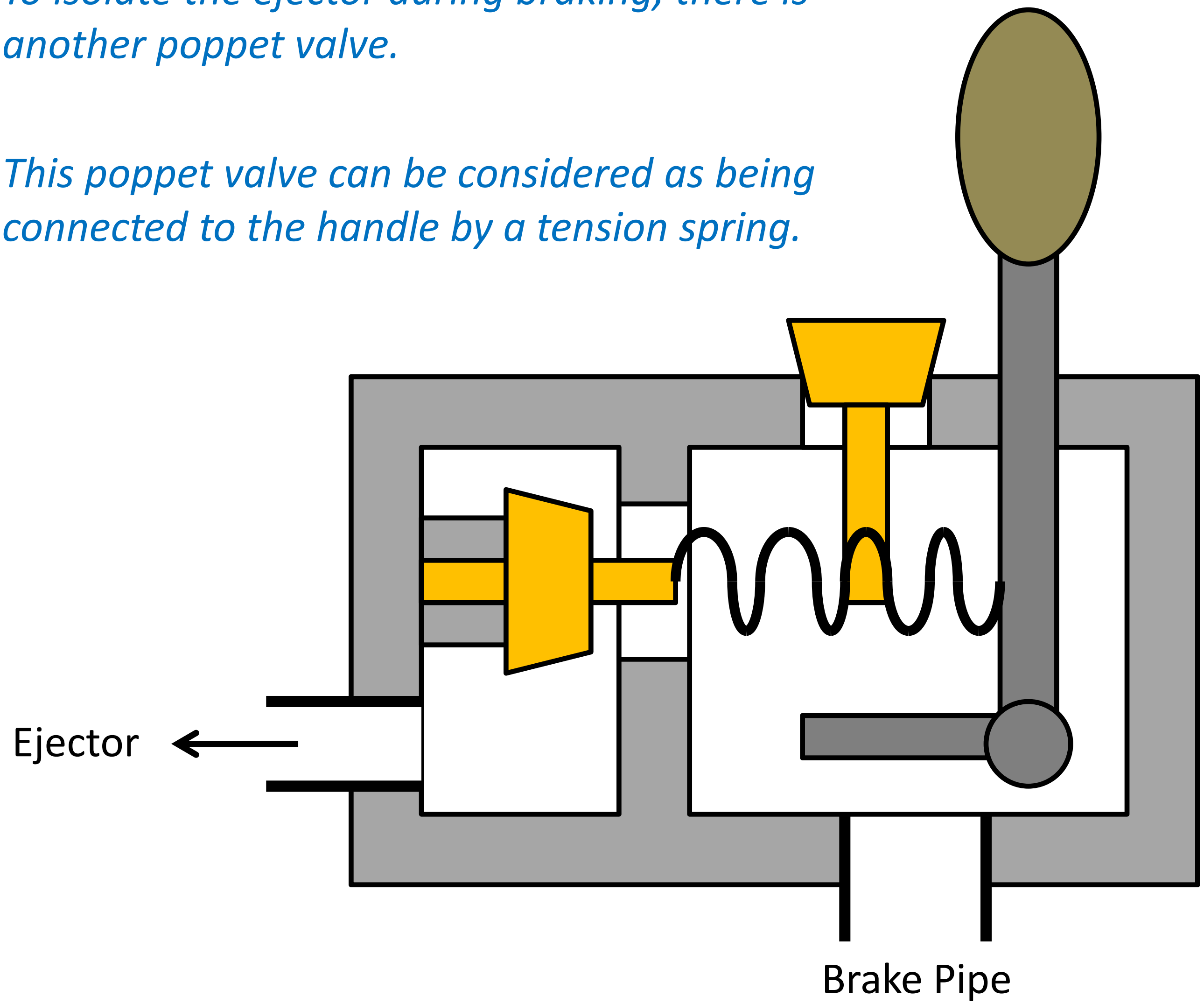
Any vacuum in the controller will suck the poppet valve onto its seat, creating a seal.



Vacuum brakes

To isolate the ejector during braking, there is another poppet valve.

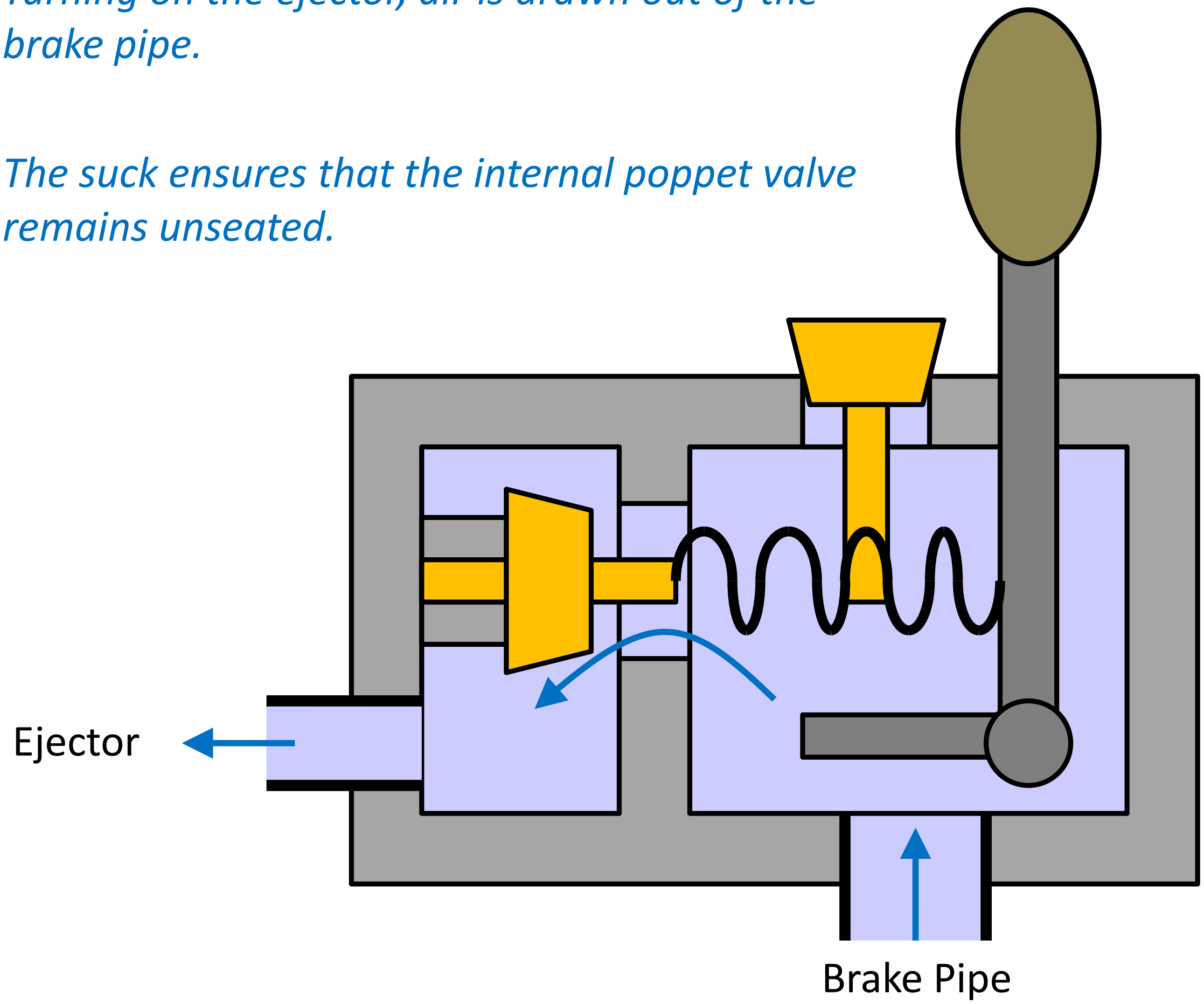
This poppet valve can be considered as being connected to the handle by a tension spring.



Vacuum brakes

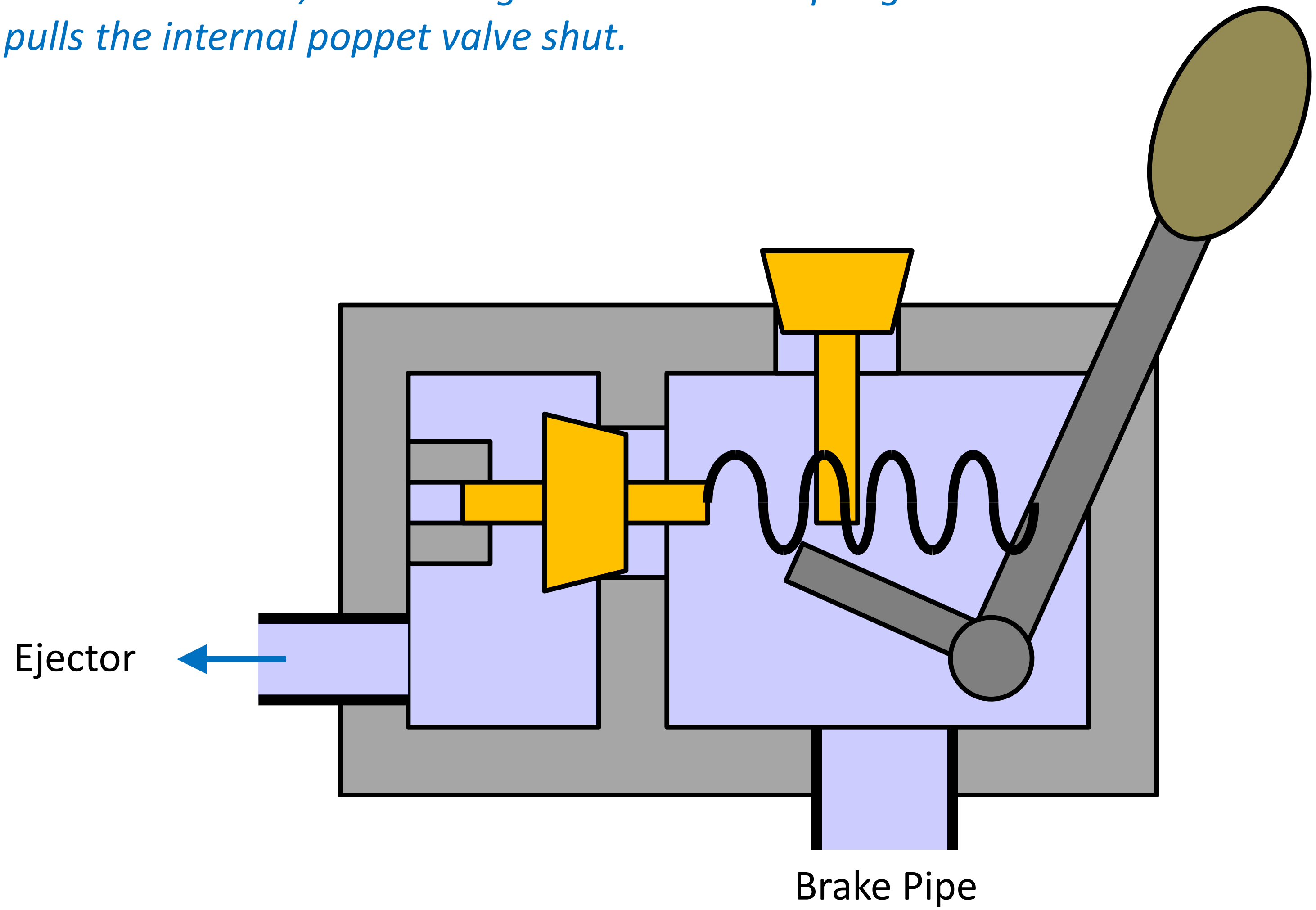
Turning on the ejector, air is drawn out of the brake pipe.

The suck ensures that the internal poppet valve remains unseated.



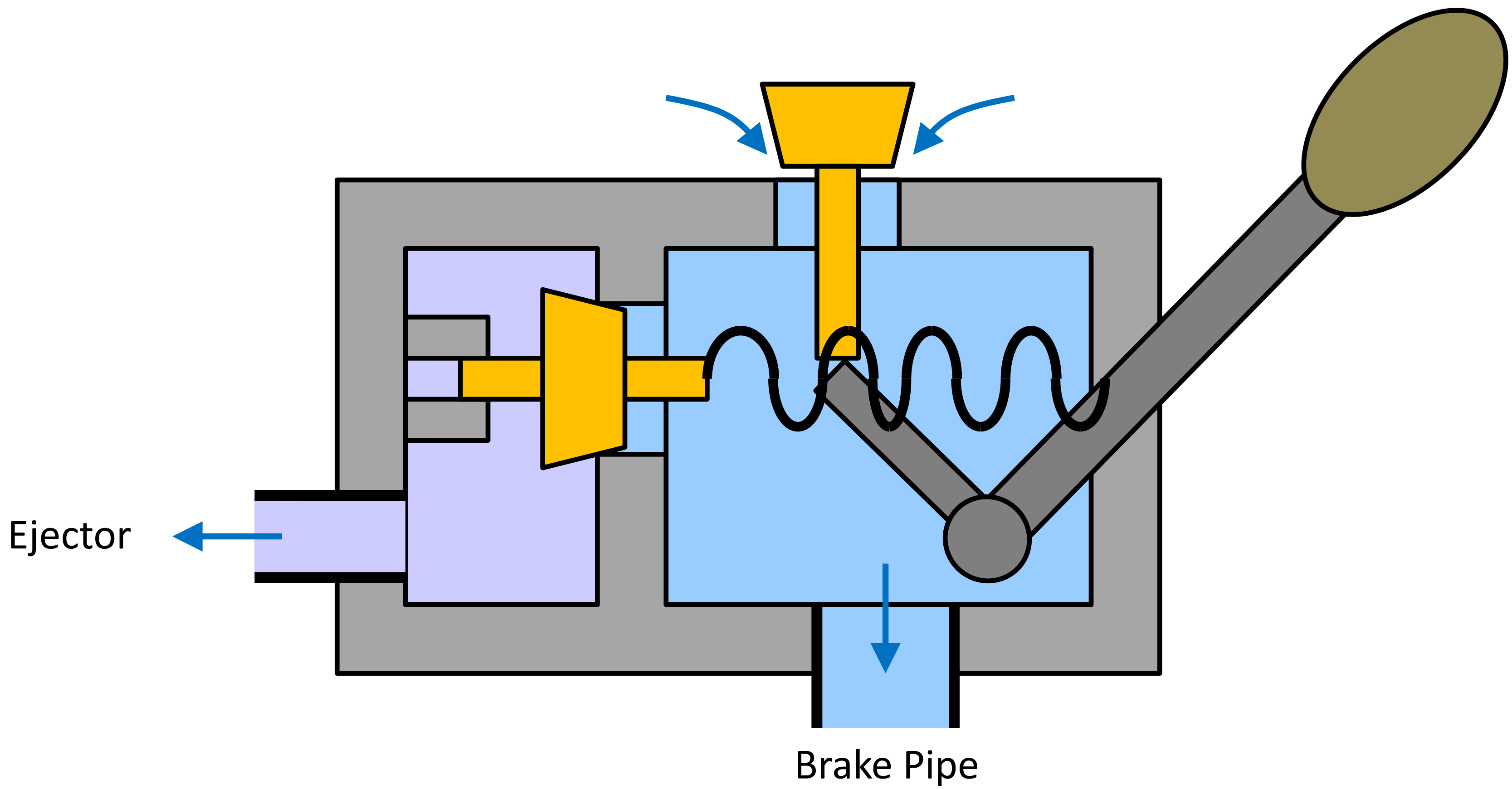
Vacuum brakes

When a brake application is made by moving the main controller handle, tension is generated in the spring which pulls the internal poppet valve shut.



Vacuum brakes

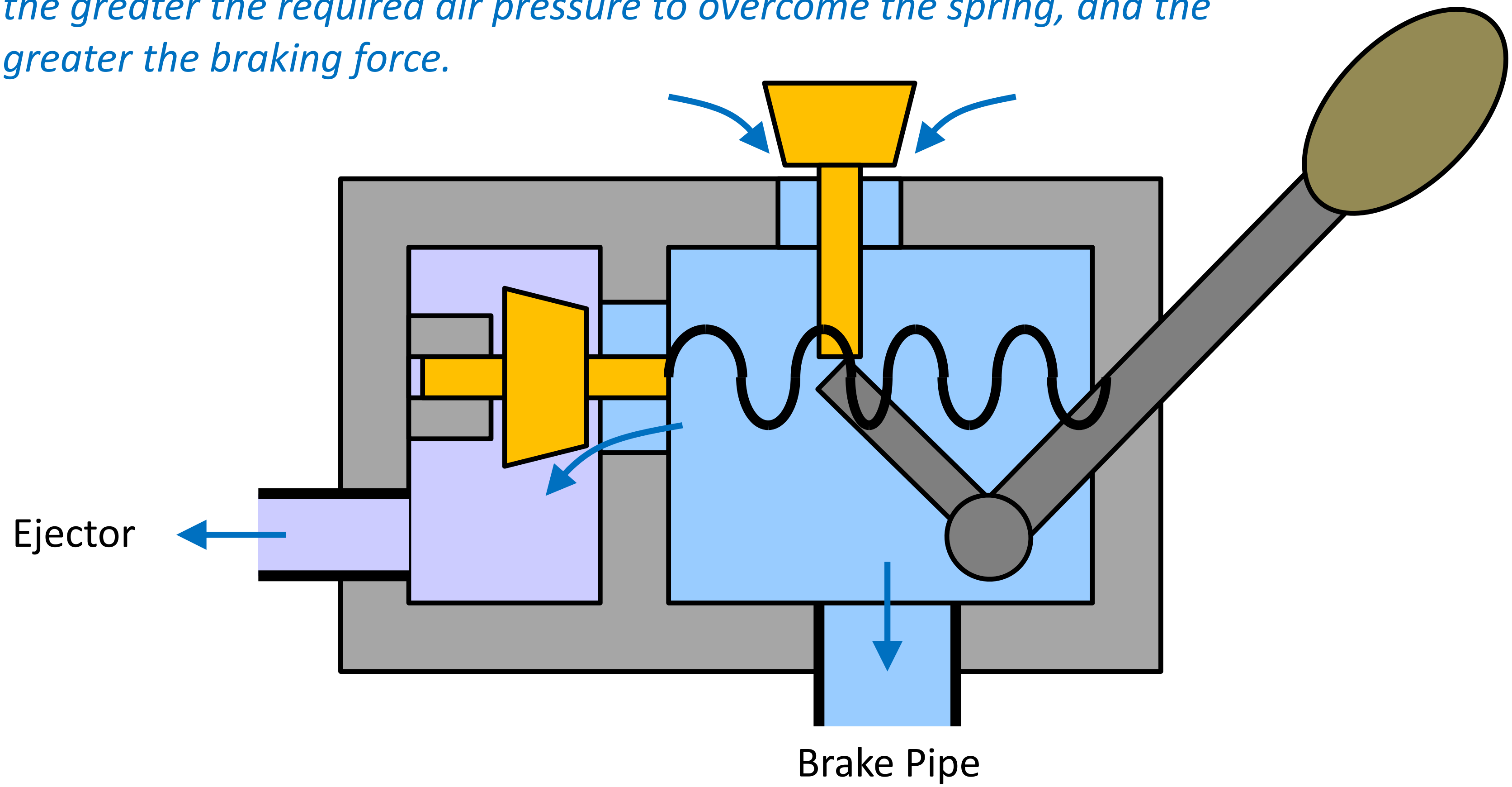
Further movement of the handle will force open the outer poppet valve, allowing air to enter the train brake pipe.



Vacuum brakes

If the handle is held in this position, the air pressure will eventually overcome the spring and escape via the ejector.

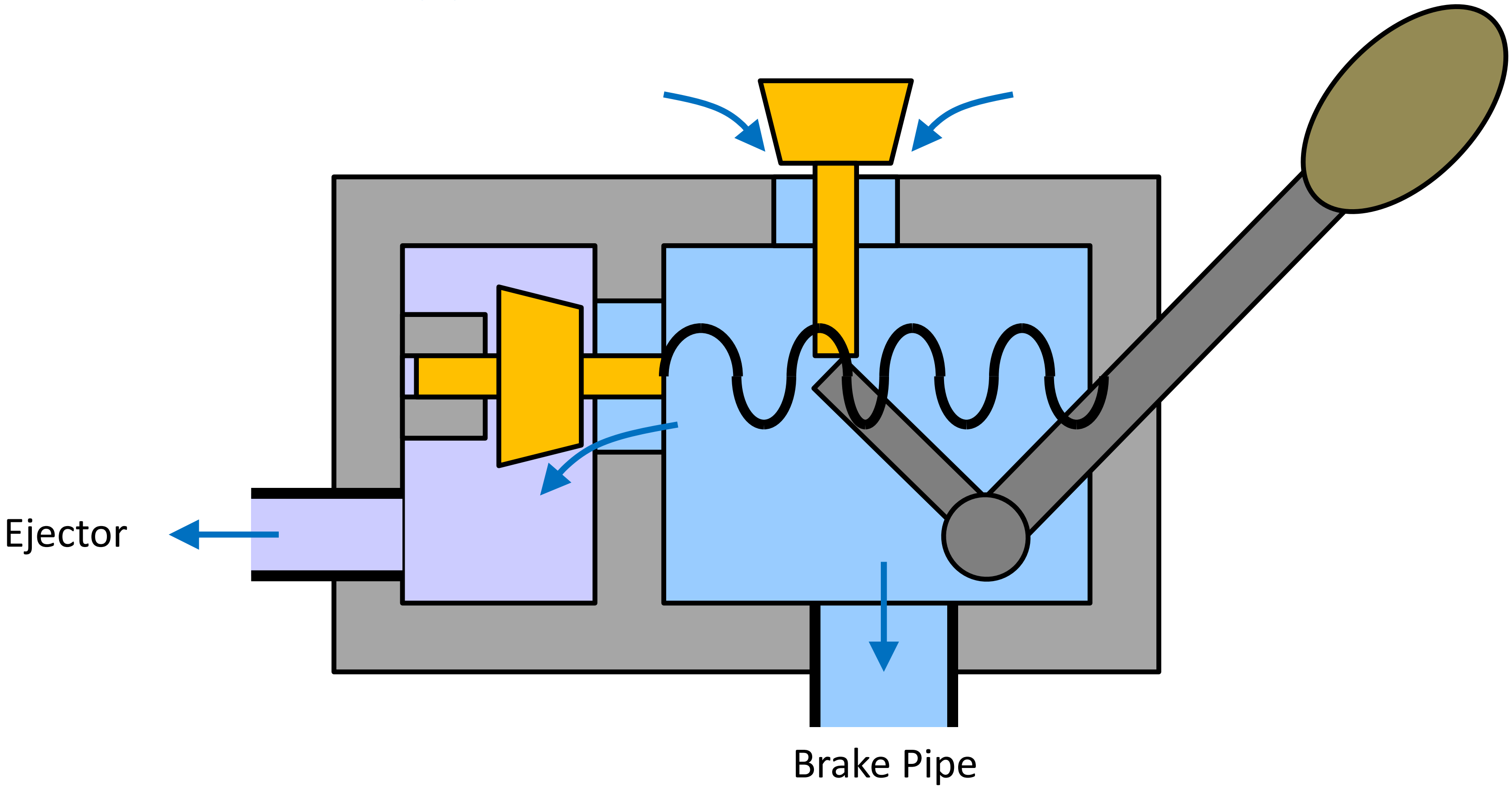
The further the handle is moved, the greater the tension in the spring, the greater the required air pressure to overcome the spring, and the greater the braking force.



Vacuum brakes

Hence, the SJ is a continuous type of controller. The further the handle is moved the greater the braking force will be.

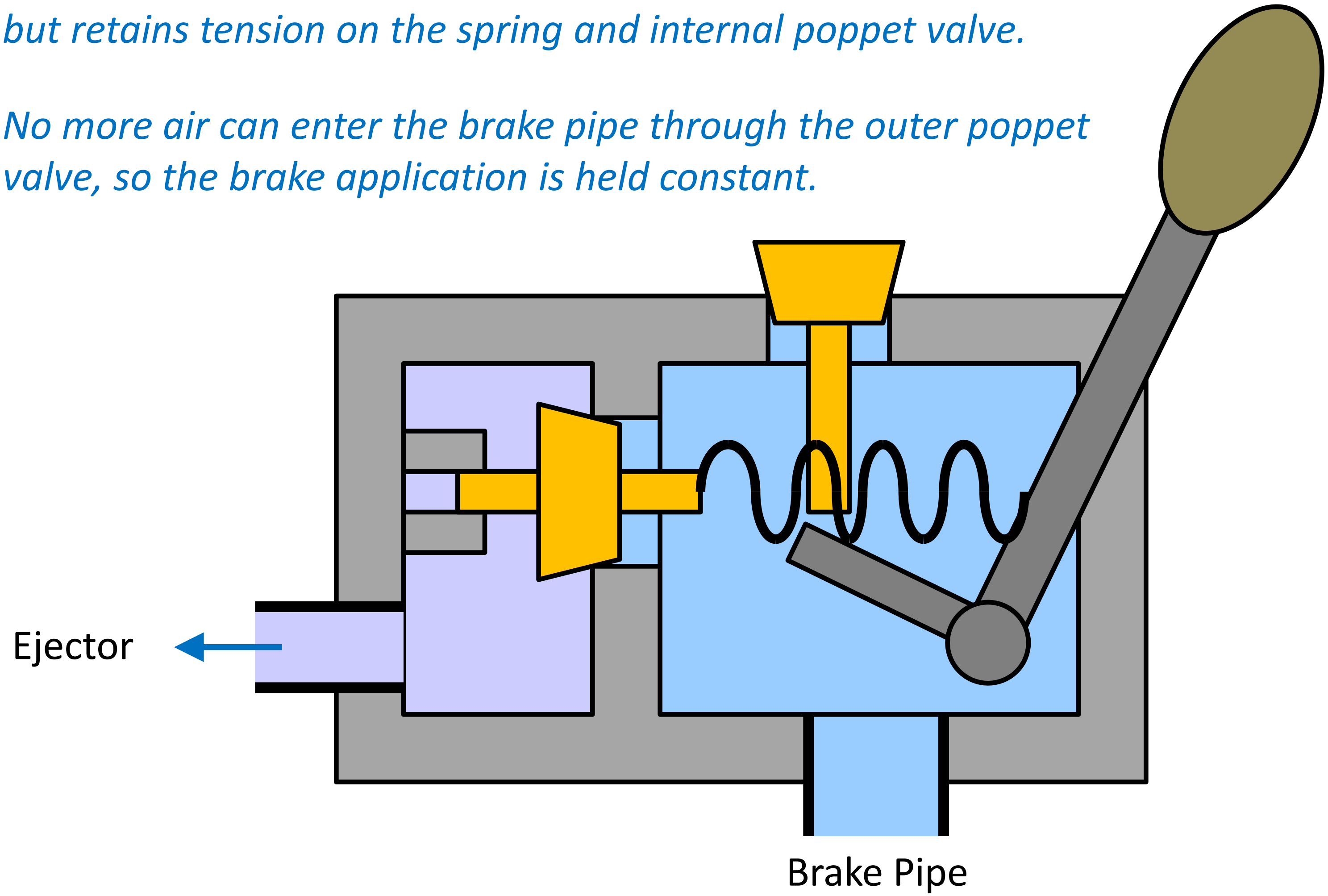
However, it also has a lap position...



Vacuum brakes

After initiating a brake application the handle can be moved back towards release so that it allows the outer poppet valve to close, but retains tension on the spring and internal poppet valve.

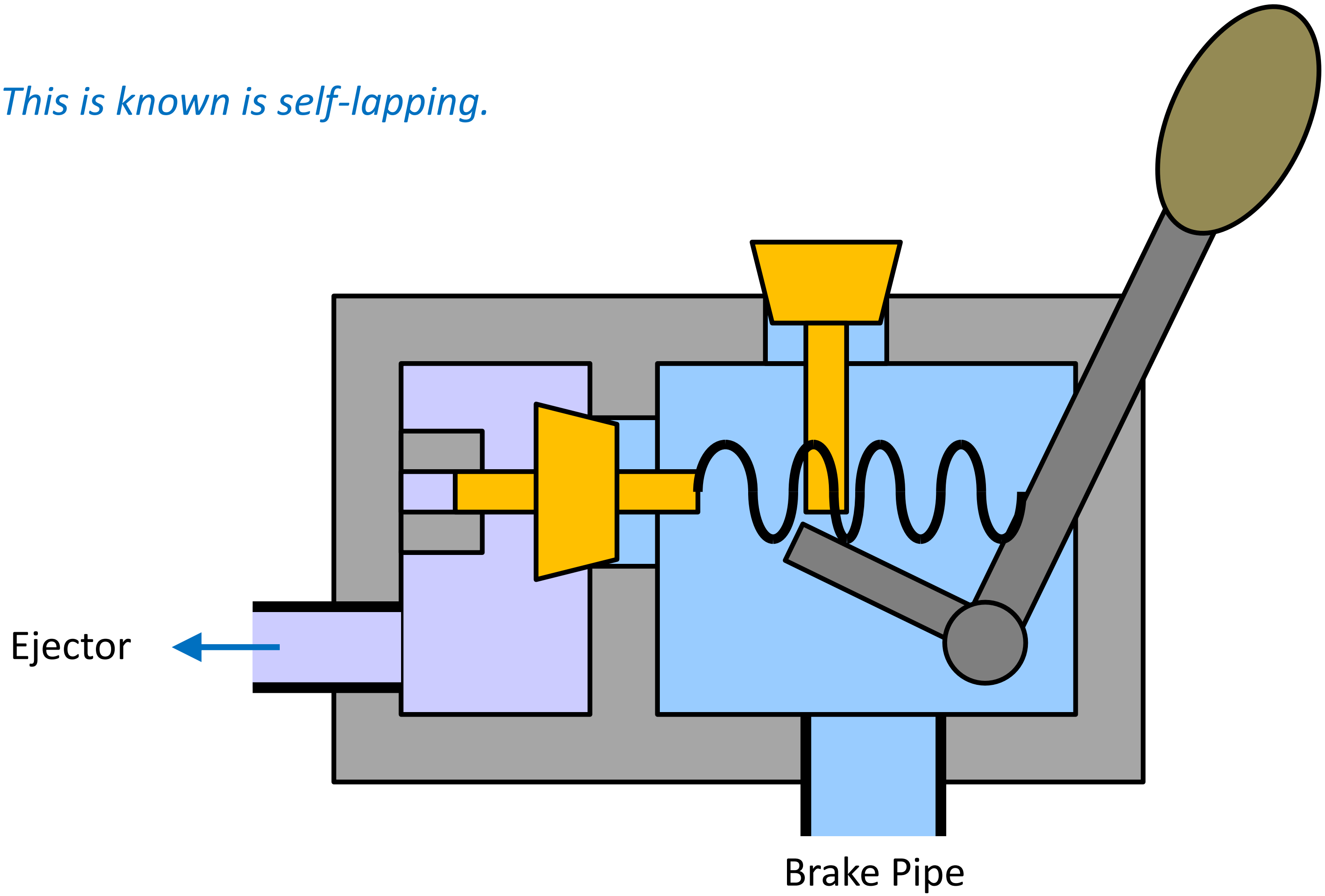
No more air can enter the brake pipe through the outer poppet valve, so the brake application is held constant.



Vacuum brakes

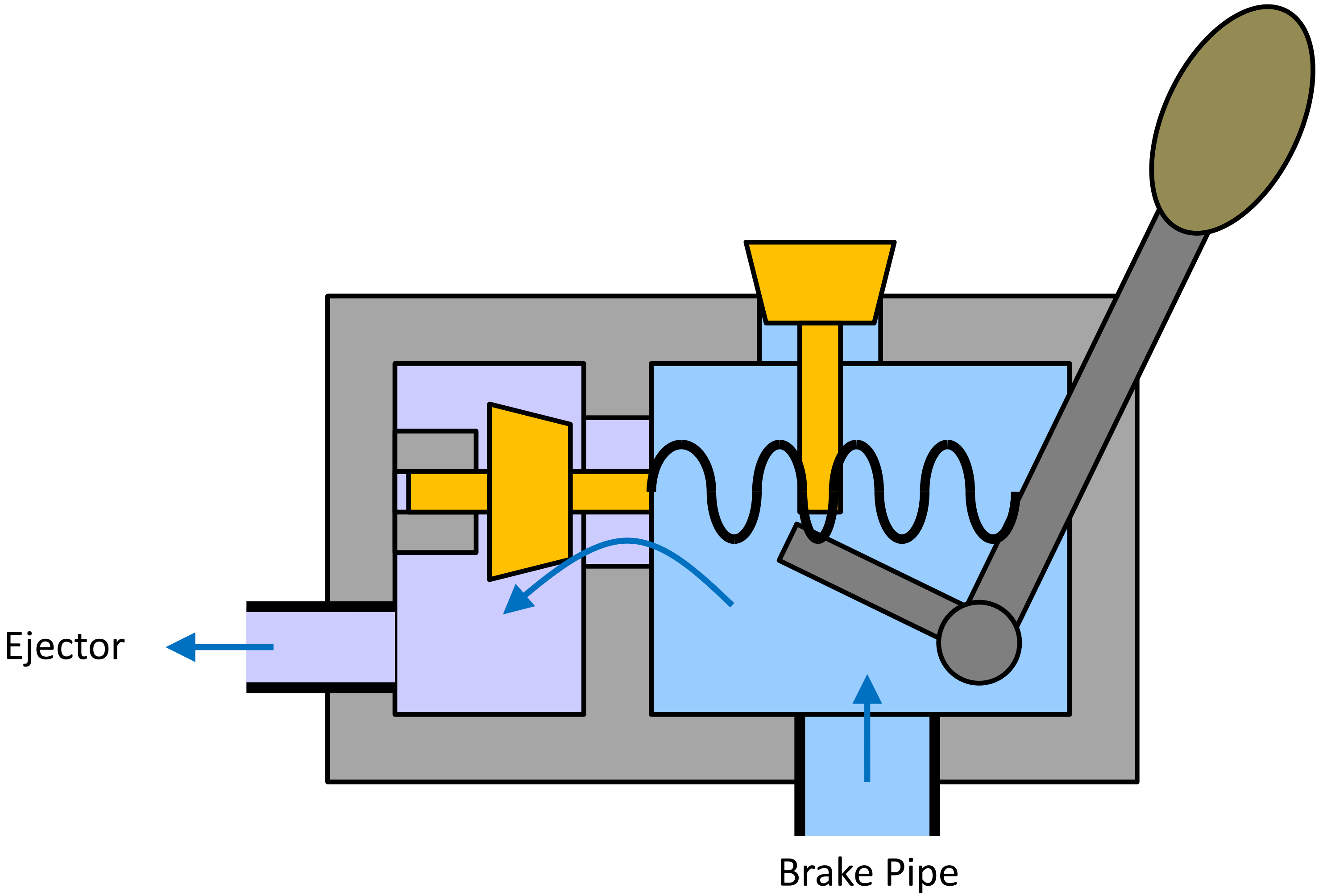
Due to the internal spring and poppet valve, this lap position will actually compensate for any leakage in the brake pipe system.

This is known is self-lapping.



Vacuum brakes

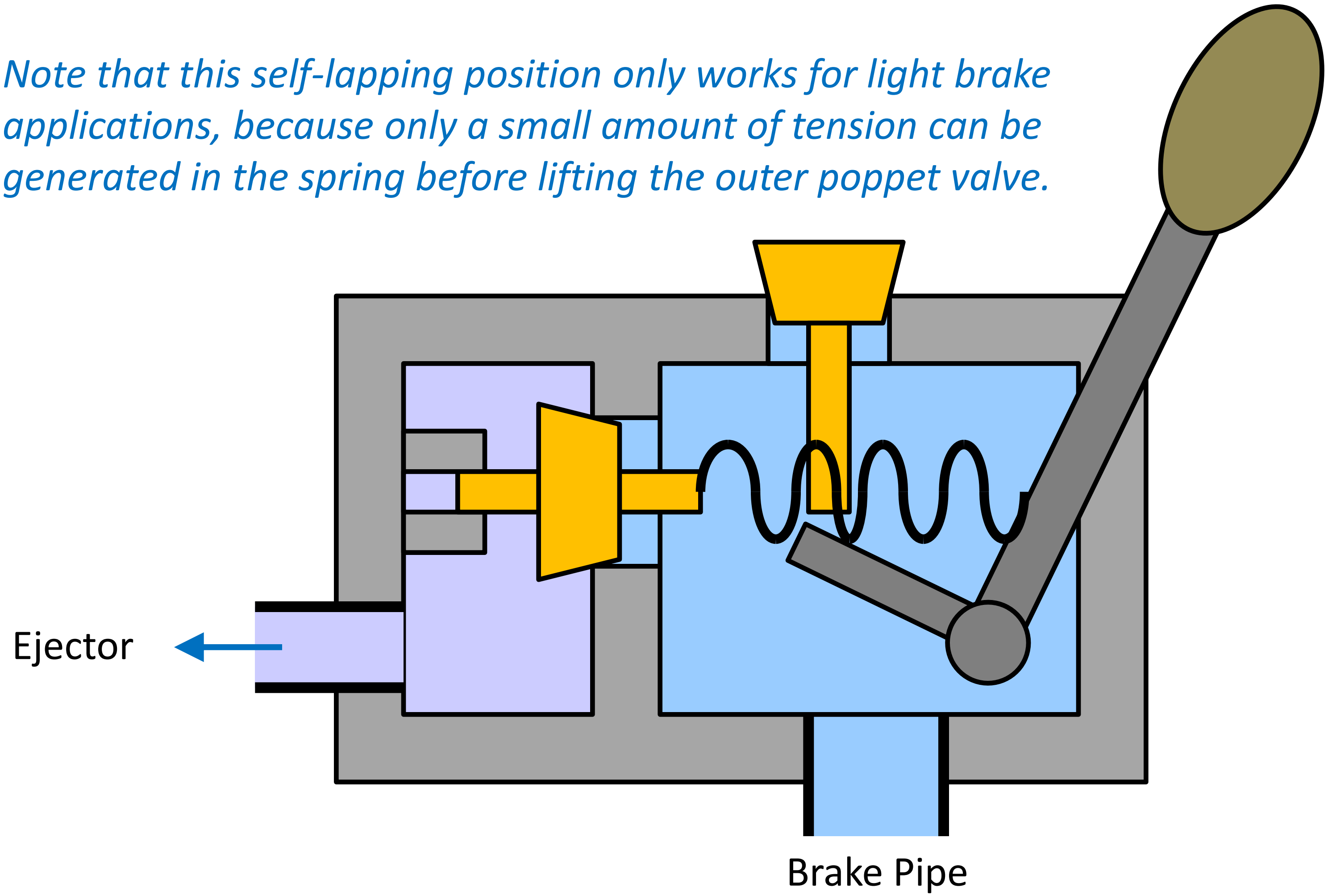
Any increase in brake pipe pressure will overcome the spring force, lift the internal poppet valve and escape via the ejector.



Vacuum brakes

When the brake pipe pressure (or partial vacuum) is restored, the spring pulls the valve shut, isolating the ejector once again.

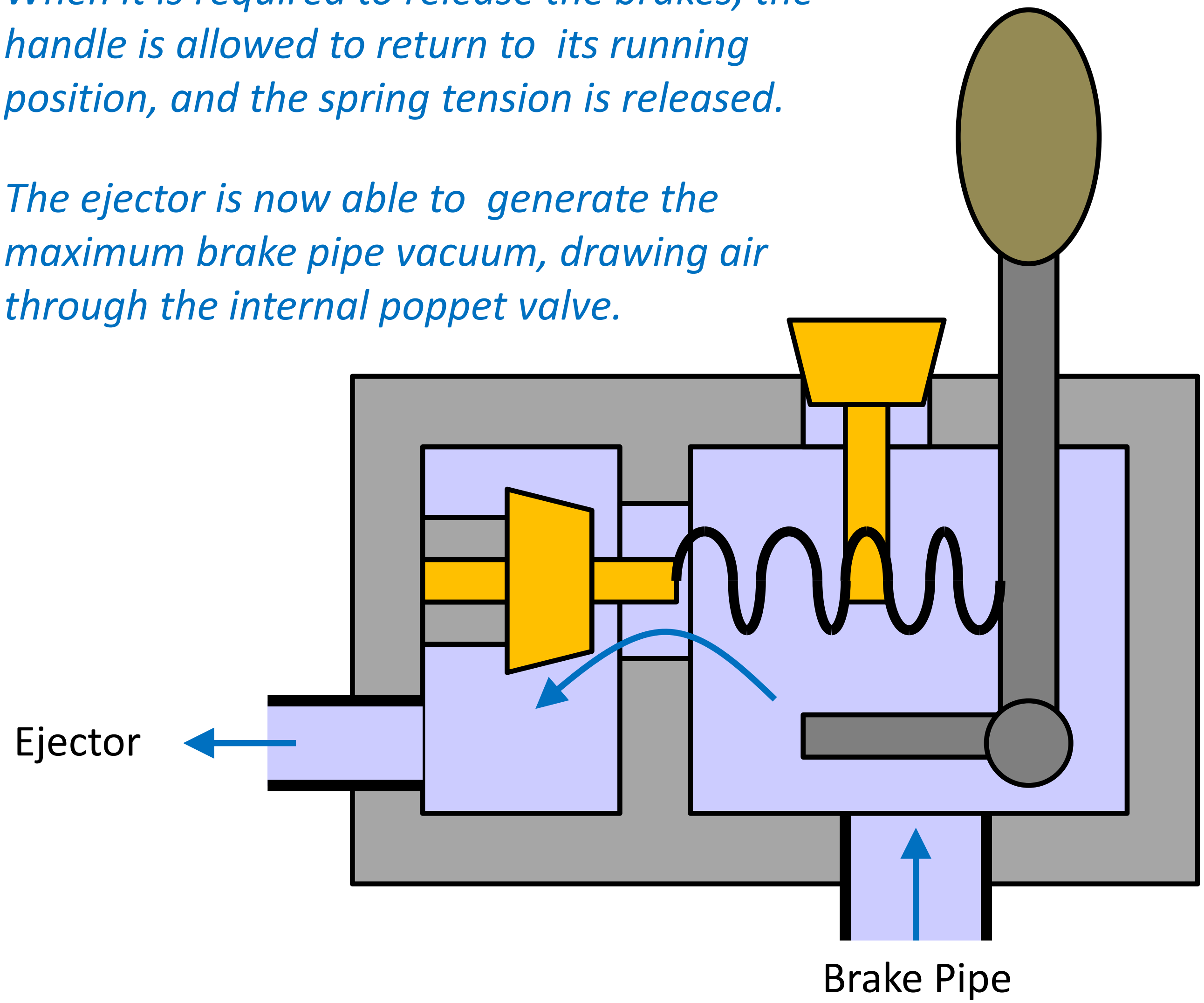
Note that this self-lapping position only works for light brake applications, because only a small amount of tension can be generated in the spring before lifting the outer poppet valve.



Vacuum brakes

When it is required to release the brakes, the handle is allowed to return to its running position, and the spring tension is released.

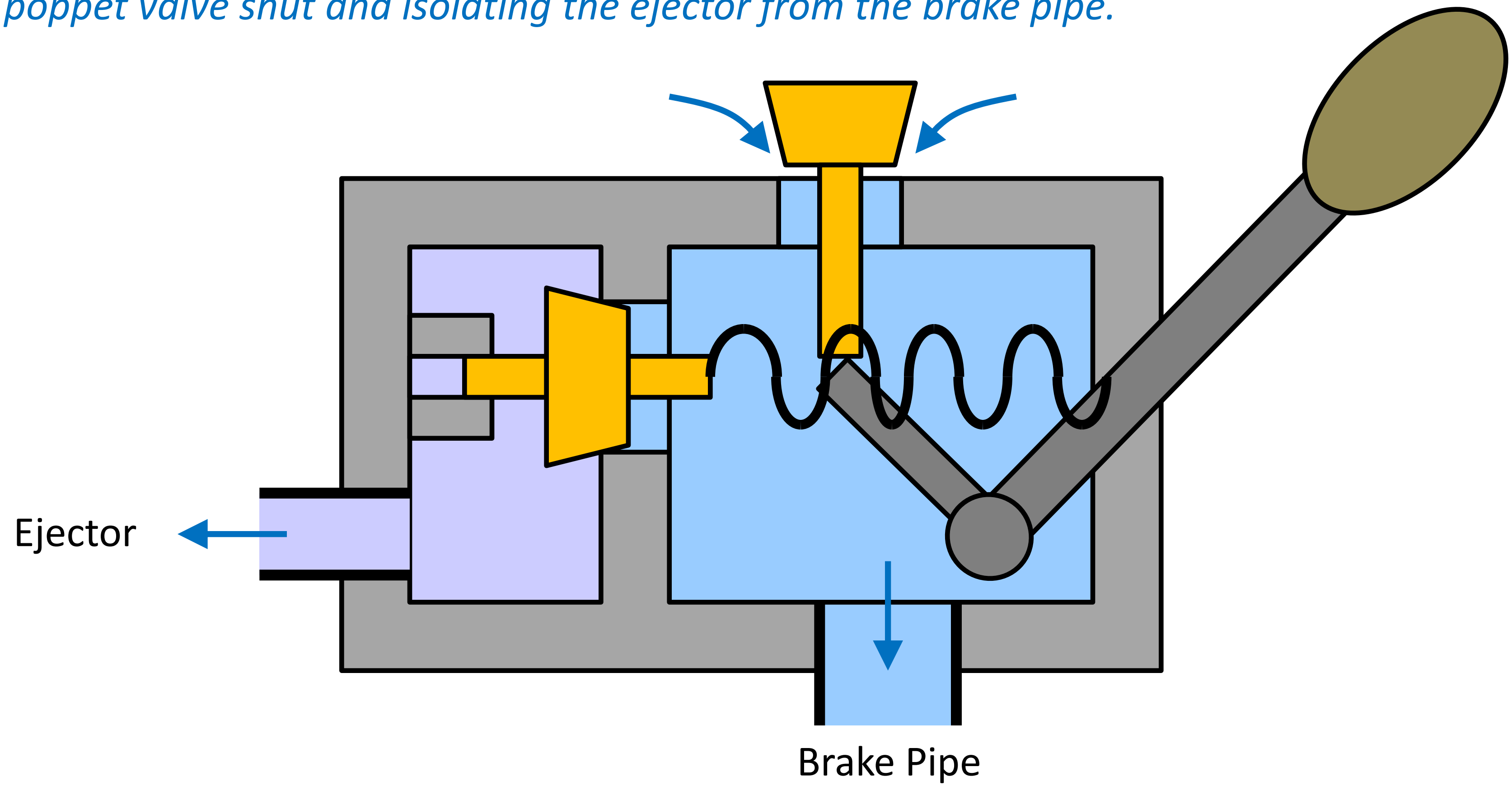
The ejector is now able to generate the maximum brake pipe vacuum, drawing air through the internal poppet valve.



Vacuum brakes

In an emergency, the handle is pulled fully back. This allows the maximum amount of air to enter the brake pipe through the outer poppet valve.

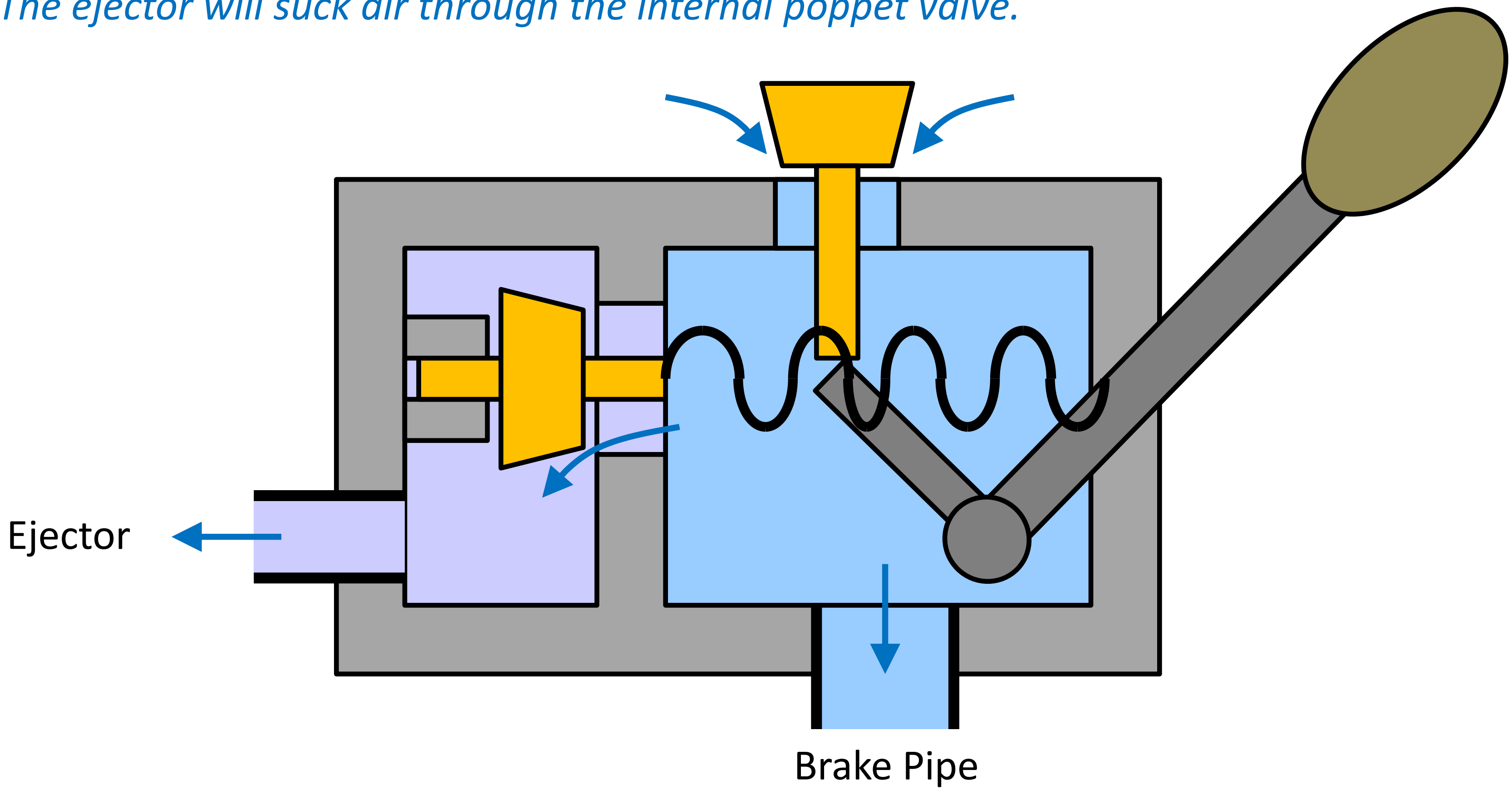
The handle generates maximum tension on the spring, holding the internal poppet valve shut and isolating the ejector from the brake pipe.



Vacuum brakes

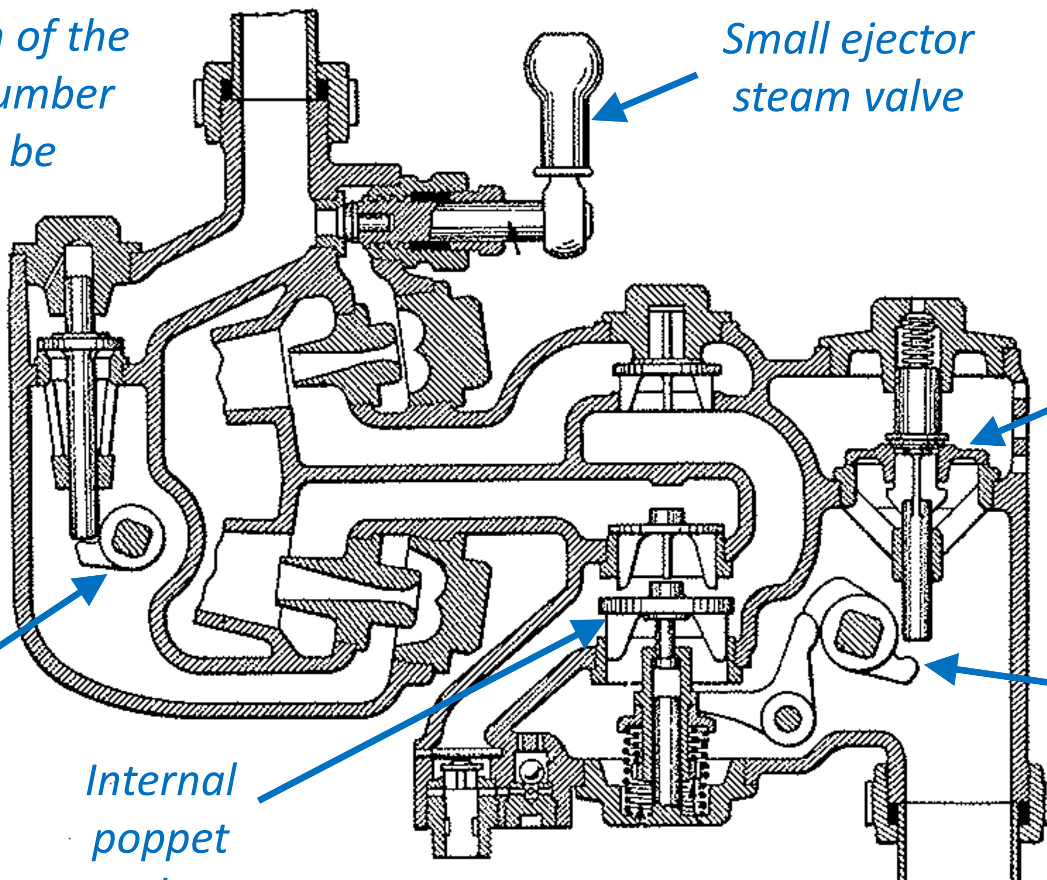
Once the brakes are fully applied (brake pipe vacuum fully destroyed), the incoming air will overcome the spring and force open the internal poppet valve.

The ejector will suck air through the internal poppet valve.



Vacuum brakes

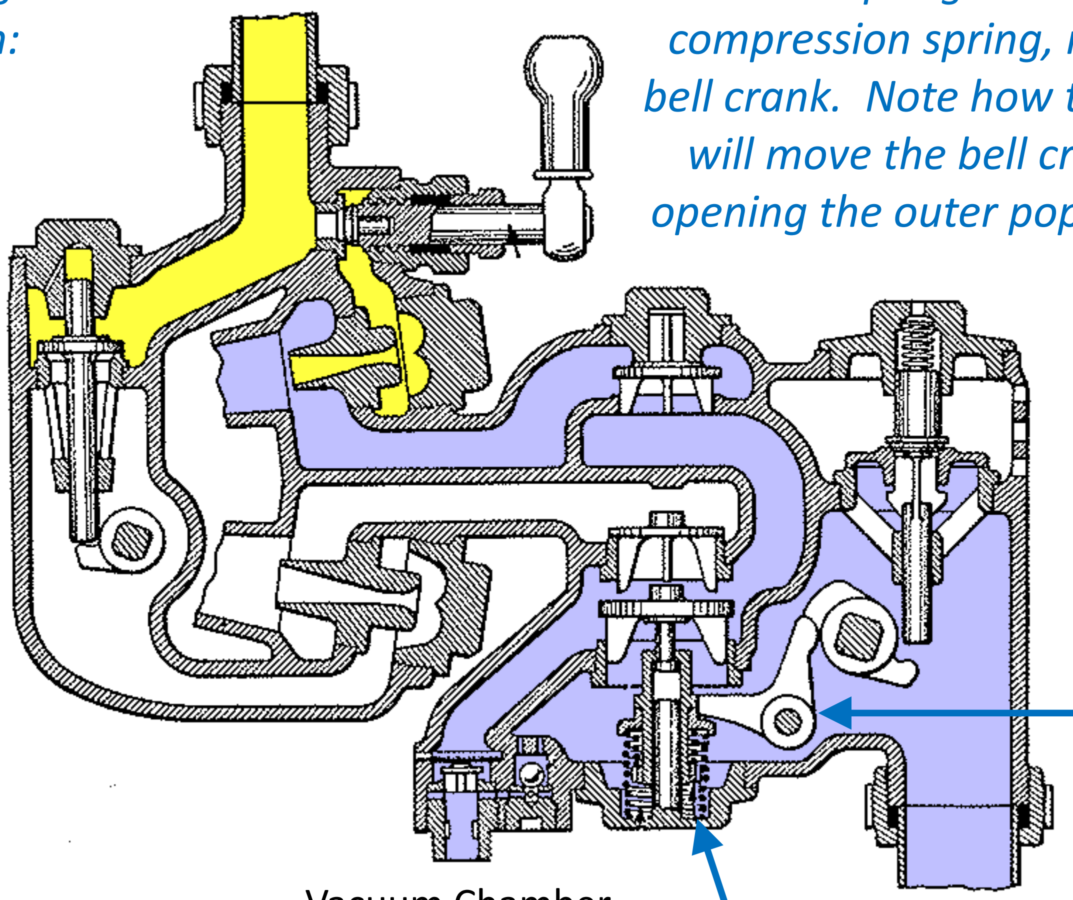
Returning to look at the detailed diagram of the SJ controller, a number of parts can now be identified.



Vacuum brakes

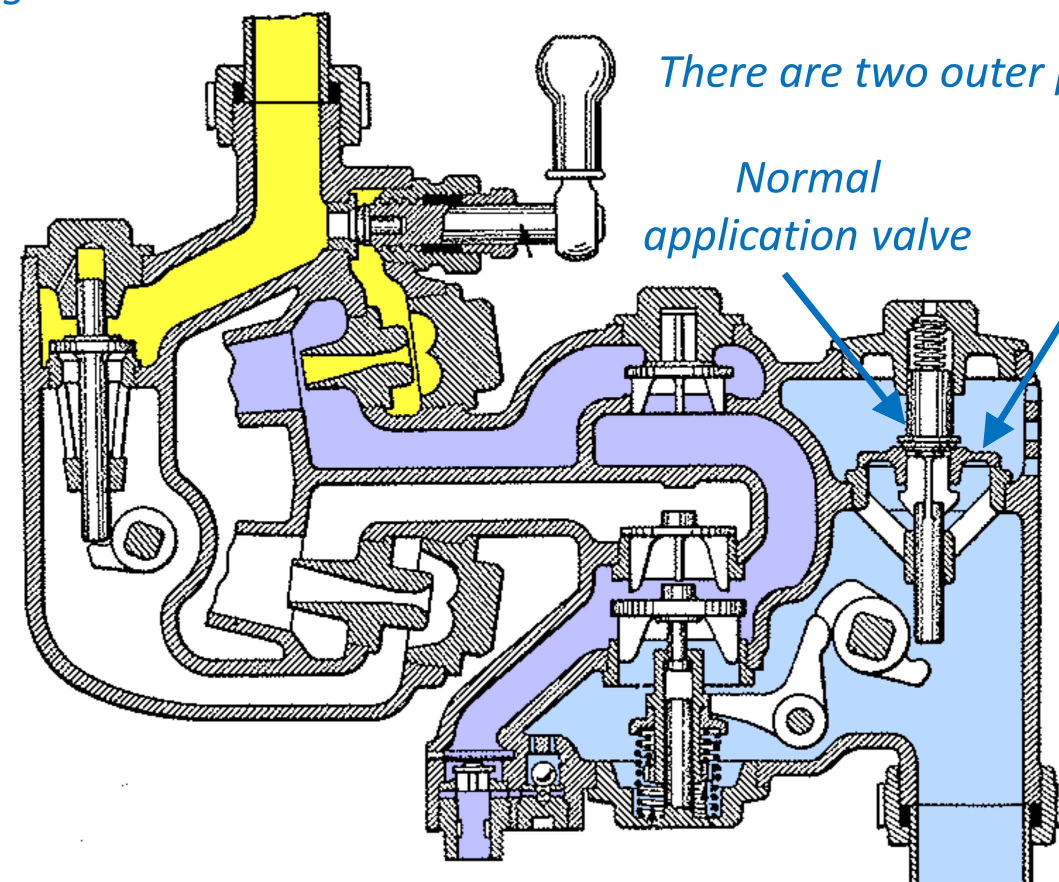
Diagram showing small ejector turned on:

The spring is actually a compression spring, moved via a bell crank. Note how the controller will move the bell crank before opening the outer poppet valve(s).



Vacuum brakes

Diagram showing brake application:



There are two outer poppet valves.

Normal application valve

Emergency valve

The small valve lifts first for normal light brake applications.

The large valve for emergency brake applications only lifts if the handle is pulled fully back.

Vacuum brakes

Independent brakes

Vacuum brakes

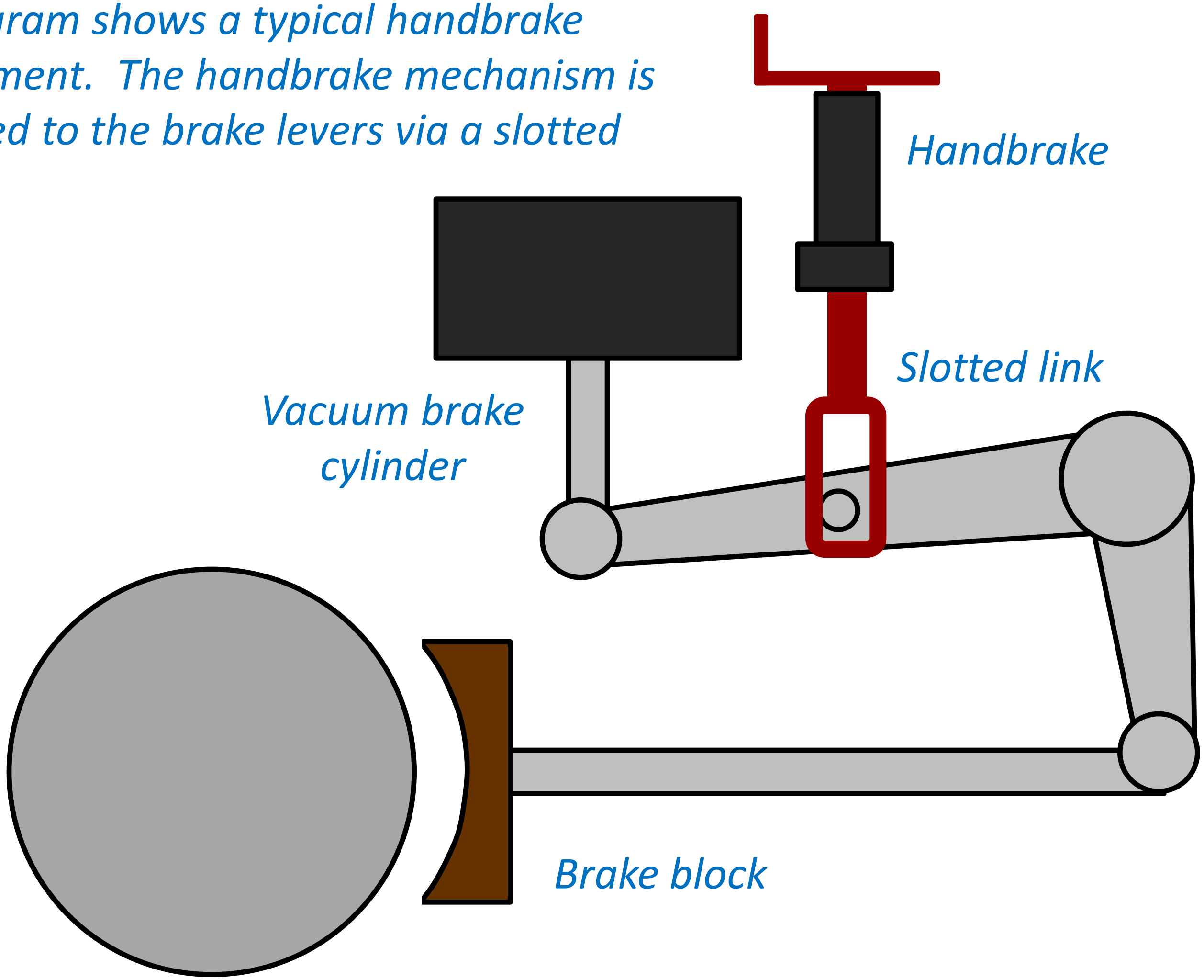
Independent brakes

Besides the vacuum brake system, most locomotives have supplementary brakes that work either in conjunction with the vacuum brake system or are completely independent. The following systems will be examined in the following slides.

- *Handbrake*
- *Vacuum parking brake (fitted on NGG16 locomotives)*
- *Steam brake*
- *Air brake (fitted on the Diesel locomotives)*

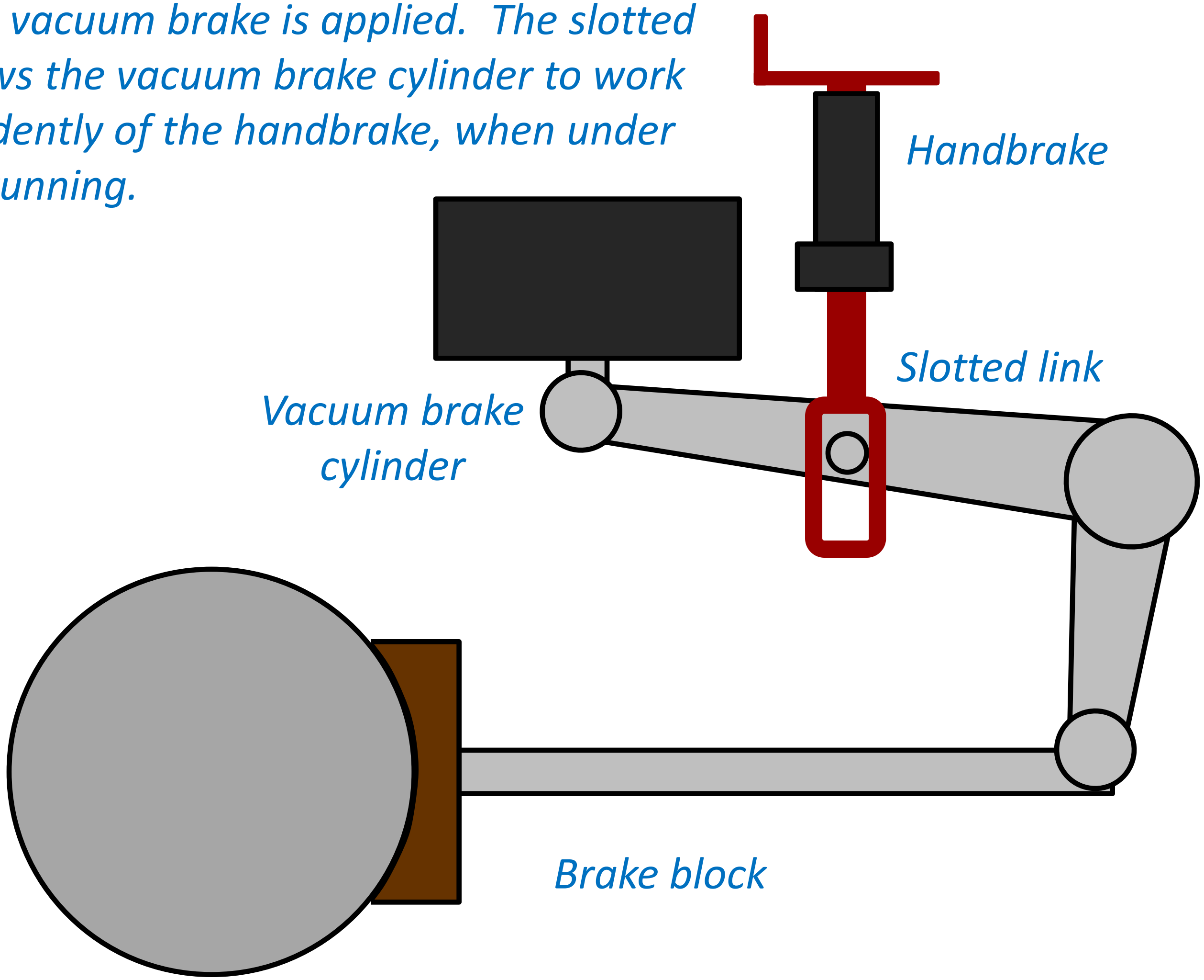
Vacuum brakes (handbrake)

This diagram shows a typical handbrake arrangement. The handbrake mechanism is connected to the brake levers via a slotted link.



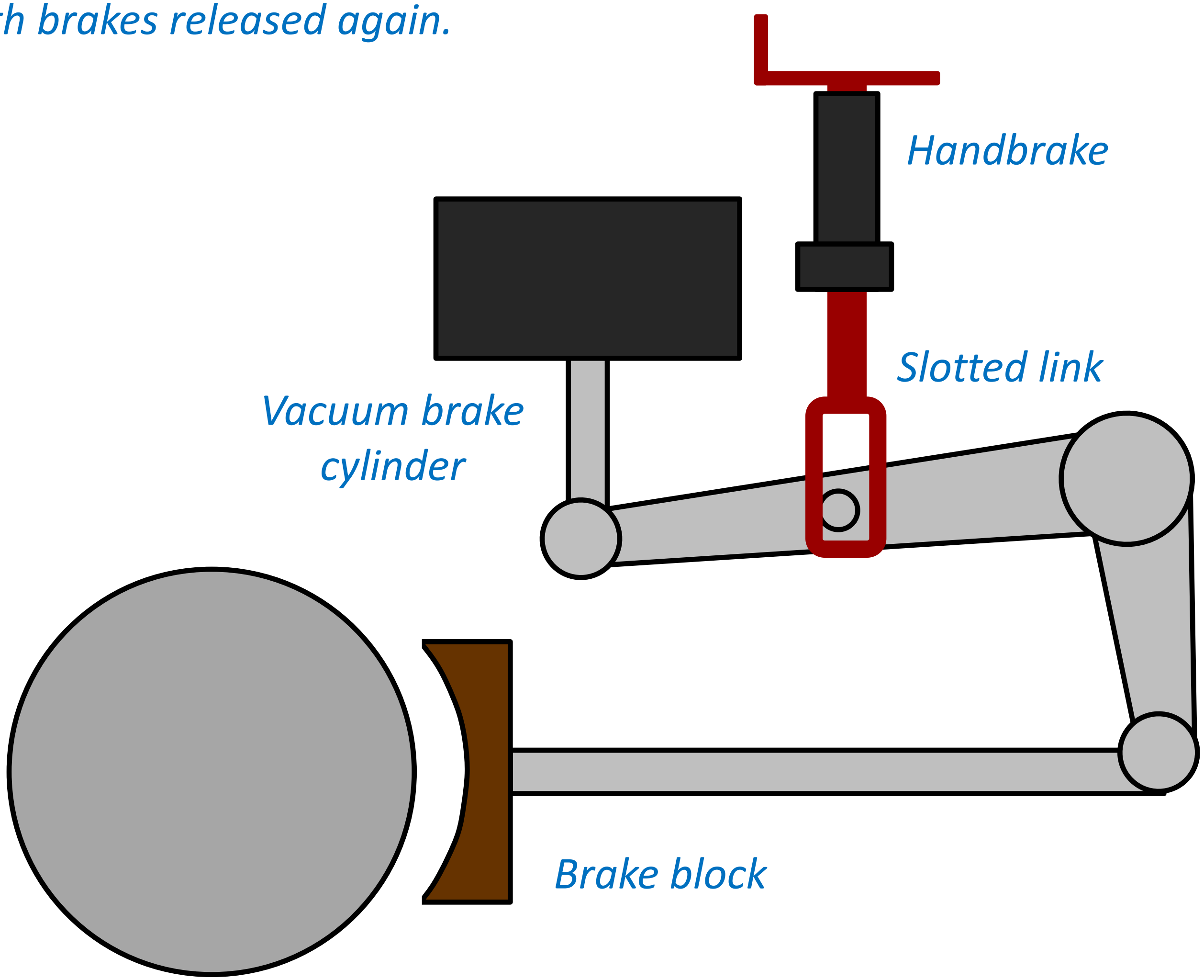
Vacuum brakes (handbrake)

Here the vacuum brake is applied. The slotted link allows the vacuum brake cylinder to work independently of the handbrake, when under normal running.



Vacuum brakes (handbrake)

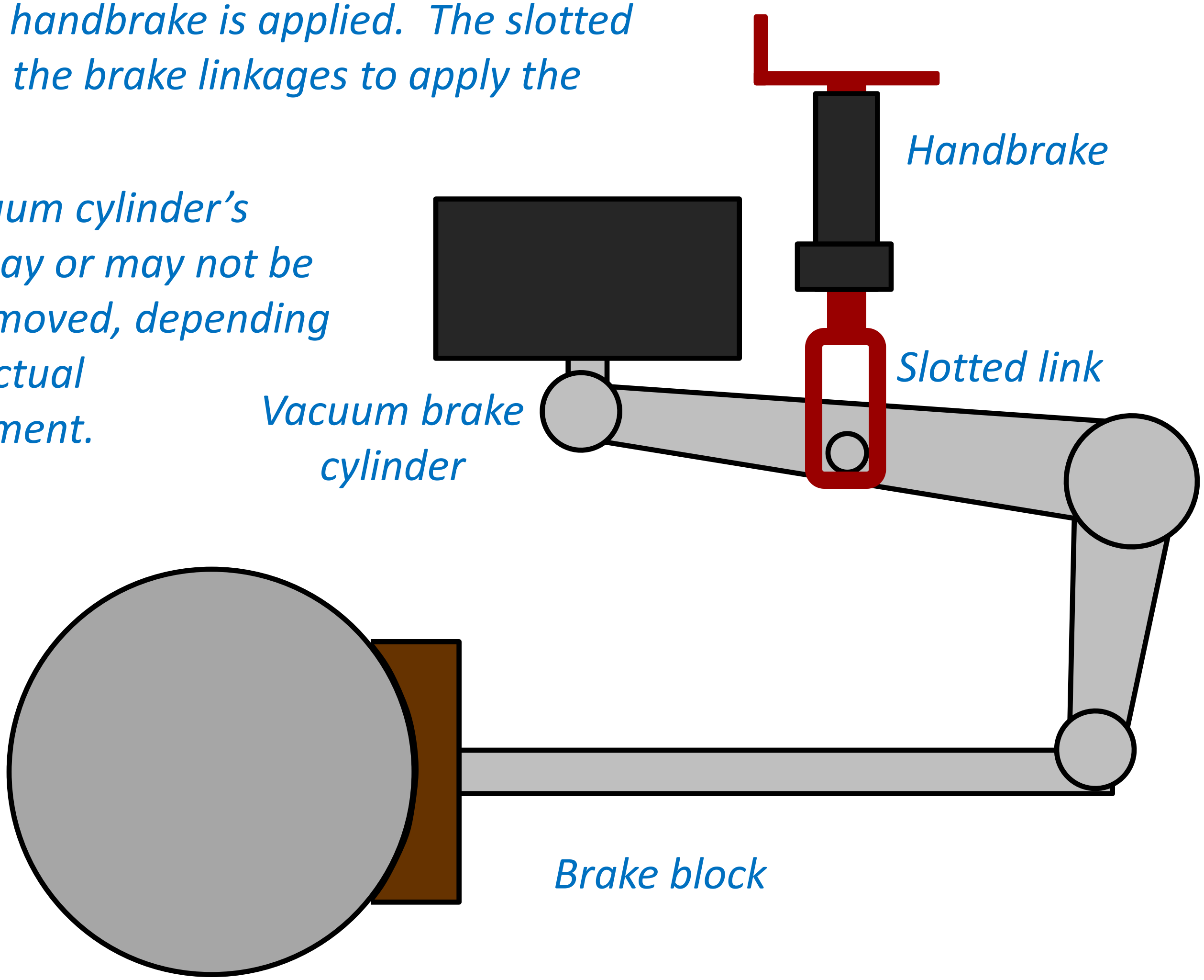
With both brakes released again.



Vacuum brakes (handbrake)

Here the handbrake is applied. The slotted link pulls the brake linkages to apply the brake.

The vacuum cylinder's piston may or may not be forcibly moved, depending on the actual arrangement.



Vacuum brakes

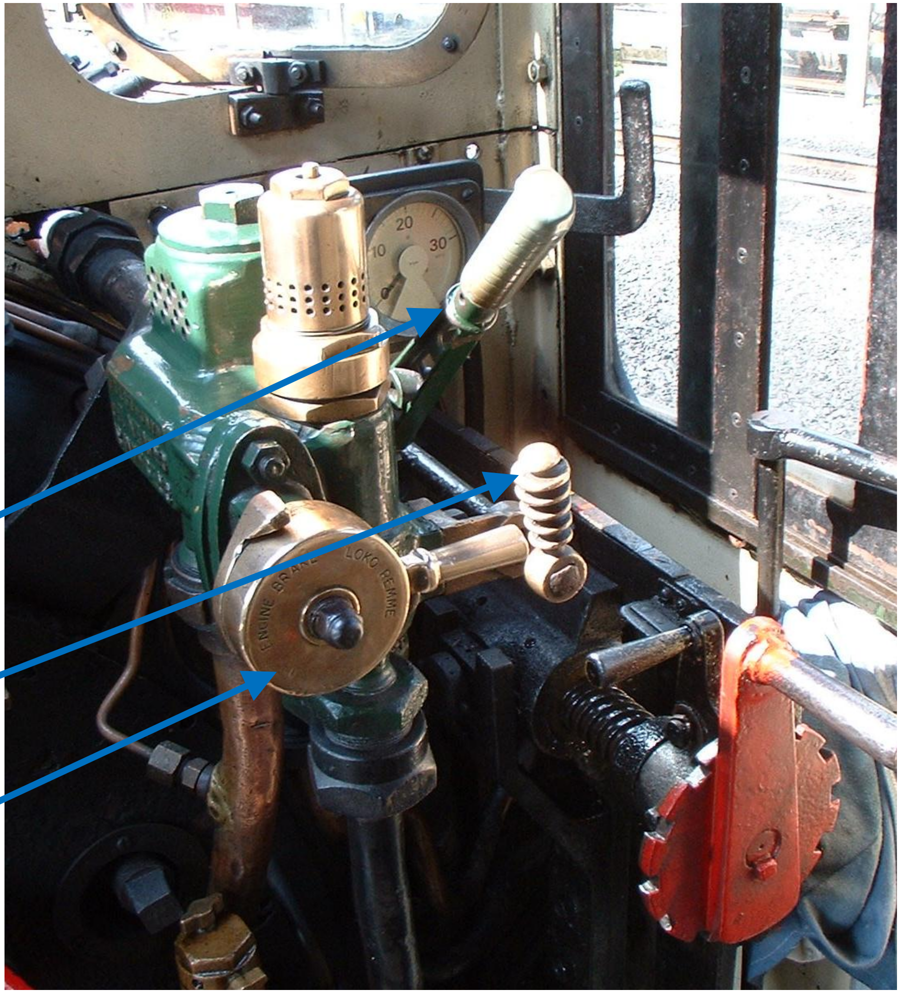
The next few slides explain the principle of the locomotive parking brake used on the NGG16s.

This is a vacuum operated parking brake system, which is unusual in the UK.

Train brake handle

Small ejector handle

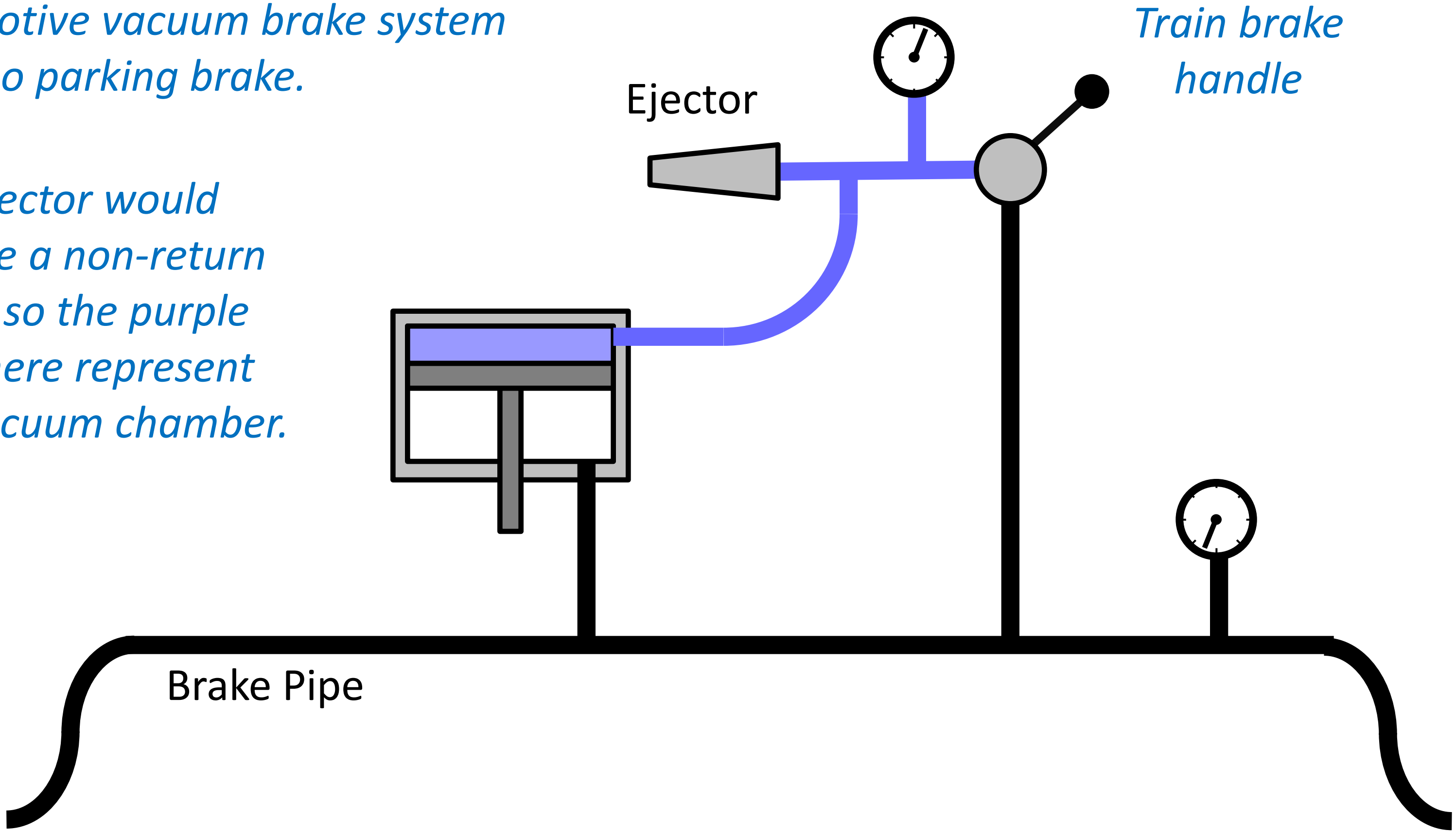
Parking brake handle



Vacuum brakes

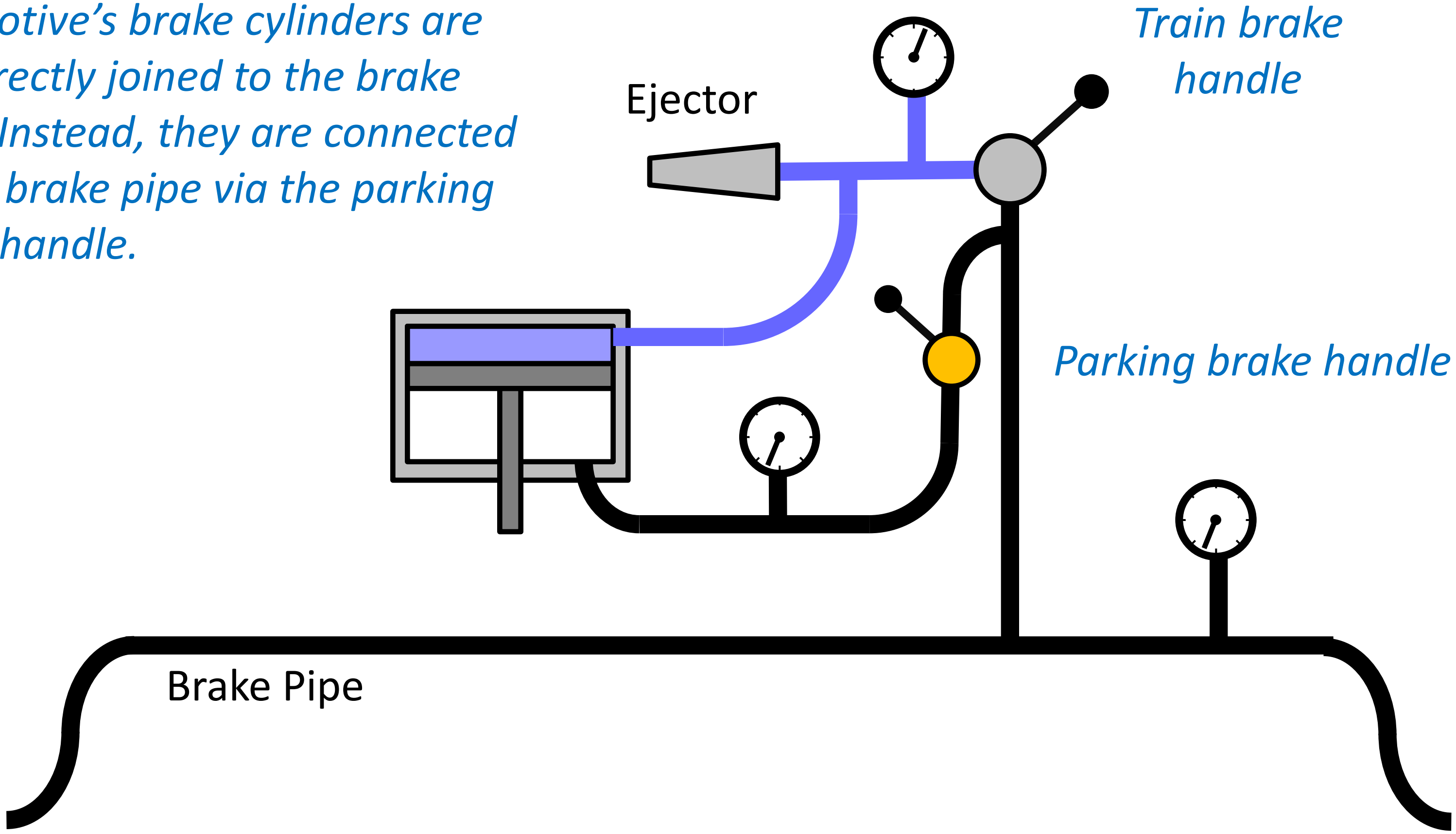
Here is a diagram showing a locomotive vacuum brake system with no parking brake.

The ejector would include a non-return valve, so the purple lines here represent the vacuum chamber.



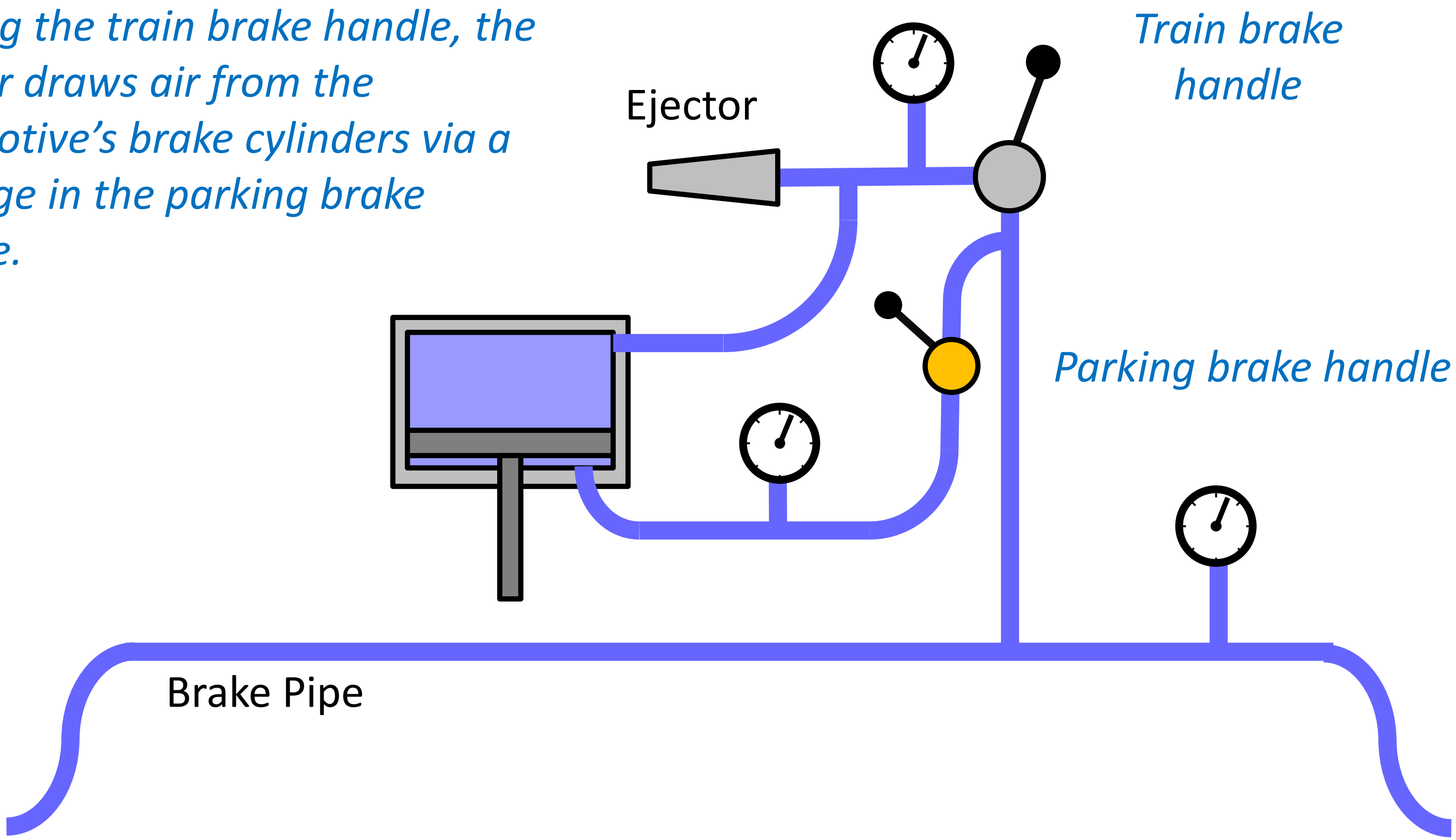
Vacuum brakes

To provide the parking brake, the locomotive's brake cylinders are not directly joined to the brake pipe. Instead, they are connected to the brake pipe via the parking brake handle.



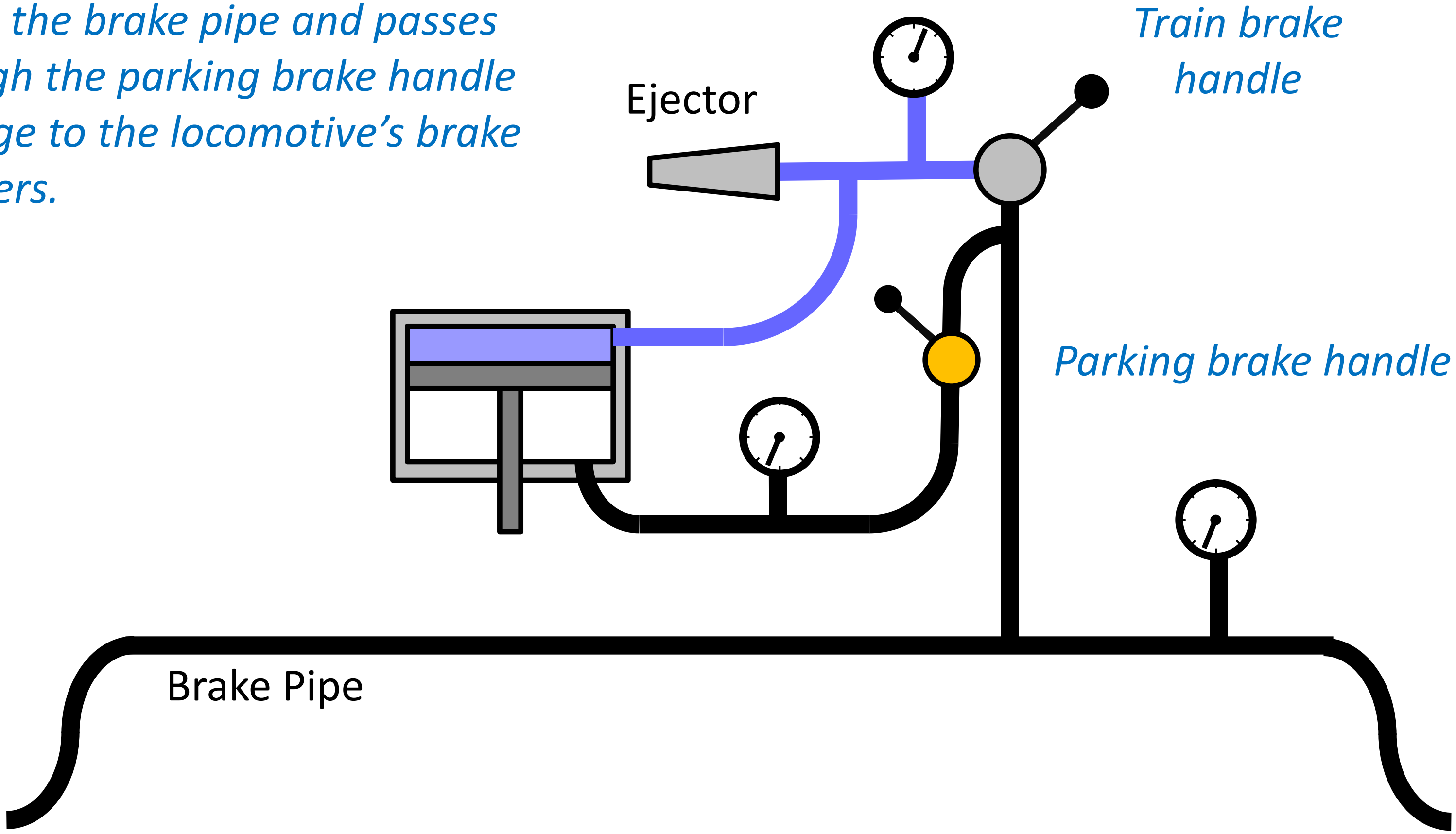
Vacuum brakes

When the train brake is released by moving the train brake handle, the ejector draws air from the locomotive's brake cylinders via a passage in the parking brake handle.



Vacuum brakes

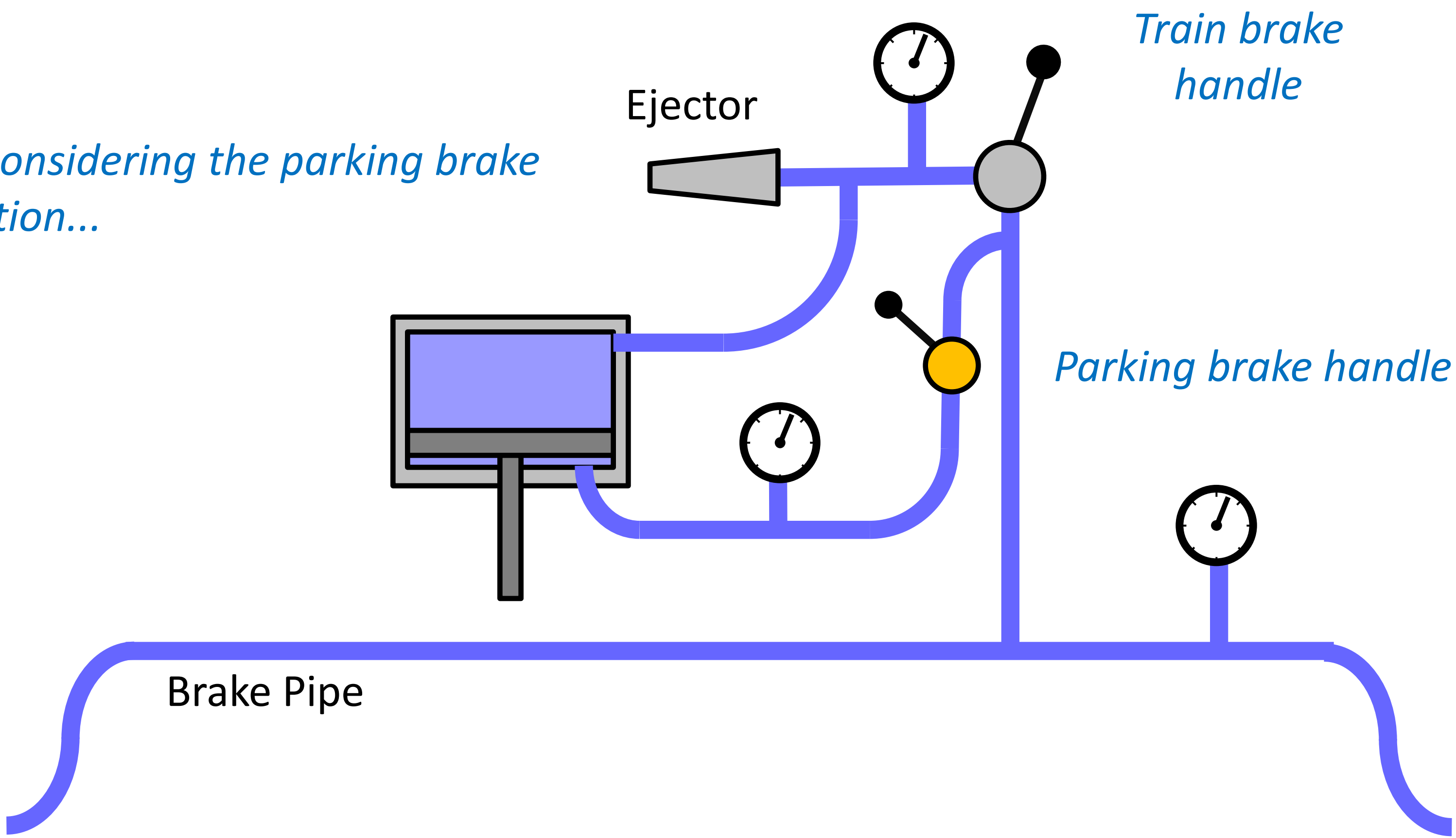
When the train brake is applied, air enters the brake pipe and passes through the parking brake handle passage to the locomotive's brake cylinders.



Vacuum brakes

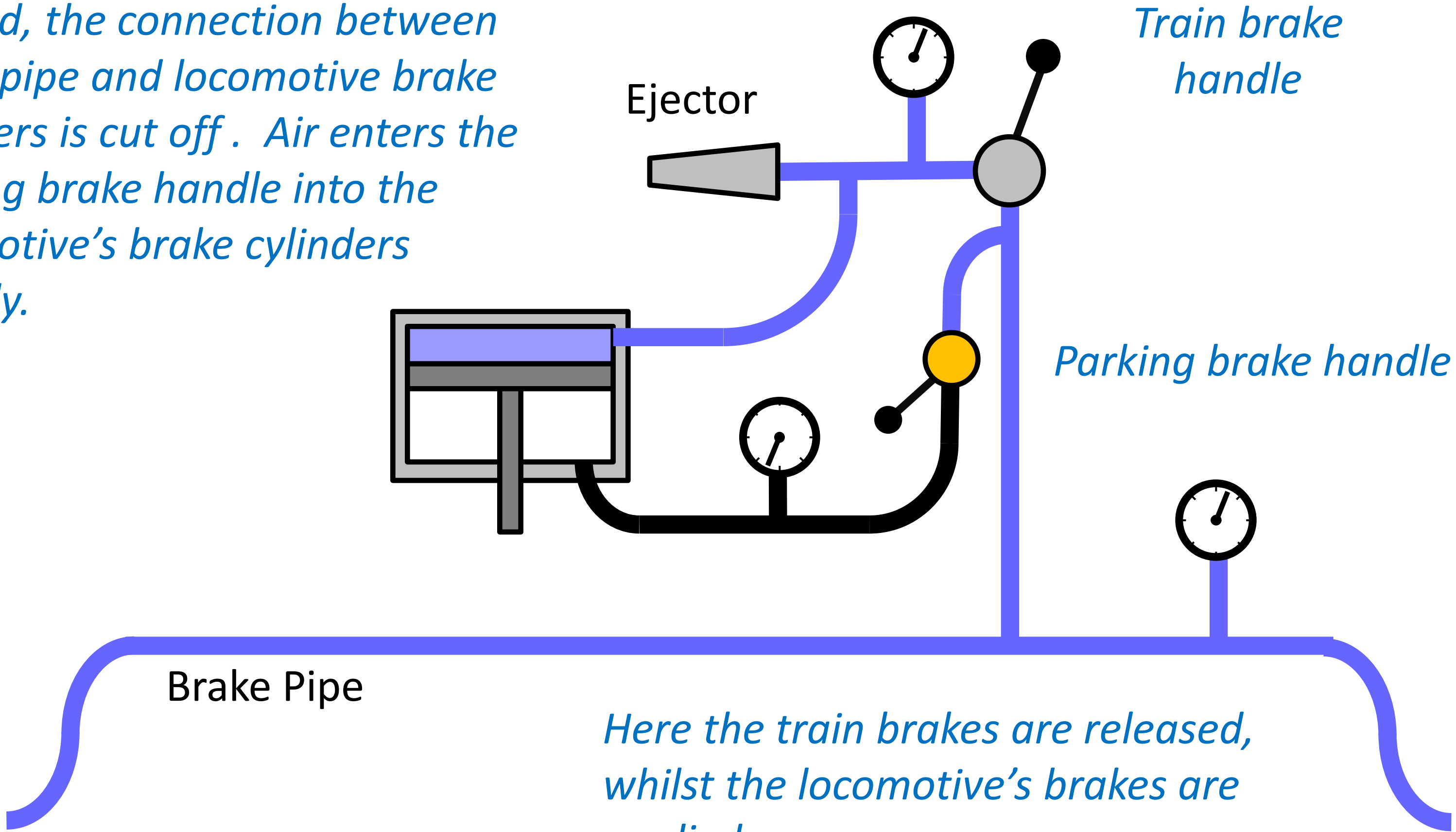
Here the brakes are released again.

Now considering the parking brake operation...



Vacuum brakes

When the parking brake only is applied, the connection between brake pipe and locomotive brake cylinders is cut off . Air enters the parking brake handle into the locomotive's brake cylinders directly.



Here the train brakes are released, whilst the locomotive's brakes are applied.

Vacuum brakes

Important notes on the NGG16‘s parking brake

The locomotive parking brake is ideal for short station stops and waiting at signals. When the train has come to a standstill the parking brake is applied and the train brakes are released. When clear to proceed, the releasing of only the locomotive's brakes will be much quicker than the whole train's brakes.

However, care must be taken if the train is on a gradient, where the parking brake may not be sufficient to hold the train.

In normal service, the parking brake should not be used to stop a train using only the locomotive's brakes. This could cause excessive wear of the locomotive's brake blocks and sliding of the wheels along the rails. The latter would lead to flats on the driving wheels and subsequent expensive repair.

Vacuum brakes

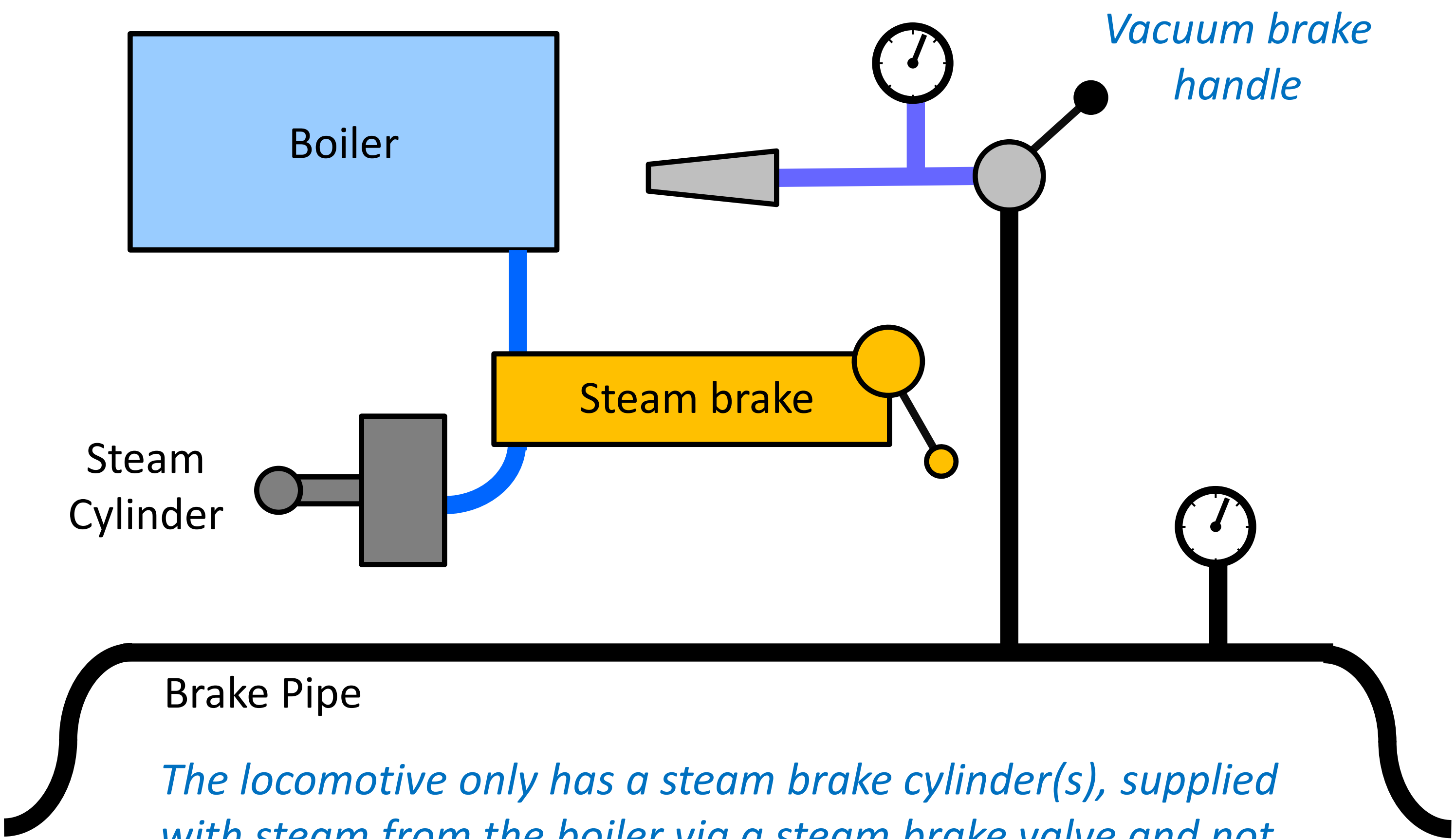
Important notes on the NGG16's parking brake

The parking brake controller is not designed to give fine control for braking the locomotive when independent of a train. A light locomotive should still be braked using the train brake controller. The parking brake is intended as a switch, being either on or off.

If referring to the South African Railways (SAR) brake diagrams, be aware that the quick acting valves (intended for use with very long trains) have been removed from the Welsh Highland Railway's locomotives.

Vacuum brakes (steam brake)

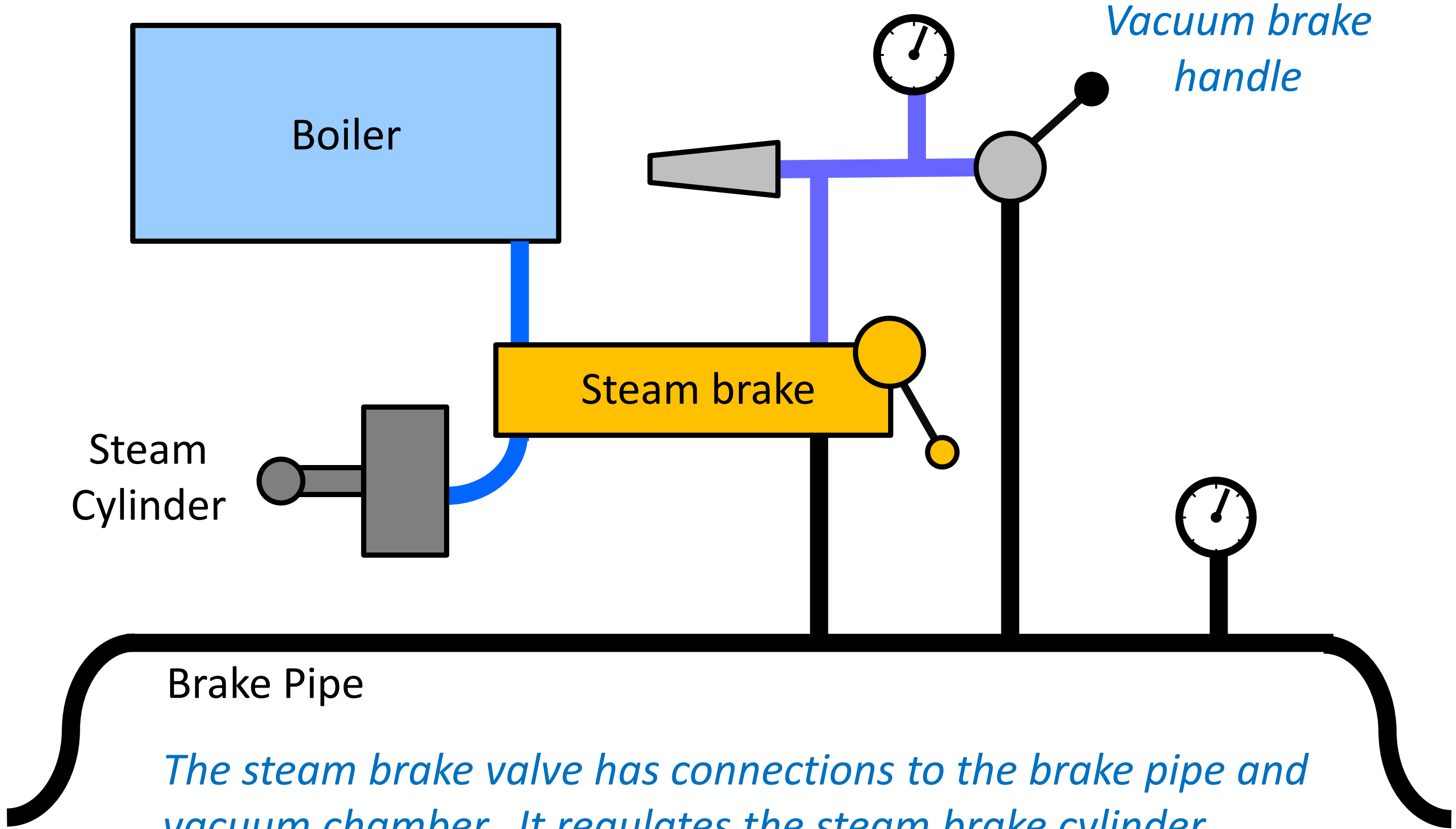
Here is part of a diagram of the steam brake.



The locomotive only has a steam brake cylinder(s), supplied with steam from the boiler via a steam brake valve and not directly connected to the vacuum brake pipe.

Vacuum brakes (steam brake)

Here is the complete diagram of the steam brake.



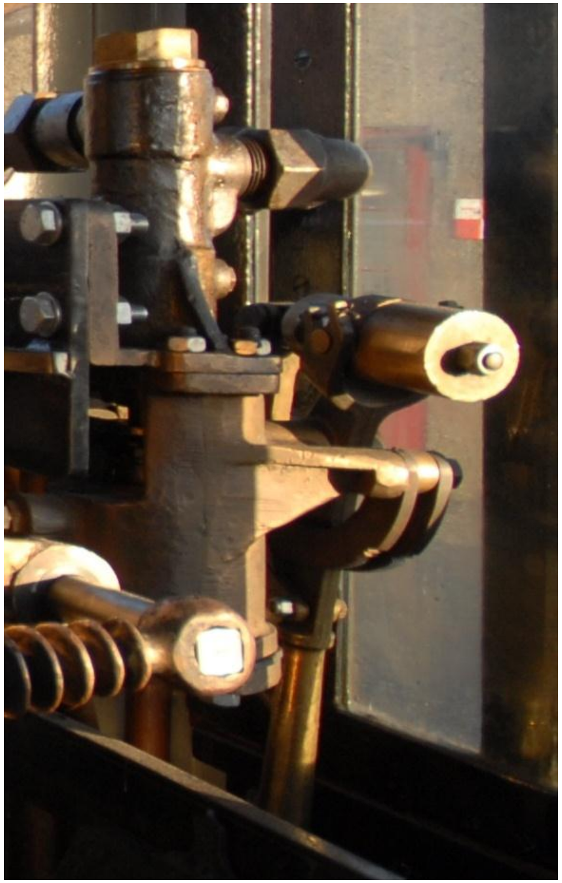
The steam brake valve has connections to the brake pipe and vacuum chamber. It regulates the steam brake cylinder pressure in proportion to the vacuum brake demand.

Vacuum brakes (steam brake)

The steam brake valve used as standard on the Ffestiniog and Welsh Highland Railways is a Gresham and Craven design identical to that fitted on the BR standard steam locomotives.

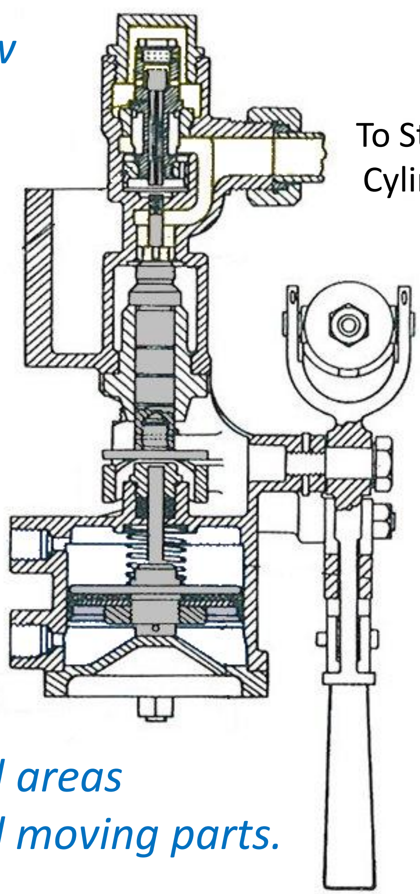
It is mounted in the cab and has an external handle that allows the steam brake to be applied independently of the vacuum brake. It can be used both as a parking brake and when running light loco.

Most locomotives fitted with steam brakes can be run light loco without the vacuum brake system needing to be turned on. However, there are exceptions, for example locomotive number 87. On this locomotive one power bogie requires the vacuum brake.

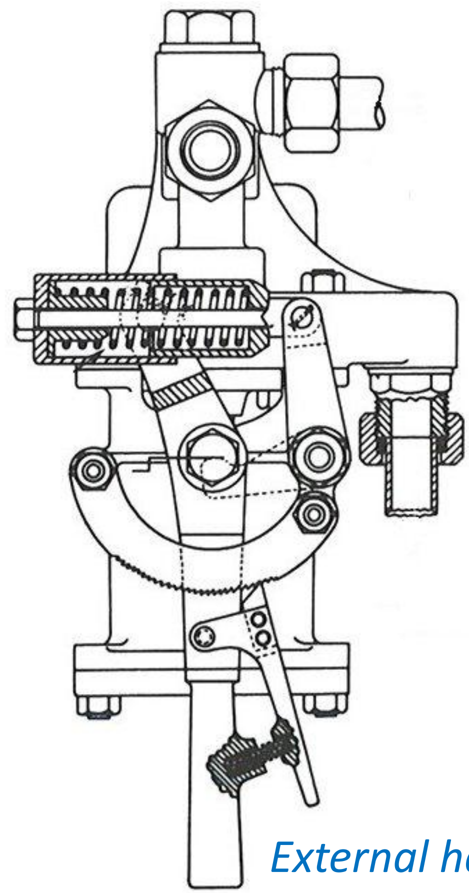


Vacuum brakes (steam brake)

Here is an explanation of how the steam brake valve works.

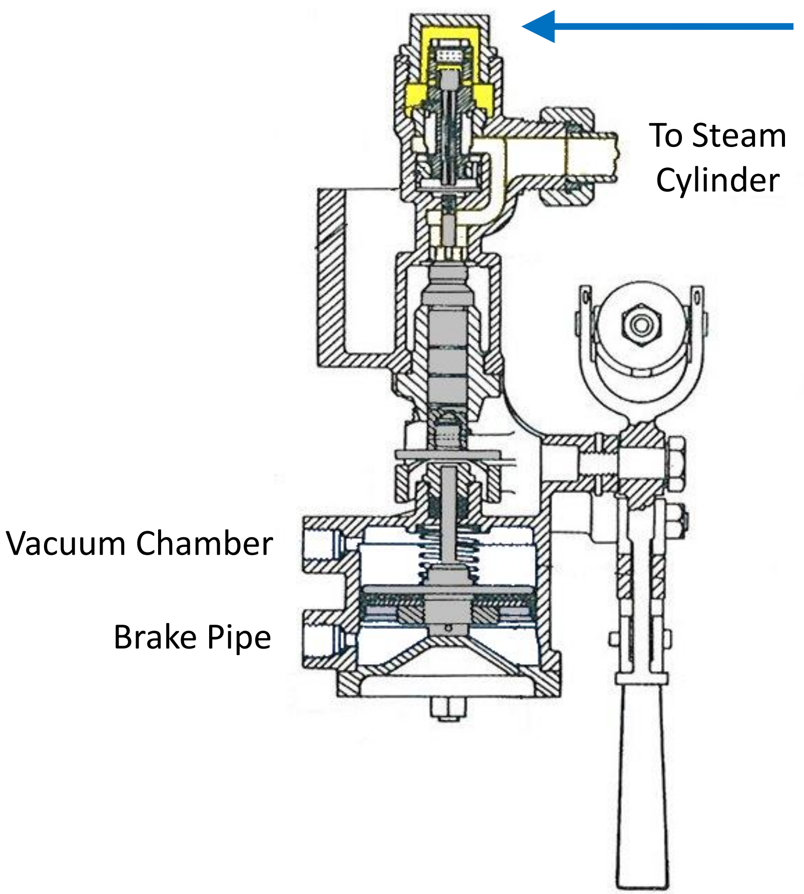


The grey coloured areas represent internal moving parts.



External handle with ratchet mechanism

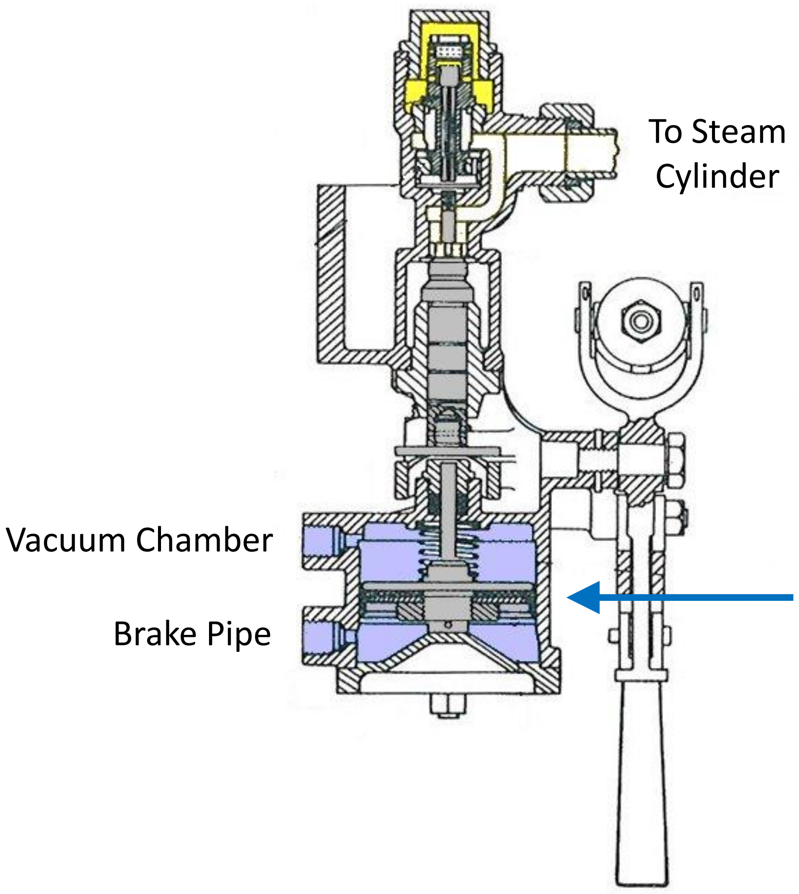
Vacuum brakes (steam brake)



Steam is supplied to the top of the valve. The steam is shown in yellow.

With no vacuum in the system, the steam will not progress any further, because it bears down on the inlet valve, holding it shut.

Vacuum brakes (steam brake)

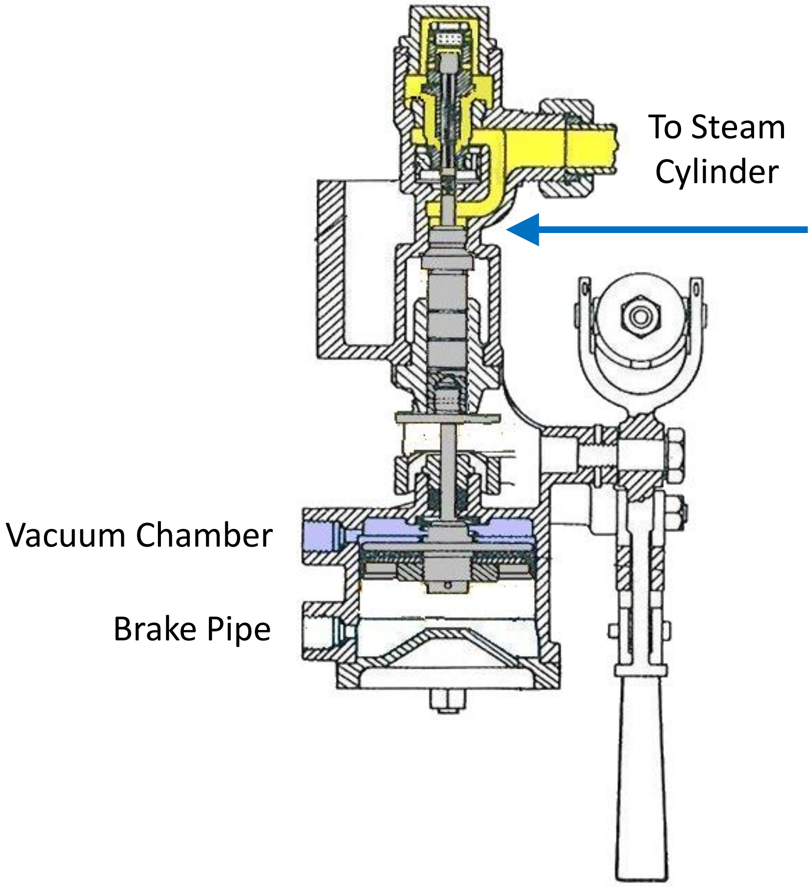


When the vacuum brake system is turned on, both the brake pipe and vacuum chamber are evacuated of air.

The steam brake valve has a miniature vacuum brake cylinder at its base.

With vacuum in both the brake pipe and vacuum chamber, the miniature piston is in equilibrium and is held at the bottom of the cylinder by a spring.

Vacuum brakes (steam brake)

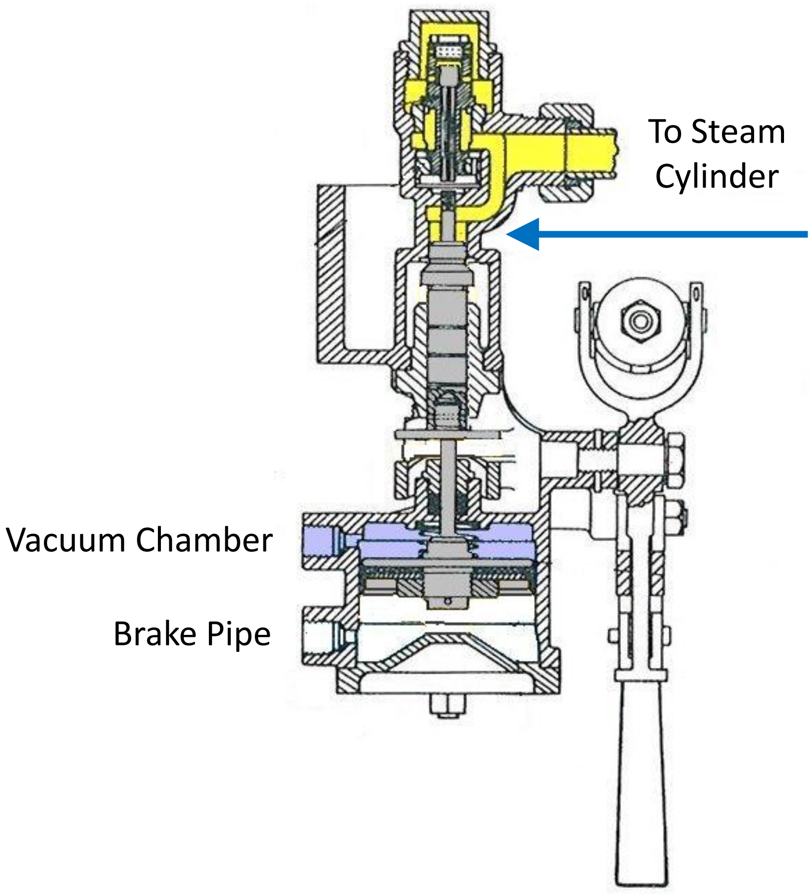


When a brake application is made, the miniature piston is forced up its cylinder by the incoming air pressure.

The piston rod pushes up on the steam valve, closing the brake cylinder exhaust outlet and then forcing open the steam inlet.

Steam is supplied from the boiler to the brake cylinder.

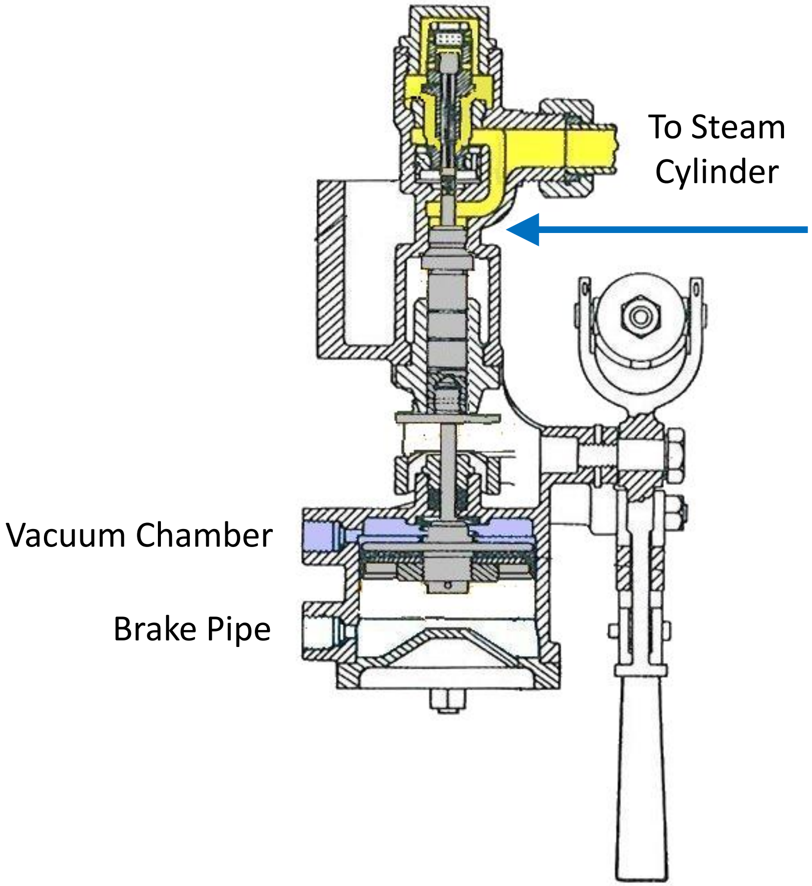
Vacuum brakes (steam brake)



The steam pressure entering the brake cylinder bears down on the exhaust valve. This creates a downward force on the piston rod.

When the steam pressure has become sufficient to balance the input force from the miniature vacuum cylinder, the piston rod moves to allow the steam inlet valve to close. However, the exhaust valve remains shut, so a constant steam pressure is obtained in the brake cylinder.

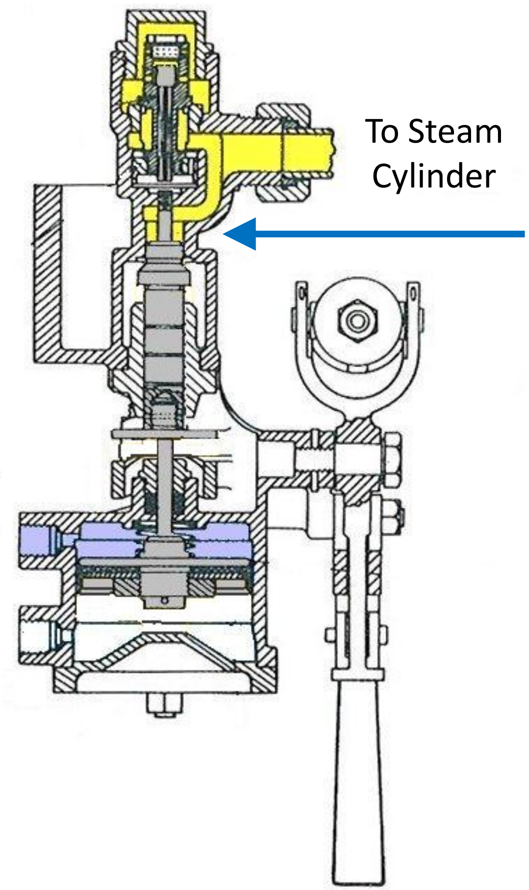
Vacuum brakes (steam brake)



If there is a further reduction in brake pipe vacuum, the miniature vacuum brake cylinder will increase its upwards force on the steam valve. More steam pressure will be allowed to enter the brake cylinder until the forces balance again.

The same event will happen if there is a leak in the steam brake cylinder. If there is a loss of steam pressure, the valve will be forced upwards by the miniature vacuum brake cylinder, allowing more steam to enter the brake cylinder to compensate for the leakage.

Vacuum brakes (steam brake)



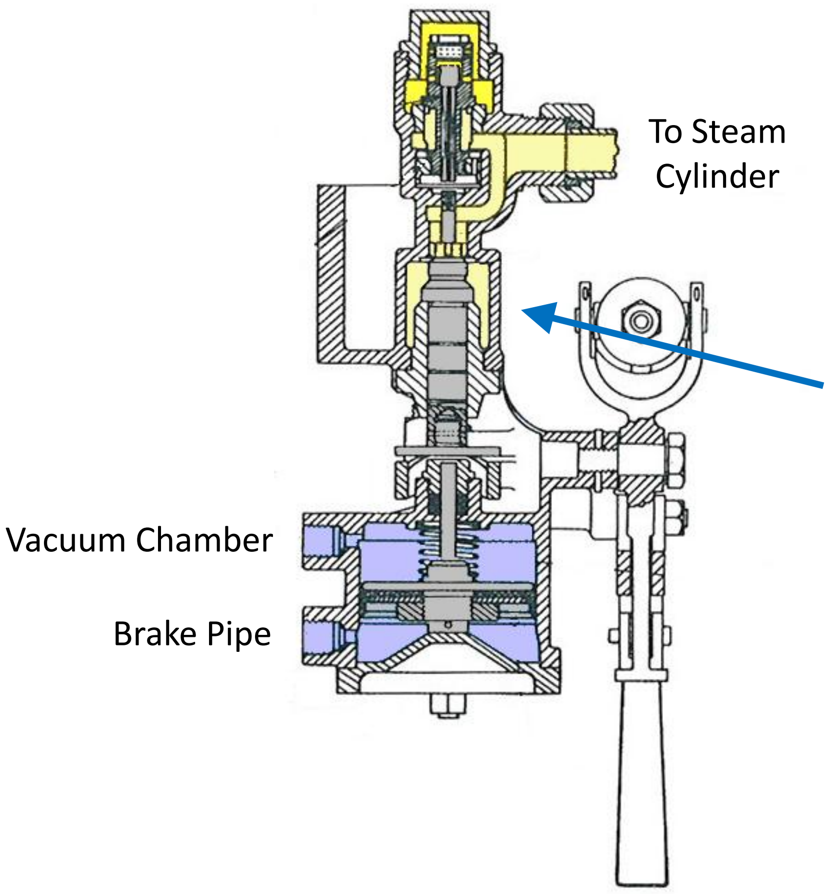
Here the valve has returned to its equilibrium.

The steam in the brake cylinder is being held at a constant pressure in proportion to the vacuum brake demand.

The steam brake valve is known as a proportional valve and it is probably the single most sophisticated valve found on any of the railway's steam locomotives.

Now releasing the brake...

Vacuum brakes (steam brake)



When the brake pipe vacuum is partially or fully restored, there is a reduction in air pressure on the underside of the piston in the miniature brake cylinder.

The upwards force on the steam valve is reduced and the steam pressure in the brake cylinder can force open the exhaust passage and start to escape to atmosphere.

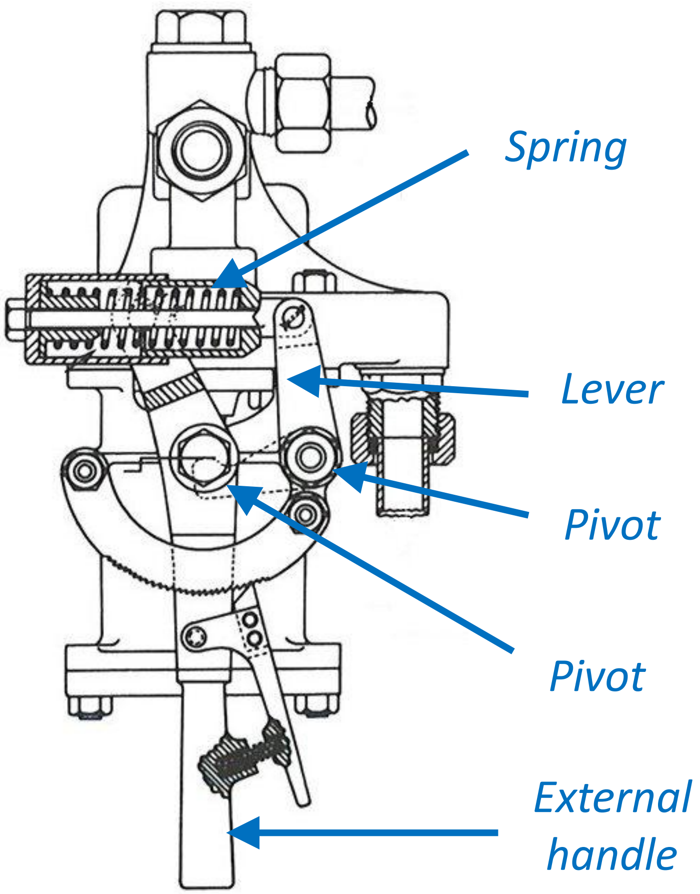
The exhaust of steam will continue until the valve is rebalanced. If vacuum is fully restored, the steam brake will fully release.

Vacuum brakes (steam brake)

The external handle of the steam brake valve is not directly connected to the internal mechanism. Instead, the handle compresses a spring. This spring then pushes on a separate mechanical lever that is connected to the valve mechanism.

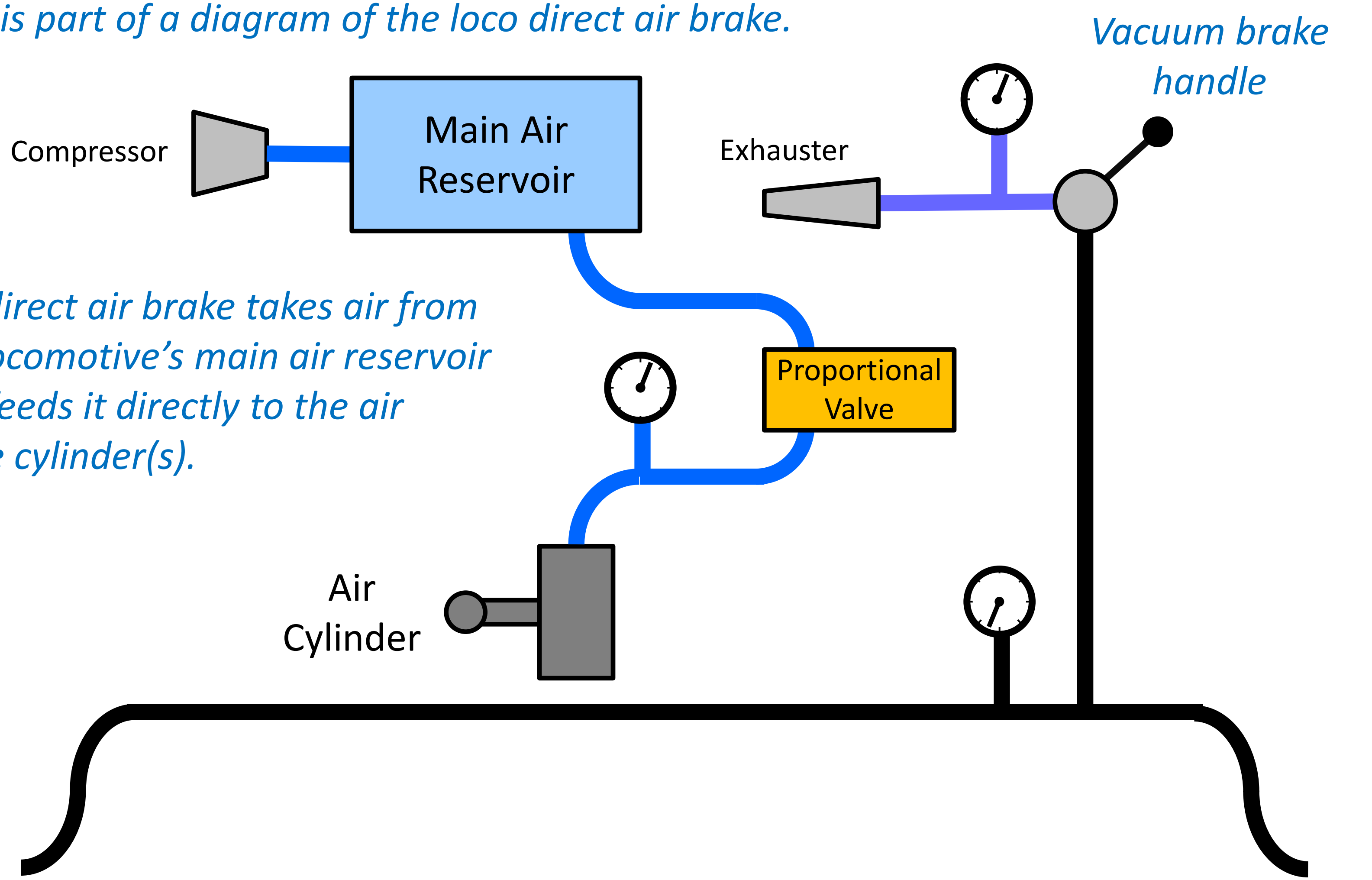
The more the handle is moved, the greater the compression on the spring and the greater the force on the valve mechanism.

In this way the handle takes the place of the internal miniature brake cylinder, applying force to the valve to create a balancing steam pressure.



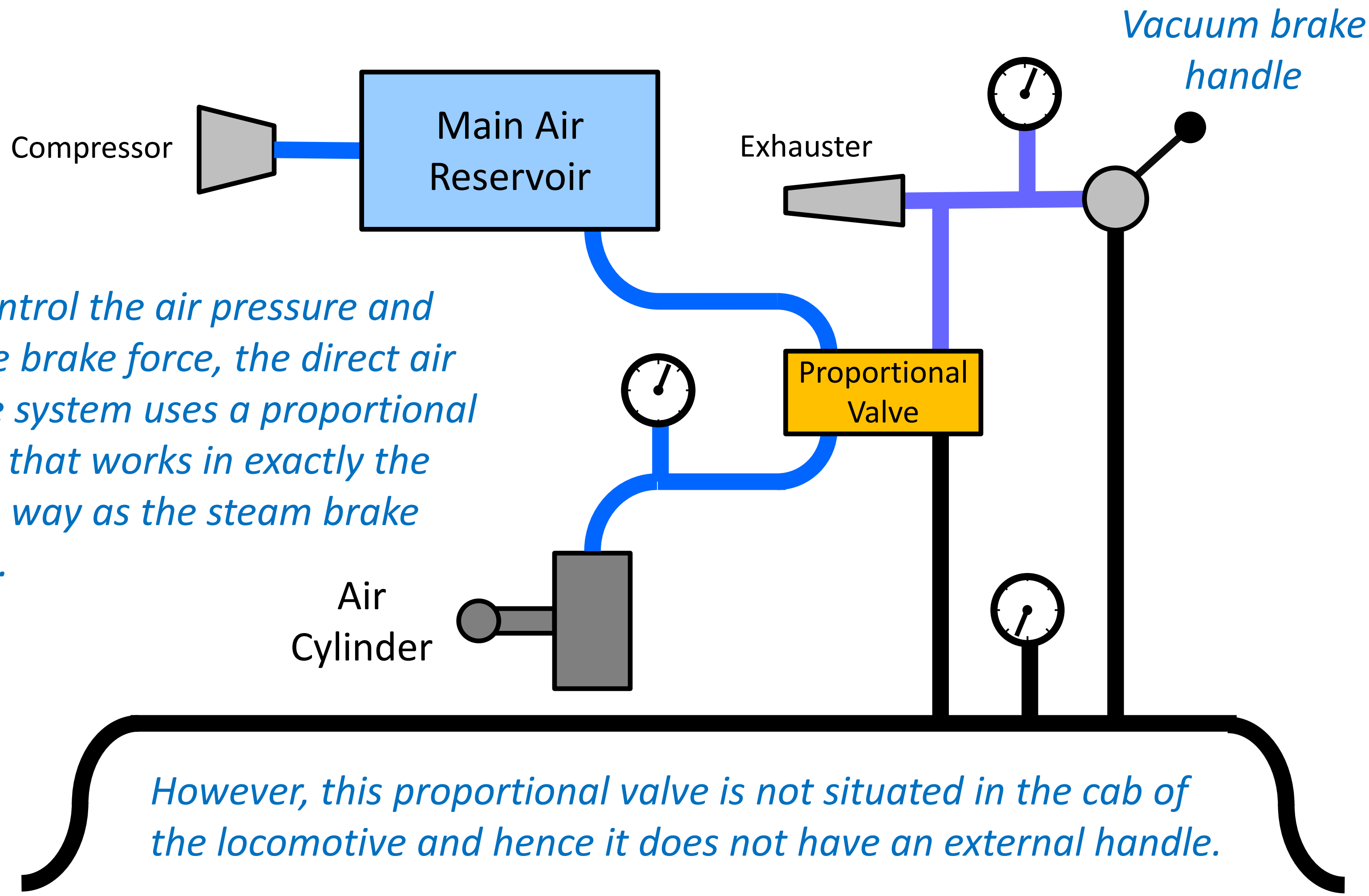
Vacuum brakes (loco air brake)

Here is part of a diagram of the loco direct air brake.



The direct air brake takes air from the locomotive's main air reservoir and feeds it directly to the air brake cylinder(s).

Vacuum brakes (loco air brake)



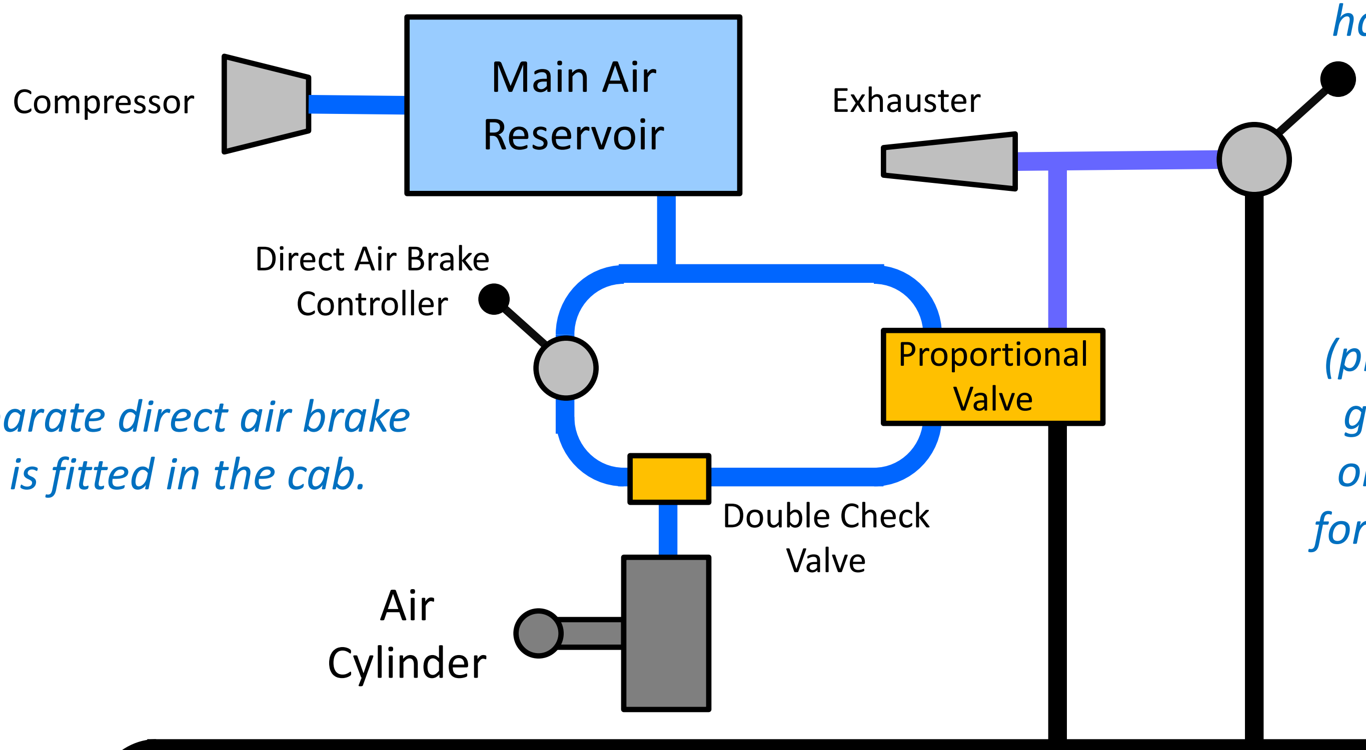
To control the air pressure and hence brake force, the direct air brake system uses a proportional valve that works in exactly the same way as the steam brake valve.

However, this proportional valve is not situated in the cab of the locomotive and hence it does not have an external handle.

Vacuum brakes (loco air brake)

Here is the complete diagram of the loco direct air brake.

Vacuum brake handle



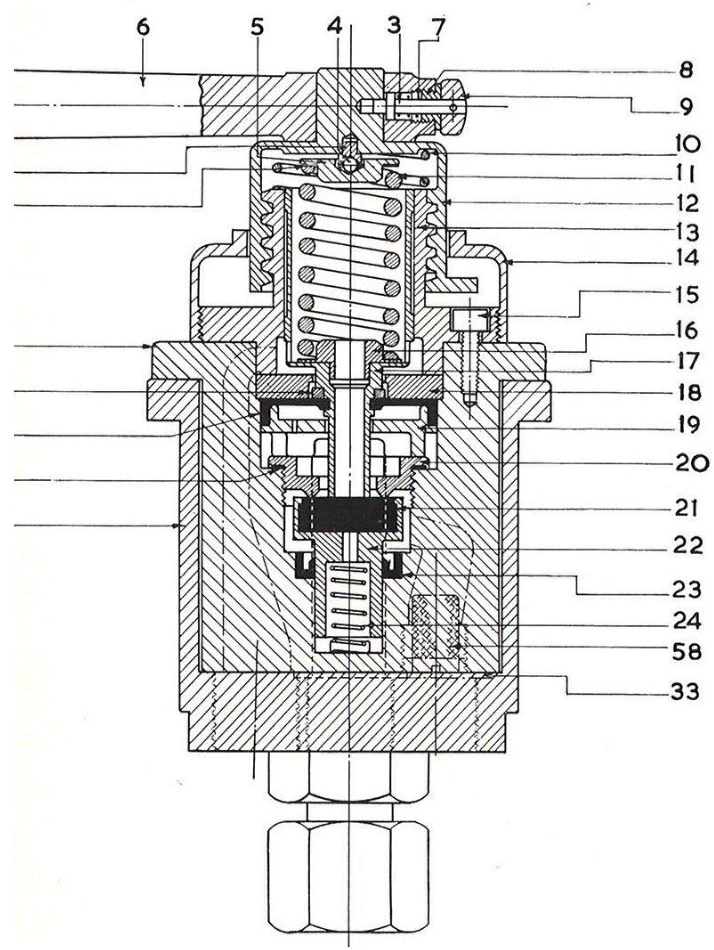
A separate direct air brake valve is fitted in the cab.

(pressure gauges omitted for clarity)

As there are two separate pipes to the brake cylinder, a double check valve is fitted to prevent air from being passed back up the other pipe.

Vacuum brakes (loco air brake)

This is a typical direct air brake valve.

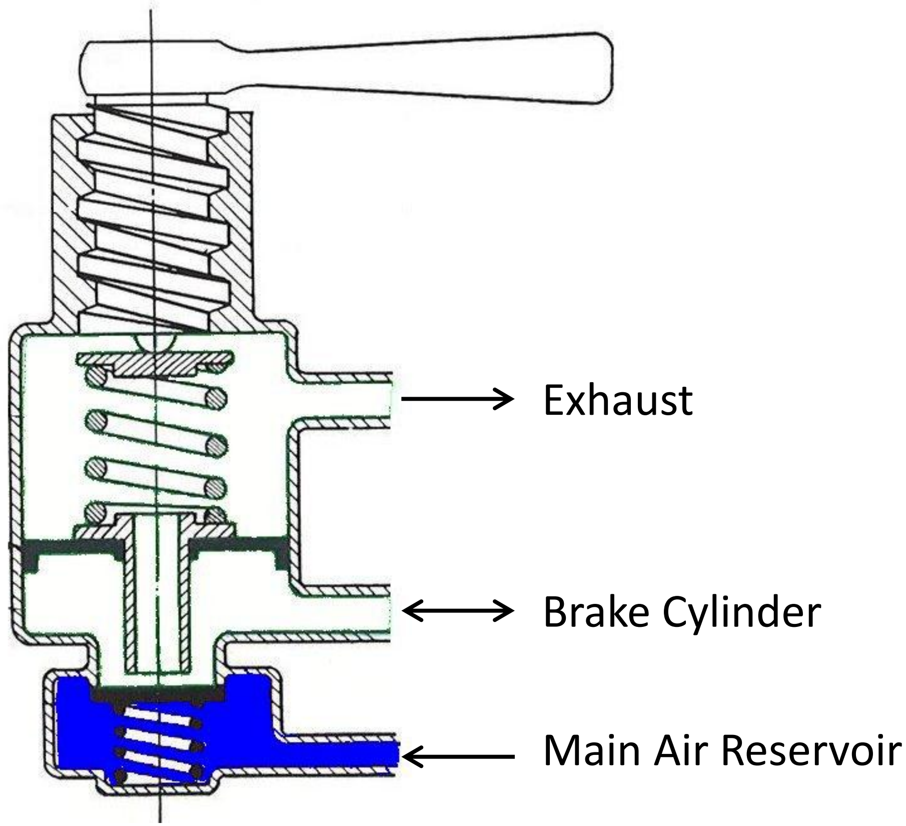


Vacuum brakes (loco air brake)

This diagram shows the internal mechanism simplified.

The valve is in the brake released position.

Main air reservoir pressure enters at the base of the valve but cannot proceed any further. It bears up on the inlet valve keeping it firmly shut.

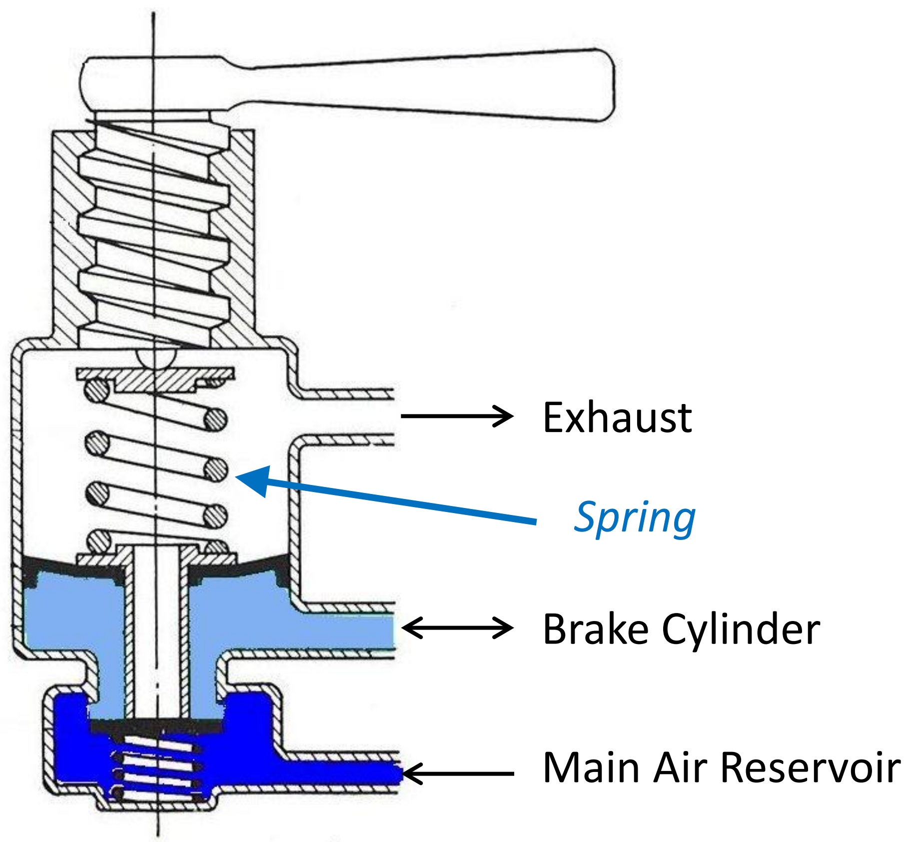


Vacuum brakes (loco air brake)

When a brake demand is made by moving the handle, the threaded valve stem causes the internal spring to be compressed.

The spring pushes on a hollow valve stem, seating it on the inlet valve.

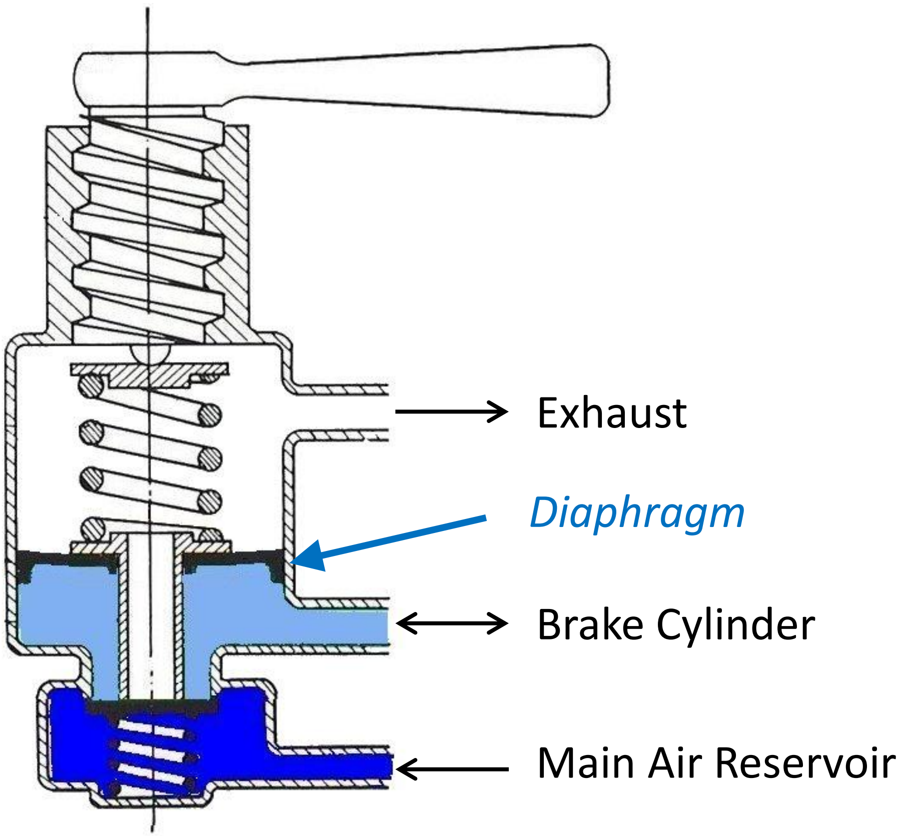
The inlet valve is then forced open, allowing air pressure to enter the brake cylinder.



Vacuum brakes (loco air brake)

The air entering the brake cylinder fills the chamber of the valve that is below the spring. Here it bears on a diaphragm, generating a counter force to the spring.

When the air pressure is sufficient to match the spring force, the inlet valve closes and the valve is held in equilibrium.

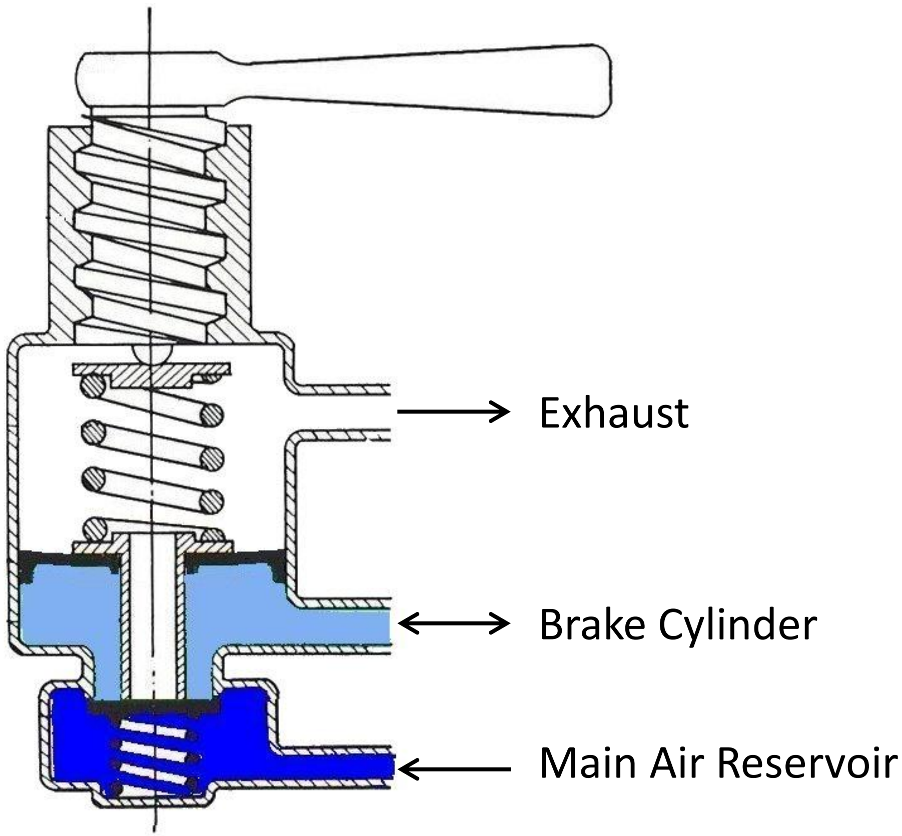


Vacuum brakes (loco air brake)

The air pressure in the brake cylinder is proportional to the distance that the handle has been moved.

If there is a leak of brake cylinder air pressure, the spring will overcome the reduced pressure and will force open the inlet valve to compensate for the leak.

This is known as a self-lapping brake controller.

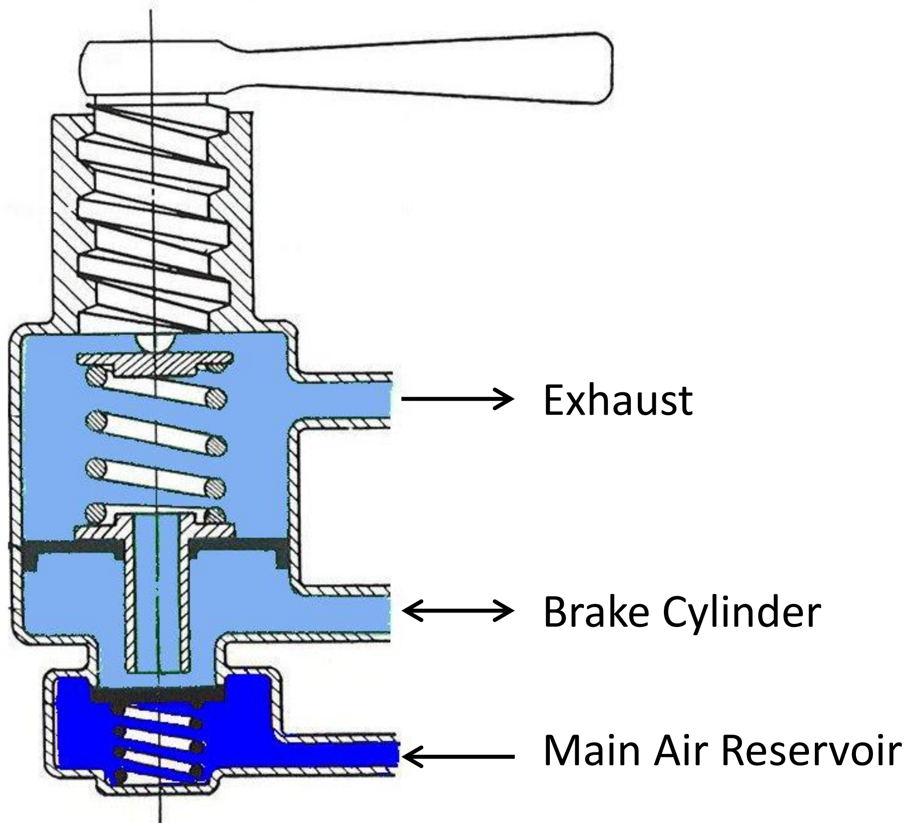


Vacuum brakes (loco air brake)

When the handle is returned towards the release position, the compression of the spring is reduced.

The air pressure in the brake cylinder (and under the diaphragm) overcomes the reduced spring force and lifts the hollow valve stem from the face of the inlet valve.

Air pressure will now escape to atmosphere through the hollow valve stem until the valve is again in equilibrium.



Vacuum brakes (loco air brake)

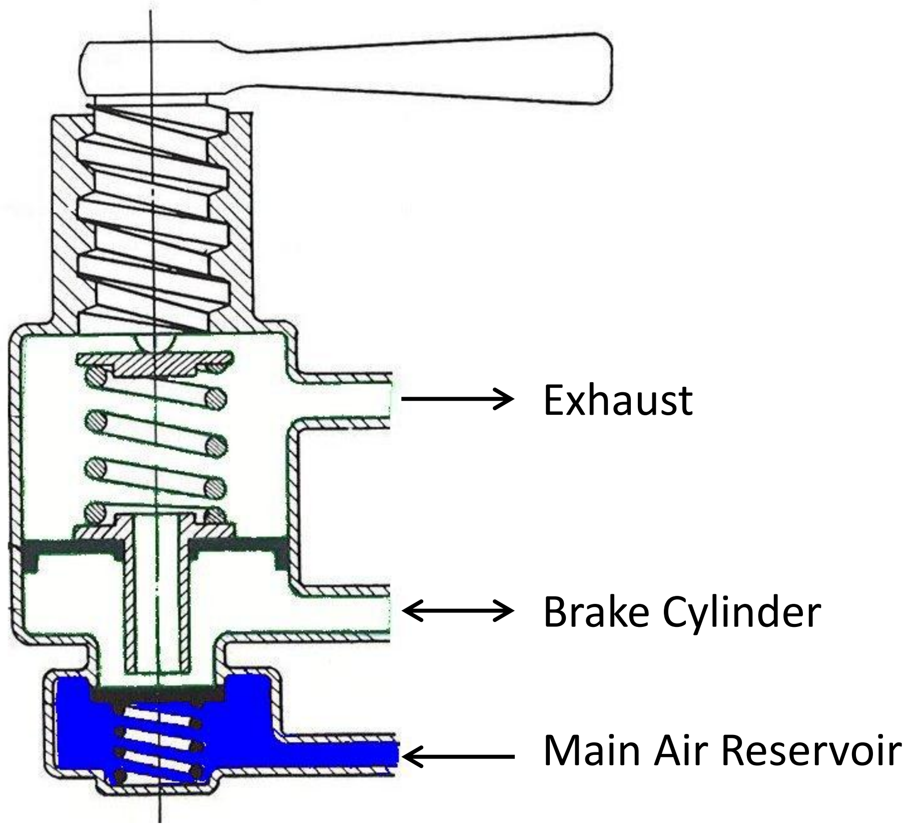
When the handle is returned completely to the release position, there is no compression of the spring .

All the air pressure in the brake cylinder will now escape to atmosphere through the hollow valve stem.

The brake is released.

<u>Question:</u>

What is the drawback with this controller?



Vacuum brakes (loco air brake)

Answer:

When compressed, the internal spring will apply a force back on the control handle. This force makes the handle susceptible to unwind into the brake released position when disturbed by any vibration.

Unlike the steam brake valve, there is no ratchet to hold the direct air brake handle in the applied position.

Therefore, a train must not be parked and left unattended with only the locomotive direct air brake applied.

Vacuum brakes

Operation

Vacuum brakes

<u>Question and Answer session</u>

The following slides ask various questions on the operation of the vacuum brake system. Answers providing advice on best practice are based on several years experience of testing brake equipment.

However, this section does not represent any official policies of the Ffestiniog and Welsh Highland Railways. If in any doubt regarding the operation of the brake equipment, contact the Chief Mechanical Engineer at Boston Lodge Works.

Vacuum brakes

Q: How should you carry out the continuity test?

Should you:

a) remove the coupling hose at the end of the train and check for air flow into the brake pipe? OR

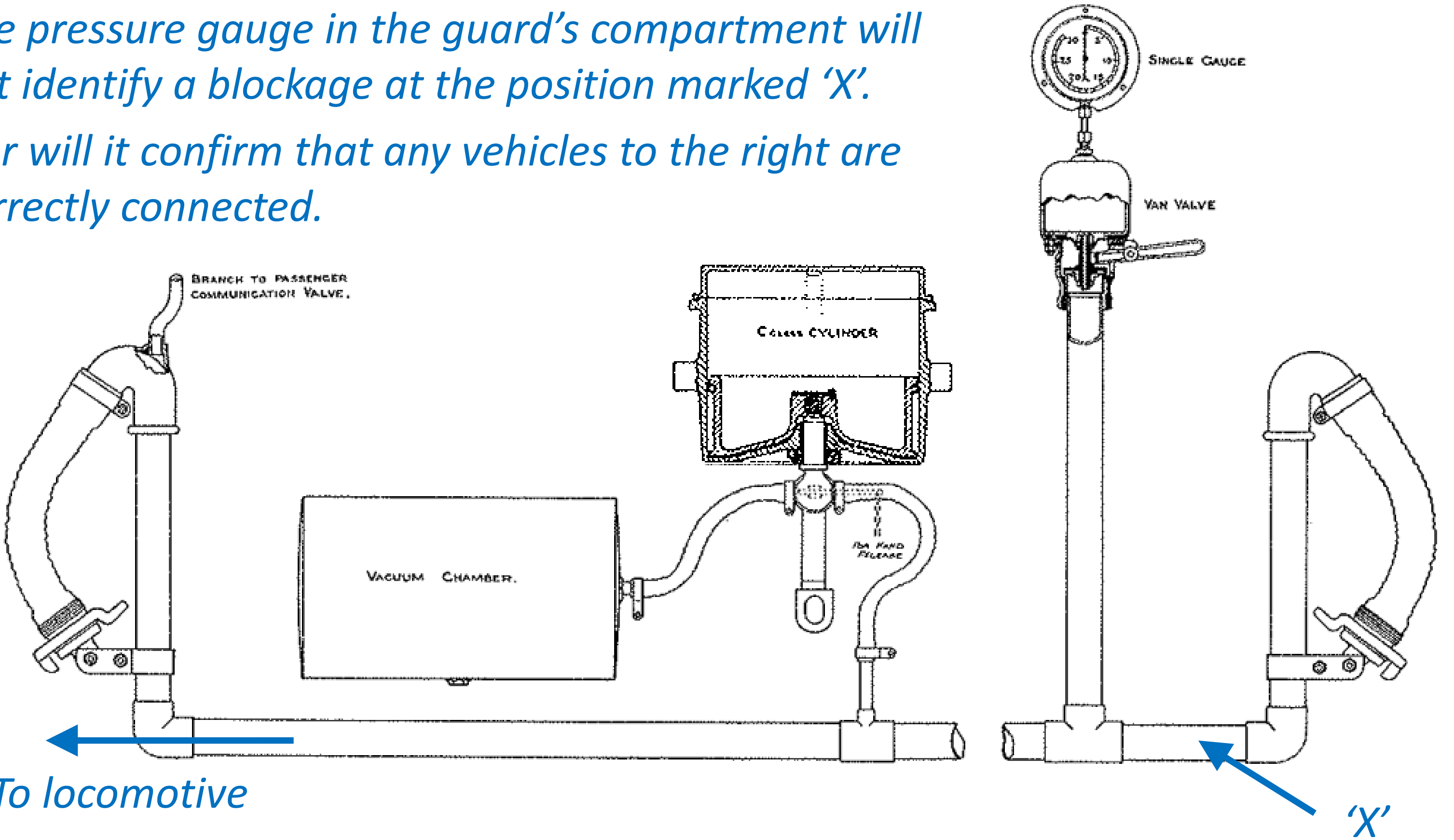
b) examine the pressure gauge in the guards compartment?

Vacuum brakes

Discussion

The pressure gauge in the guard's compartment will not identify a blockage at the position marked 'X'.

Nor will it confirm that any vehicles to the right are correctly connected.



Vacuum brakes

<u>Discussion continued</u>

Removing the end brake hose and observing that air enters the brake pipe does not confirm conclusively that there are no blockages. There could be restrictions to the flow of air. The guard's pressure gauge does give confirmation that the required vacuum is being created and destroyed quickly.

In the Republic of Ireland, the brake continuity test is carried out by connecting an end of train device to the last brake hose of the train. This device has both a pressure gauge and a venting cock to allow the operator to ensure correct brake continuity.

Vacuum brakes

A: In summary, it is best to test for brake continuity at both the end brake hose and the guard's pressure gauge.

- The end brake hose will confirm that the brake pipe is complete.
- The pressure gauge will indicate that the required vacuum is being generated.

Vacuum brakes

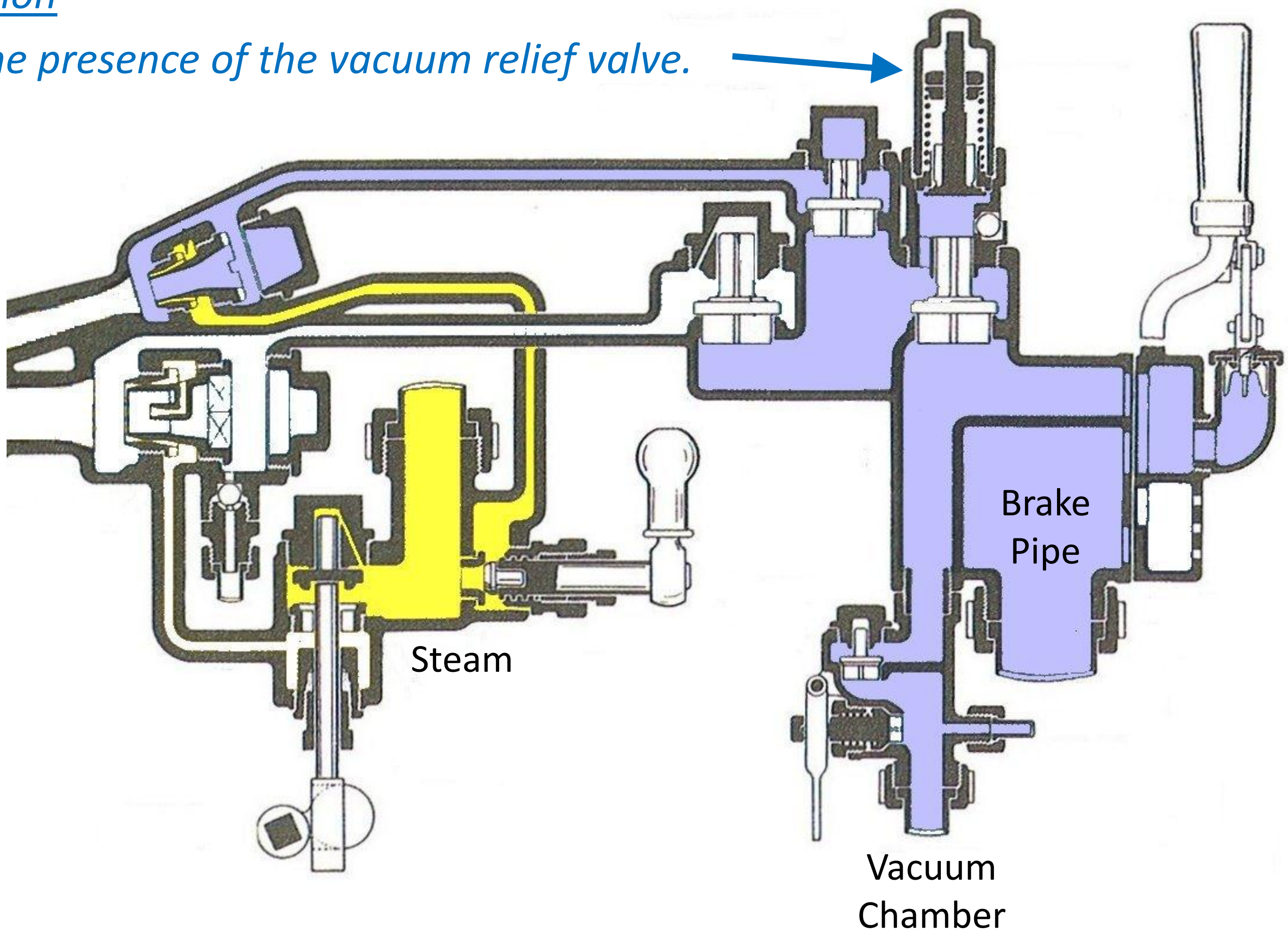
Q: How is it best to setup the small ejector?

- Do you set it to just enough to maintain 21 inches of vacuum?
- Why?

Vacuum brakes

Discussion

Note the presence of the vacuum relief valve.



Vacuum brakes

Discussion continued

If the ejector tries to generate a vacuum greater than the nominal 21 inches, the vacuum relief valve will open automatically to allow air into the brake pipe to destroy the excess vacuum. Therefore, the energy used to generate the excess vacuum is wasted. This wastes steam from the boiler and ultimately more fuel is burned.

It should be observed that the amount that the steam valve has to be opened to generate and maintain 21 inches of vacuum will depend on the length of the train (and hence the volume of the train brake pipe). Similarly, when running light loco, the least amount of opening will be required of the steam valve to the ejector.

Vacuum brakes

<u>Discussion continued</u>

Care should be taken having run round a train light loco that the small ejector is set to suit the length of the train, other wise dragging brakes will result. This is especially important on the Welsh Highland Railway, where the large and powerful NGG16 Garratt locomotives (weighing 60 tonnes) can easily overcome a brake drag on the train of carriages (weighing around 110 tonnes).

Vacuum brakes

A: In summary:

- The small ejector is set at the minimum output required to maintain vacuum in the train pipe.
- However, don’t be too mean – consider that the NGG16 Garratt locomotives are powerful enough to overcome a brake drag.

Vacuum brakes

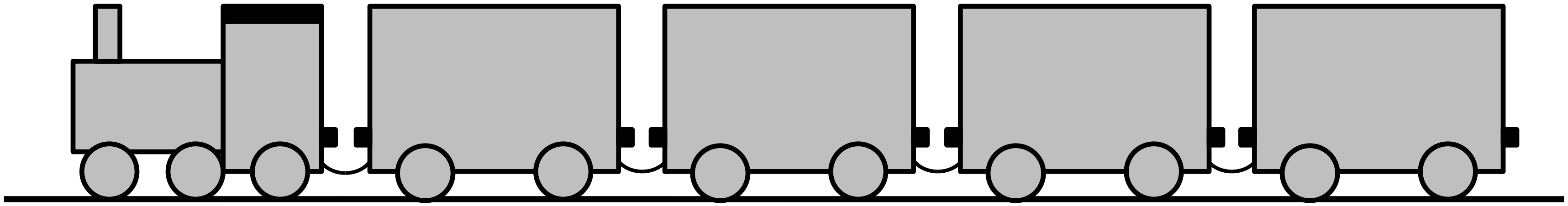
Q: What does the term “defensive driving” mean?

- A common perception is that it means accelerating and braking gently, but this is not quite the case...

Vacuum brakes

Discussion – Part 1

Consider our train travelling along at constant speed. On level track the locomotive is pulling the train to overcome friction. As a result all the couplings are stretched.

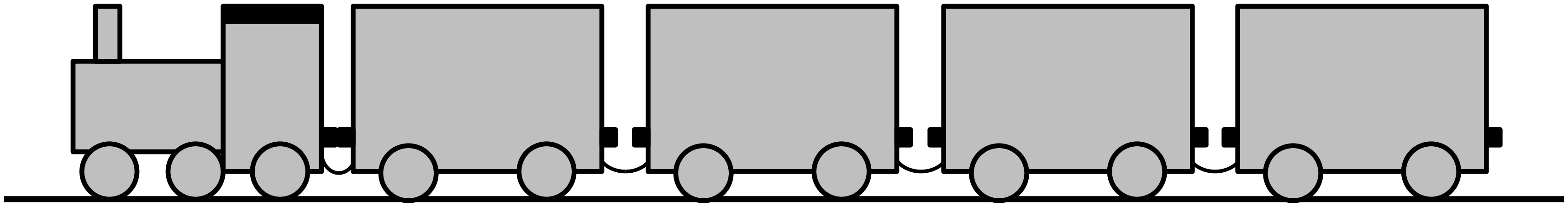


Vacuum brakes

Discussion continued

The driver applies the vacuum brake, and air rushes into the brake pipe.

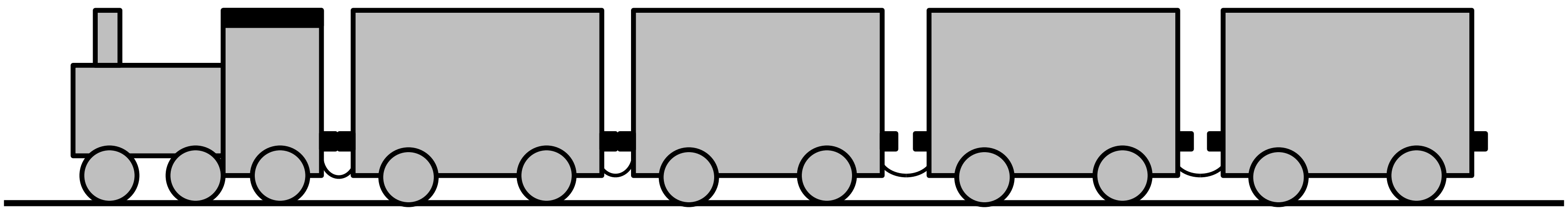
As the air enters the brake pipe it will fill the nearest brake cylinders first.



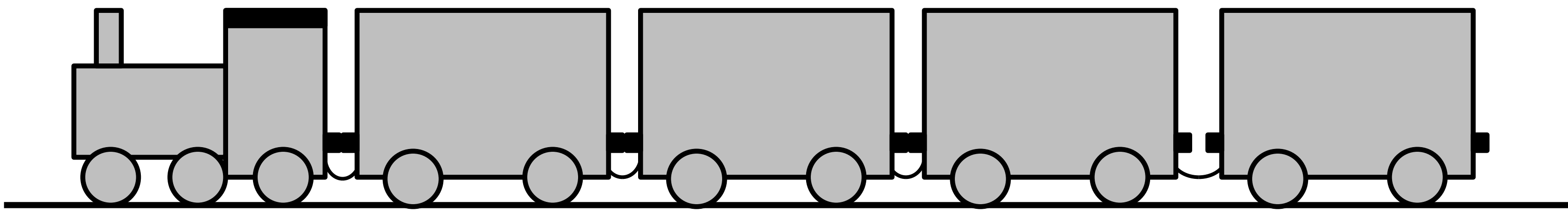
The front of the train will brake before the following vehicles, causing the couplings to be compressed.

The next few slides show this taking effect throughout the train.

Vacuum brakes



Vacuum brakes

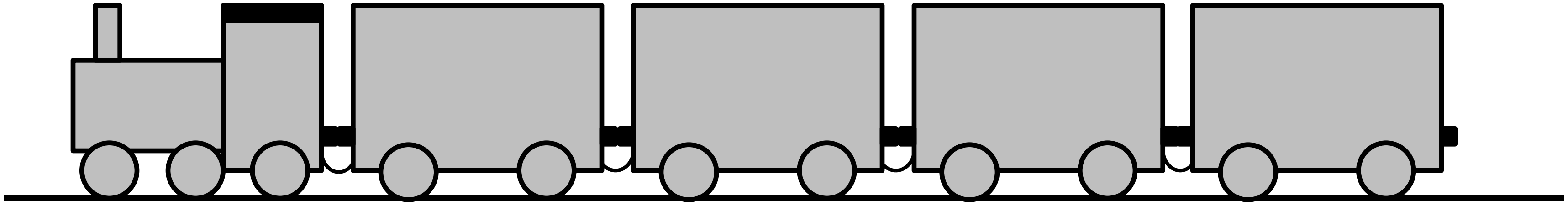


Vacuum brakes

Discussion continued

Once air has filled all the brake cylinders, all the couplings will be compressed.

To help overcome this problem locomotives are traditionally designed to brake less severely than the coaches. Thus the locomotive tends to run away from the train and in doing so tends to stretch the couplings.



Note that on a unfitted freight train the compressing of the couplings cannot be avoided.

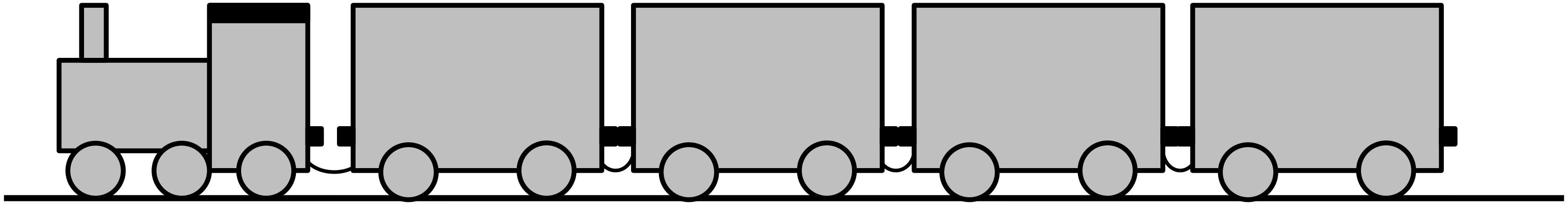
Now we shall consider the brakes being released...

Vacuum brakes

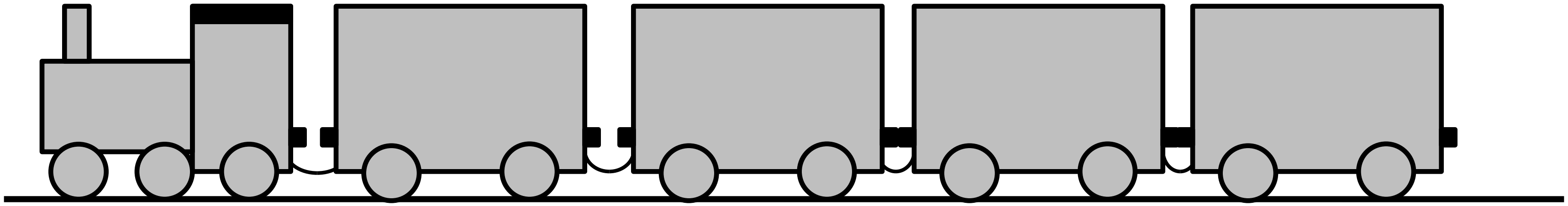
Discussion continued

As the ejector sucks air from the train brake pipe there is a tendency for the brakes on the leading vehicles to release first.

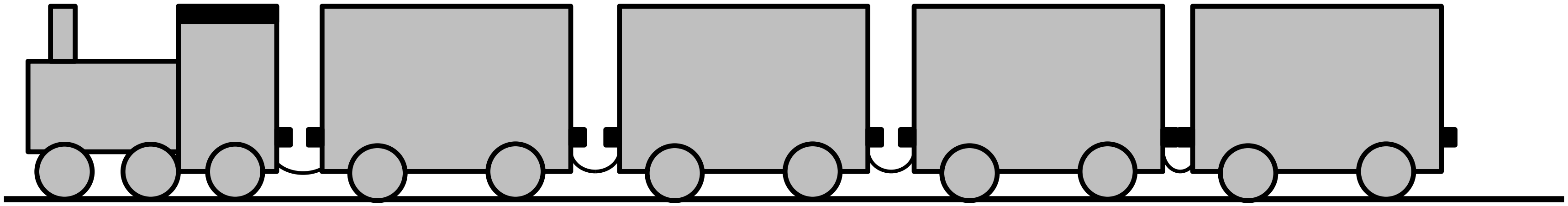
The couplings gradually stretch out, starting at the front of the train...



Vacuum brakes



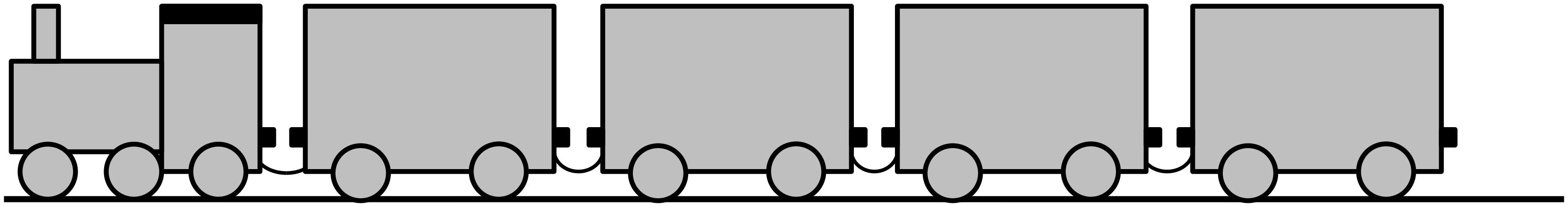
Vacuum brakes



Vacuum brakes

Discussion continued

This is one of the reasons for stopping on a rising vacuum. The train will come to rest with its couplings stretched. When the locomotive begins to haul the train again, there will be less likelihood of jolts to the trailing vehicles.



It is unlikely that stopping on a rising vacuum will stretch all of the train's couplings, but there will be a lot less couplings in which to take up slack when restarting.

Vacuum brakes

<u>Discussion continued</u>

The compression of the couplings results in jolts to the trailing vehicles. The effect will be worse when a greater volume of air is admitted into the brake pipe in a short period of time (i.e. a harsh initial brake application). However, once the train is braking and the couplings are already compressed, increasing the brake effort (by admitting a greater volume of air) will not result in severe jolts to the train.

The same is true for releasing the brakes whilst still moving. The initial release should be gentle (small ejector only) to allow the couplings to stretch gently. Once the couplings are stretched, the brake can be released quickly (using the large ejector) without causing severe jolts. Similarly, the driver should wait until the brakes are all completely released before opening the regulator, otherwise severe jolts will result at any couplings not yet stretched. Initial openings of the regulator should also always be gentle, to stretch the couplings, followed by a greater opening of the regulator (if required).

Vacuum brakes

Discussion continued

Once the train is braking with the couplings compressed, the brake application can be made more severe without causing jolts. However, one very important point must be considered:

Increasing the brake force will increase the deceleration force experienced by the passengers.

The above is fact. The quicker you decelerate the more force you feel.

Vacuum brakes

Discussion continued

Therefore, in summary for normal service brake applications:

Sequence of braking	Severity of braking
1. Initial Application	• Gentle
2. Sustained Braking	• Moderate?
3. Easing / Release	• Gentle

Vacuum brakes

<u>Discussion – Part 2</u>

The best method of braking can be a controversial topic.

Even today, engineers still differ in opinion as to whether braking (over a given distance and from a given speed) should be carried out by one constant gentle application, or by a succession of intermittent harsher brake applications.

The various positives and negatives of each approach are considered on the next slide.

Note that on heritage railways operating at only 25mph maximum speed, the scope for intermittent braking tends to be limited to braking on long gradients to control speed.

Vacuum brakes

Continuous Braking

- Smoother action
- Only one movement of the rigging and brake blocks
- Very light applications can cause brake chatter
- Continuous contact of brake blocks retains heat
- Vacuum must be retained in vacuum chambers

Intermittent Braking

- Can tend to cause jolts
- More movements and impacts of the brake rigging
- Positive and quick motion of blocks onto the wheels
- Allows air to circulate around the brake blocks
- Vacuum chambers are recharged

Vacuum brakes

<u>Discussion continued</u>

From the previous slide, it is clear that the disadvantages of continuous light brake applications tend to be because it is continuous. The disadvantages of intermittent harsher brake applications tend to be because they have to be harsher to achieve the same stopping distance.

However, an intermittent and light brake application omits many of the disadvantages of both of the above. The compromise is that the stopping distance will increase.

To achieve an intermittent and light brake application requires the driver to plan ahead. Similarly, the driver can shut off the regulator and use a rising gradient as a means of slowing the train instead of applying the brake blocks.

This is, of course, provided that the timetable permits. Although consider how many seconds are actually gained by braking later?

Vacuum brakes

A: The term “defensive driving” means planning ahead.

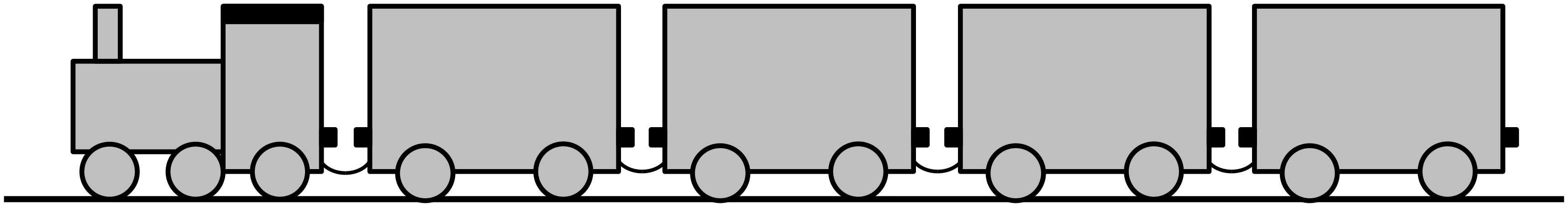
Vacuum brakes

Q: How would you change your method of braking when ascending or descending a steep gradient?

Vacuum brakes

Discussion

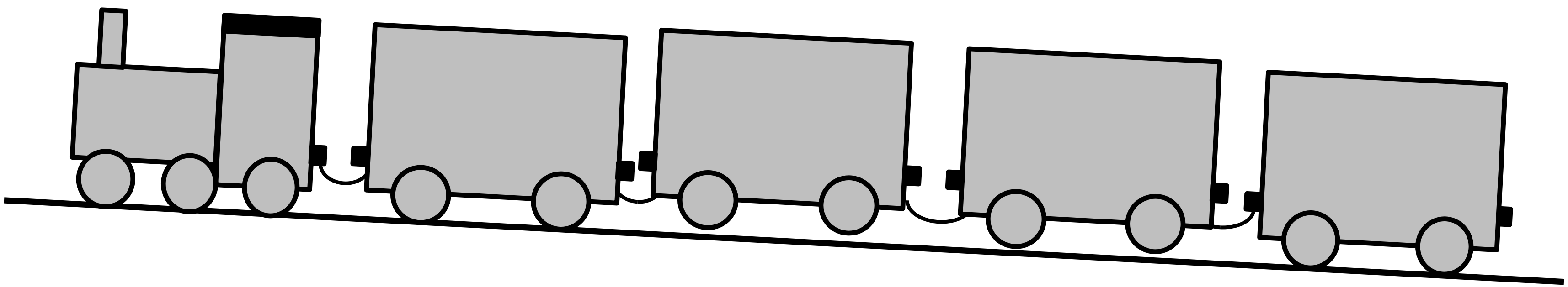
Here is a representation of the train on level track.



Vacuum brakes

Discussion continued

Here is a representation of the train ascending a gradient.



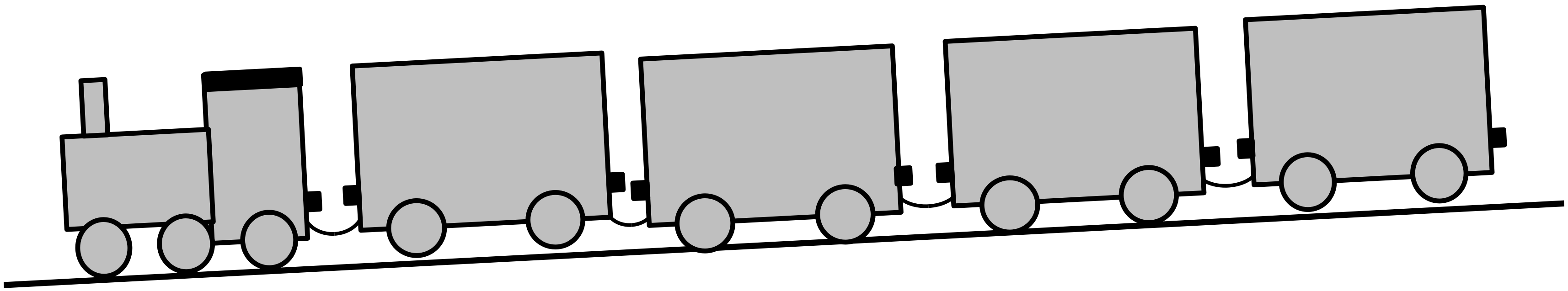
If the gradient is relatively steep and the brake application is relatively gentle, the train's couplings will remain stretched whilst the train is braking.

The gradient will act to assist the braking and in many cases only a light application will be required throughout the duration of braking.

Vacuum brakes

Discussion continued

Here is a representation of the train descending a gradient, but not braking.

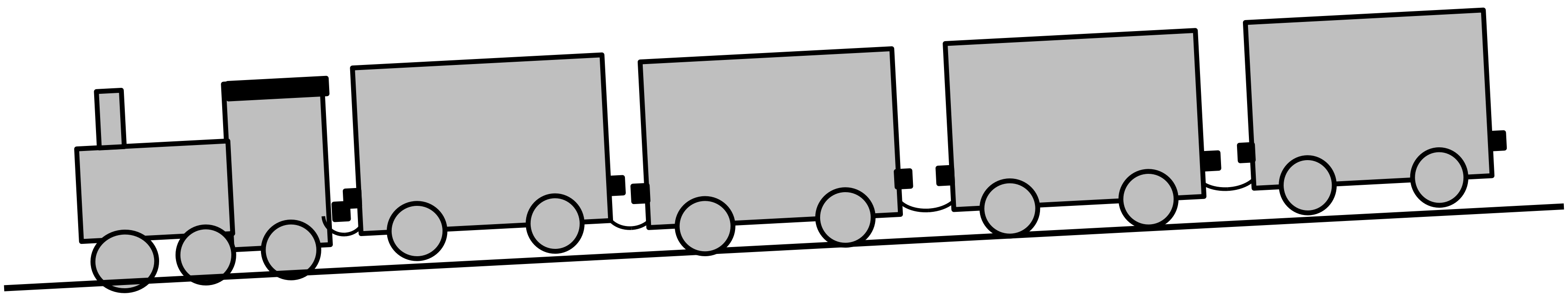


If the gradient is relatively steep, there will be a tendency for the trailing vehicles to run into the locomotive. This is because the locomotive has more resistances to its free running than trailing vehicles. For example, locomotives tend to have plain bearings, the pistons act like compressors, slowing the rotation of the wheels, and the rigid wheelbase is typically longer than a coach bogie so the curve resistance will also be greater.

Vacuum brakes

Discussion continued

This view shows the trailing vehicles catching up with the locomotive.

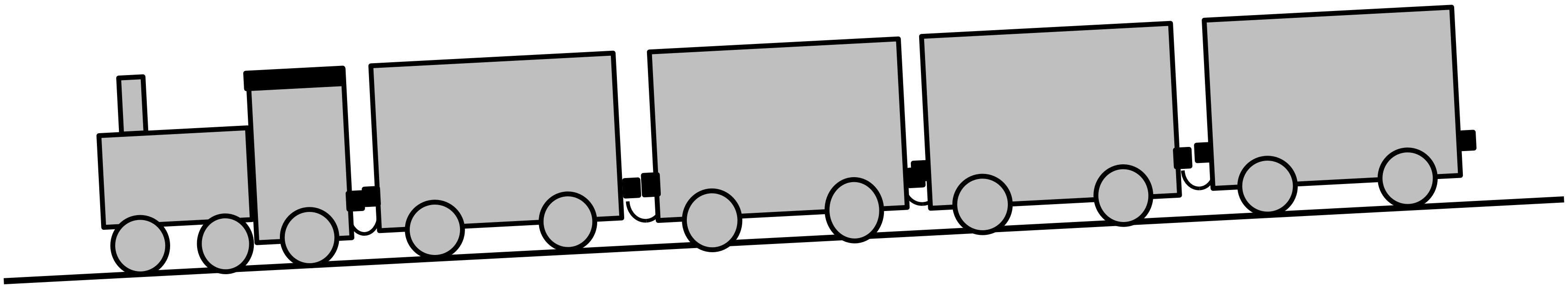


Now that the first of the trailing vehicles is resting on the locomotive, it will be slowed down. Hence, the remainder of the trailing vehicles will catch up with the locomotive and first vehicle. This process will continue until all the train's couplings are compressed.

Vacuum brakes

Discussion continued

This view shows the train with couplings compressed.



With most or all of the couplings compressed, a harsher brake application can be initiated sooner without causing severe jolts. This is useful because the steep gradient will try to counter the braking, which therefore requires a harsher application.

continued...

Vacuum brakes

Discussion continued

If the train is going to stop at a station on a steep descending gradient, there is no merit in trying to stretch the couplings by stopping on a rising vacuum. When the train starts again on its descent of the gradient, the vehicles will ultimately tend to run into each other again.

When releasing the brakes on a steep descending gradient with the couplings compressed, there will be a tendency for the brakes to release at the front of the train first (as discussed previously). To minimise this effect the brakes should be released as gently as possible (using the small ejector only and a gradual release).

Note that the previous slides have considered severe gradients. Shallow gradients will not have the same effect and braking in this case should be carried out in the same way as on level track. It may not always be possible to easily distinguish a severe gradient from a shallow one in terms of the compression of the couplings before and during braking.

Vacuum brakes

<u>Discussion continued – Drifting steam</u>

To complicate matters, drifting steam is sometimes used to retain a positive pressure in the locomotive's cylinders. From a train handling point of view, on a steep gradient there are 4 scenarios:

(1) Drifting steam exceeds the locomotive's resistances and tends to accelerate the train. If countered by braking there will be excess brake block wear. This is not ideal.

(2) Drifting steam marginally exceeds the locomotive's resistances and keeps the coupling stretched, without increasing speed. This is a good balance.

(3) Drifting steam reduces locomotive resistance to the same as the trailing vehicles. This results in the vehicles tending to coast into each other as the resistances vary slightly, such as on curves. This is not ideal.

(4) Drifting steam is not sufficient to overcome the locomotive's resistances, and the couplings remain compressed. The train behaves as described in the previous few slides. This is an acceptable scenario.

Vacuum brakes

<u>Discussion continued – Drifting steam</u>

Whilst scenario (2) is a good position, it is difficult to achieve because it can easily shift to scenarios (1) or (3) as the gradient and curves change.

Scenario (4) is also a good and tends to be easier to achieve. If anyone is in doubt about trains running with their couplings compressed, it is worth noting that the 150 wagon freight trains in the USA brake principally using the locomotive dynamic brake only and not the train brakes.

In any case, judging the changing gradient resistance, curve resistance and drifting steam assistance is not easy.

That single small handle in the cab that controls brake pipe vacuum often looks deceptively as straightforward as the foot pedal brake in your car. Anyone without skill could pull it and cause the train to stop. However, braking a train smoothly for the passengers in trailing vehicles is not easy and should not be underestimated.

Vacuum brakes

A:

On a steep rising gradient, it should be possible to apply the brakes gently enough that the couplings remain stretched.

On a steep falling gradient, where the couplings tend to be compressed, the brakes should be released gently.

Braking smoothly is not easy.

Vacuum brakes

Q: How is it best to determine the severity of the brake application?

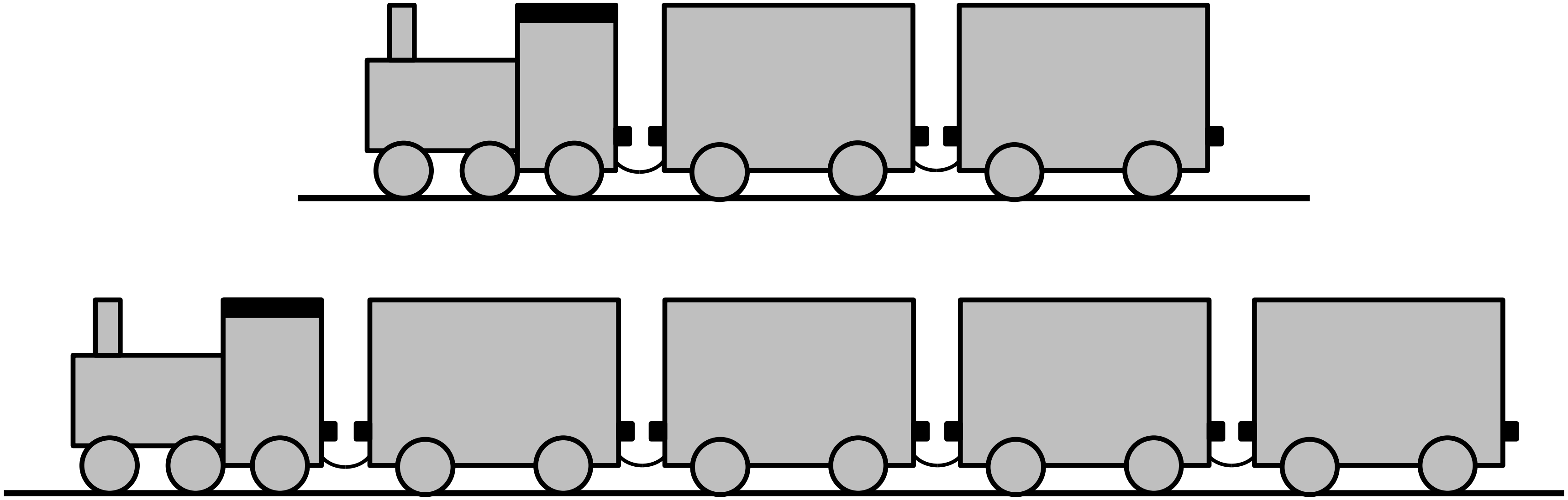
Is it:

a) By experience?
b) By judgement?
c) By referring to the pressure gauge?

Vacuum brakes

Discussion

These drawings provide a clue. Consider how the brakes will behave differently for the different lengths of train.



Vacuum brakes

Discussion continued

If you double the length of the train you double the volume of air required to achieve the same severity of brake application. This is because the brake pipe is twice as long and there are double the number of brake cylinders to fill with air.

The brake controller will have to be applied for longer to allow sufficient time for the greater amount of air to enter the brake pipe.

A driver familiar with short train formations will tend to under-brake a long train.

A driver familiar with long train formations will tend to over-brake a short train.

Vacuum brakes

Discussion continued

This is not to detract too much from experience. A certain amount of experience is also beneficial. The pressure gauges in the locomotive cab only illustrate the pressure at that point in the train. Changes in pressure can take several seconds to take effect throughout the train. Pressure gauges can also be faulty.

It is important to remember that whilst the pressure gauge informs you of the brake demand being made along the brake pipe, it does not represent an actual deceleration of the train. The latter could be affected by slippery rails. Judgement of the weather conditions and reference to other gauges like the speedometer are also important.

Vacuum brakes

A: Best practice is to use a combination of experience, judgement and the pressure gauge.

Don’t ignore the pressure gauge. It is there for a reason.

Vacuum brakes

Enhancements

Vacuum brakes

Enhancements

The following slides look at equipment that can be fitted onto vacuum brake systems to improve their performance:

- *Vacuum Pump **
- *Piston head non-return valve*
- *Slipping band piston seal **
- *Direct admission valves **

*As of 2011, the items marked * are not fitted on Ffestiniog and Welsh Highland Railway rolling stock. However, it is beneficial to be aware of them because it is quite possible they could be fitted in future. Also, if you visit any other railways as guest drivers it is beneficial to be aware that their vacuum brake systems may behave differently as a result of such enhancements.*

Vacuum brakes

<u>Vacuum Pump</u>

The vacuum pump is a device which is directly connected to the locomotive's motion. The pump operates whenever the locomotive is moving, and draws air from the brake pipe so that the ejector can be turned off, conserving steam.

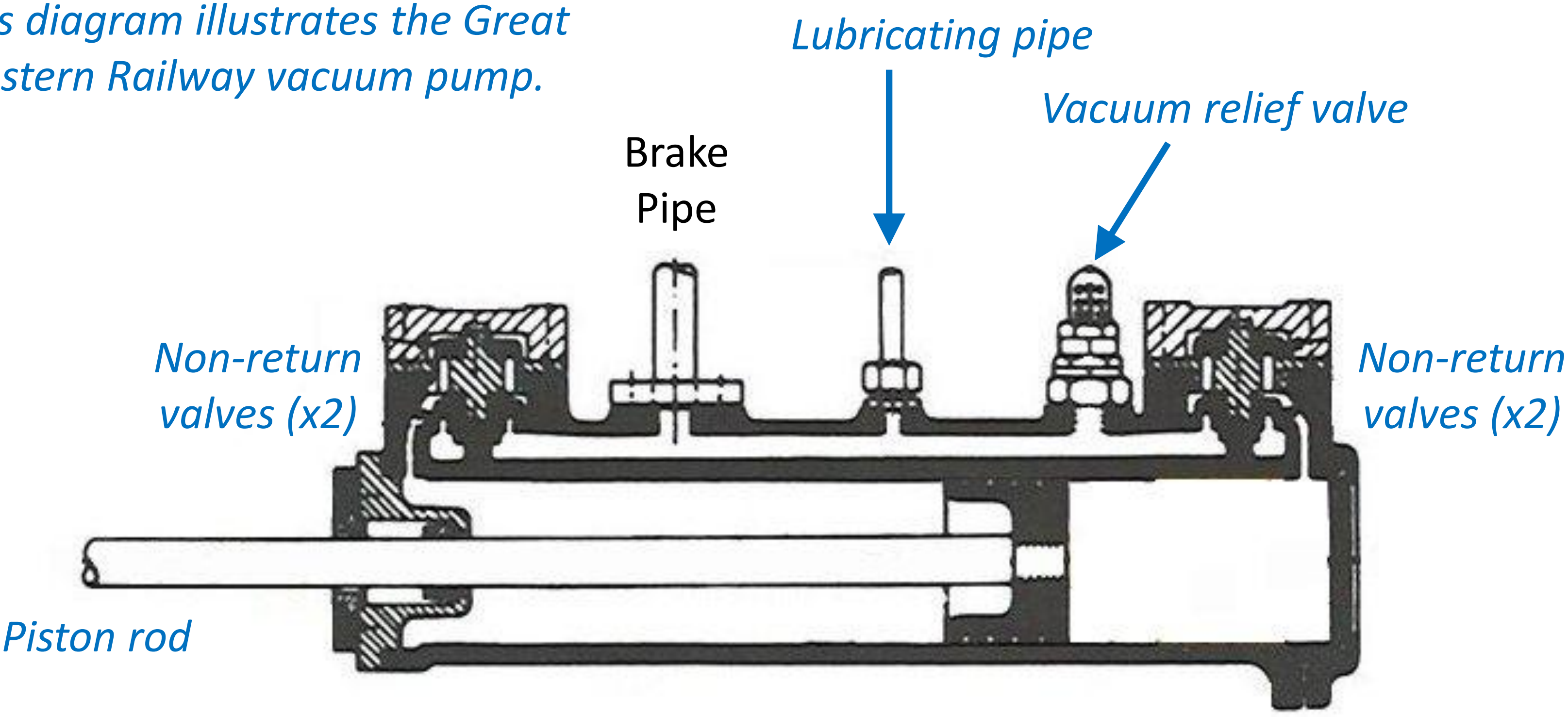
When the regulator is open, the vacuum pump is of little benefit. A portion of the steam being supplied to the cylinders is being used to overcome the resistance of the pump.

However, when the regulator is closed the pump maintains brake pipe vacuum without using any steam. Also, the pump's resistance provides brake effort without brake block wear. The vacuum pump conserves steam usage and therefore saves fuel.

On the Ffestiniog Railway's 11 miles of continuous downhill running, a vacuum pump would offer potentially large savings in steam and fuel usage.

Vacuum brakes

This diagram illustrates the Great Western Railway vacuum pump.

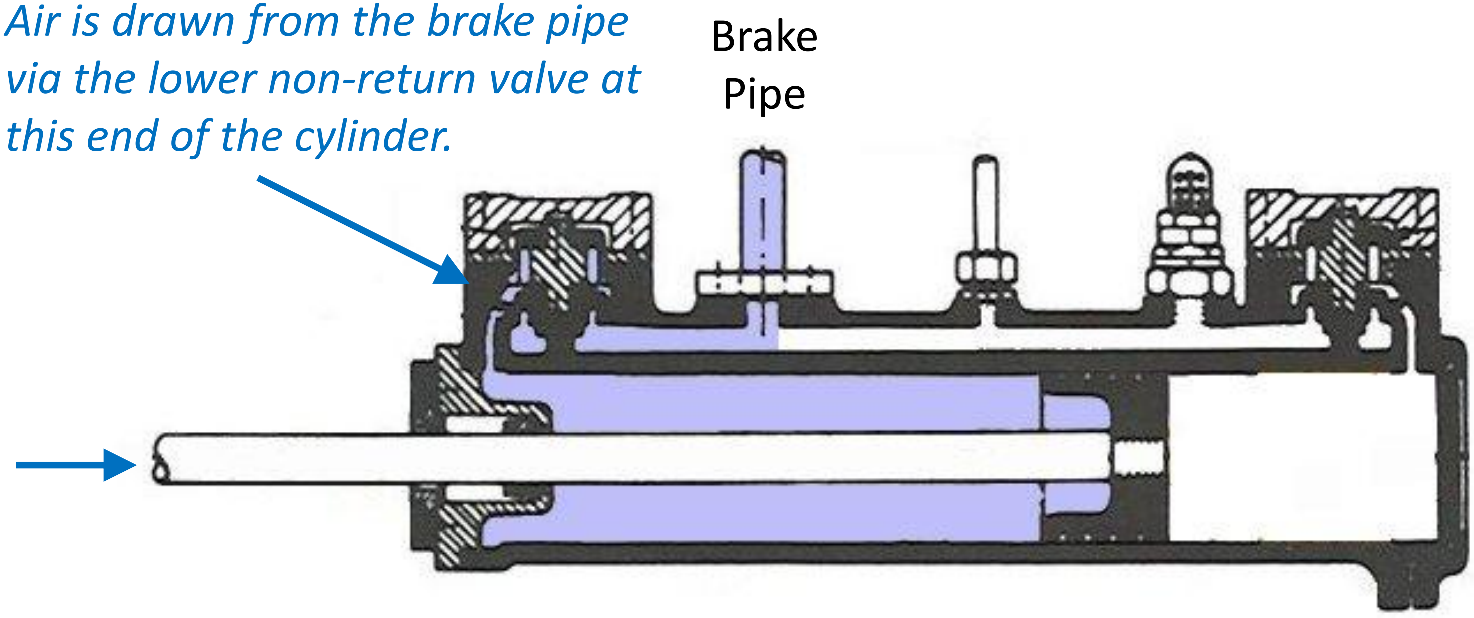


The vacuum pump is fitted in close proximity to one of the locomotive's steam cylinders. The piston rod of the vacuum pump is connected to the crosshead, so that the pump is moved back and forth whenever the locomotive is moving.

Vacuum brakes

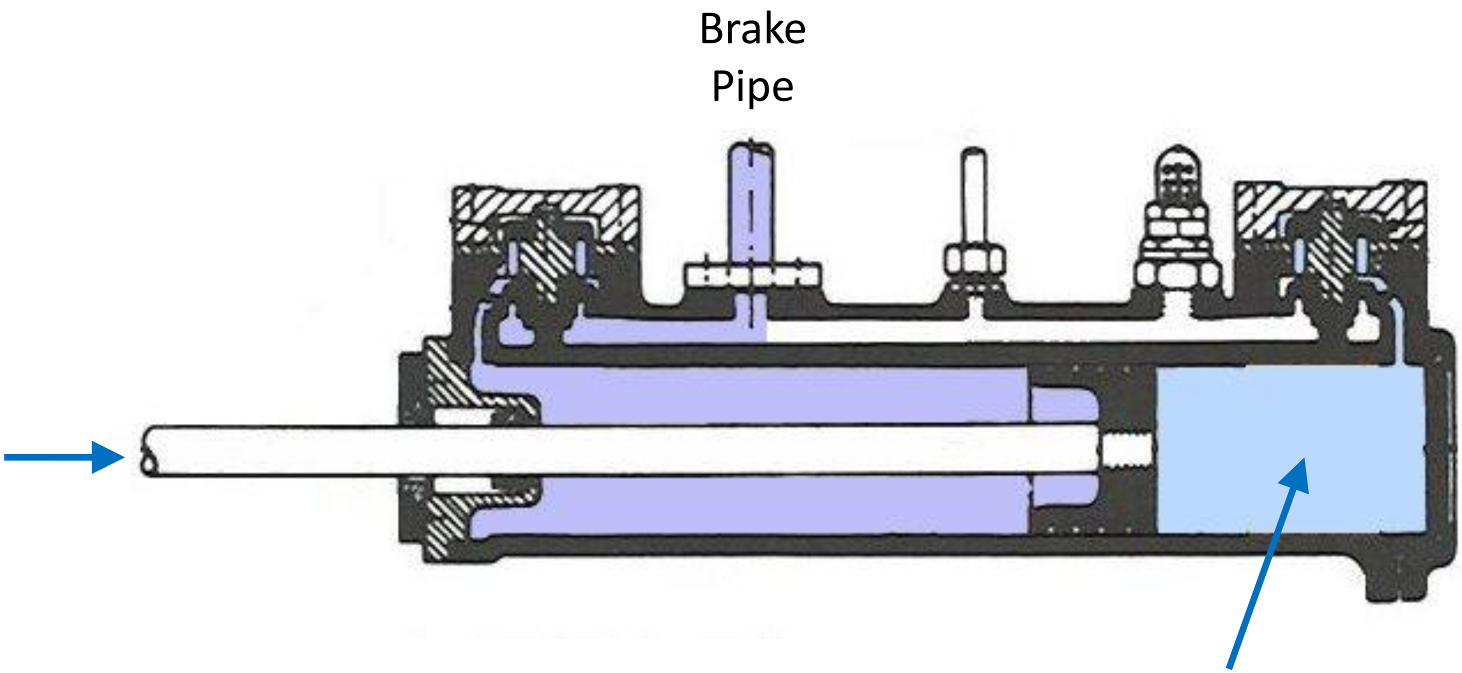
In this diagram the piston rod is being pushed to the right.

Air is drawn from the brake pipe via the lower non-return valve at this end of the cylinder.



Vacuum brakes

In this diagram the piston rod is being pushed to the right.

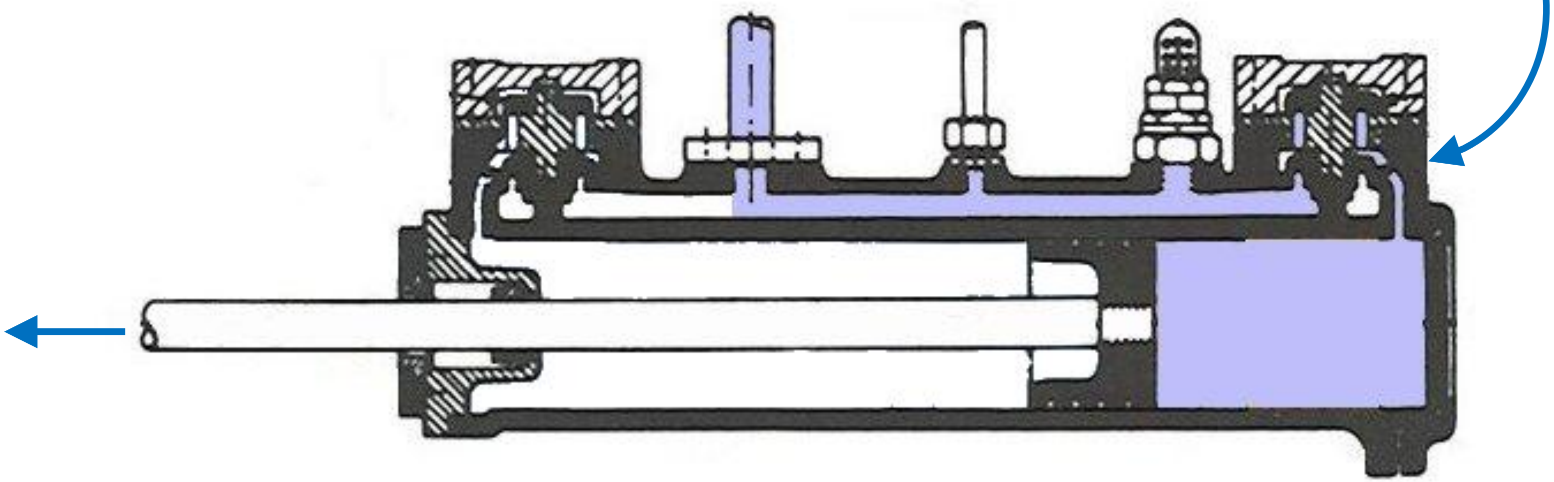


Air would be compressed at this end of the cylinder if it cannot escape. This is why there are two non-return valves. The upper non-return valve at this end of the cylinder allows the air to escape to the surrounding atmosphere.

Vacuum brakes

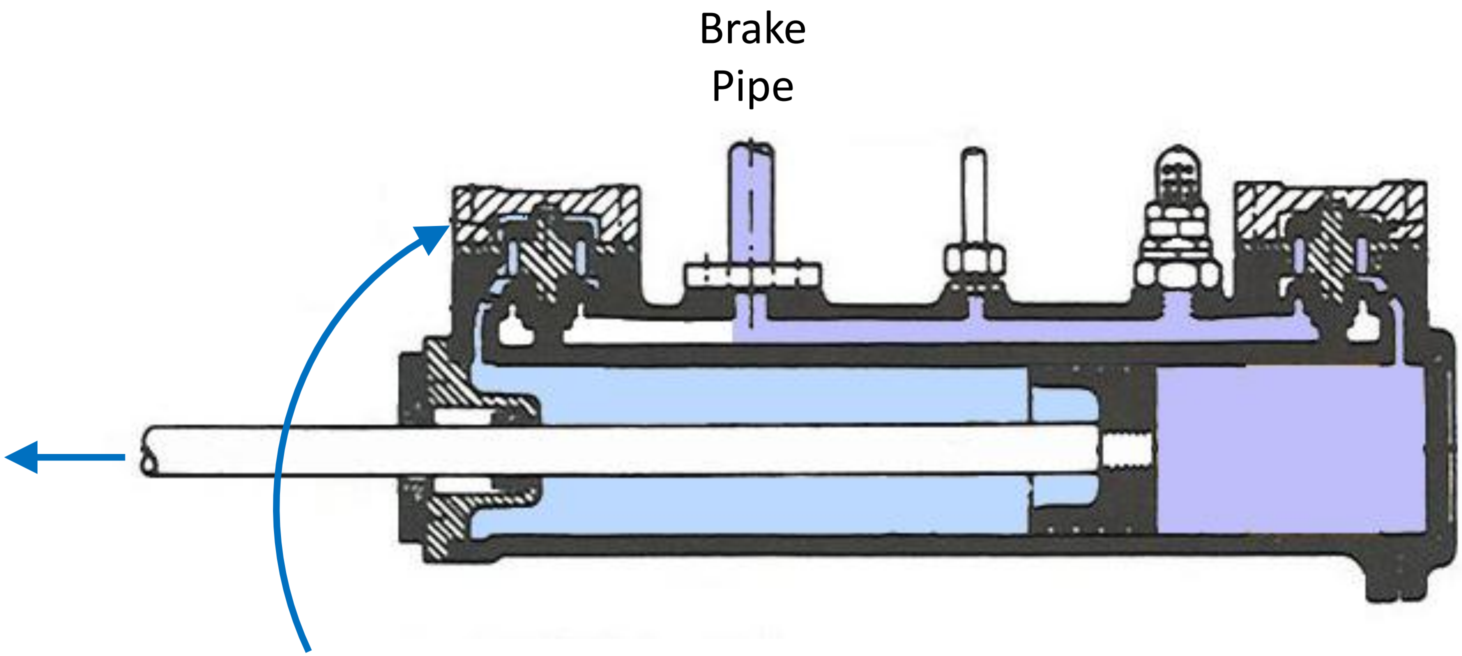
In this diagram the piston rod is being pulled to the left.

Air is drawn from the brake pipe via the lower non-return valve at this end of the cylinder.



Vacuum brakes

In this diagram the piston rod is being pulled to the left.

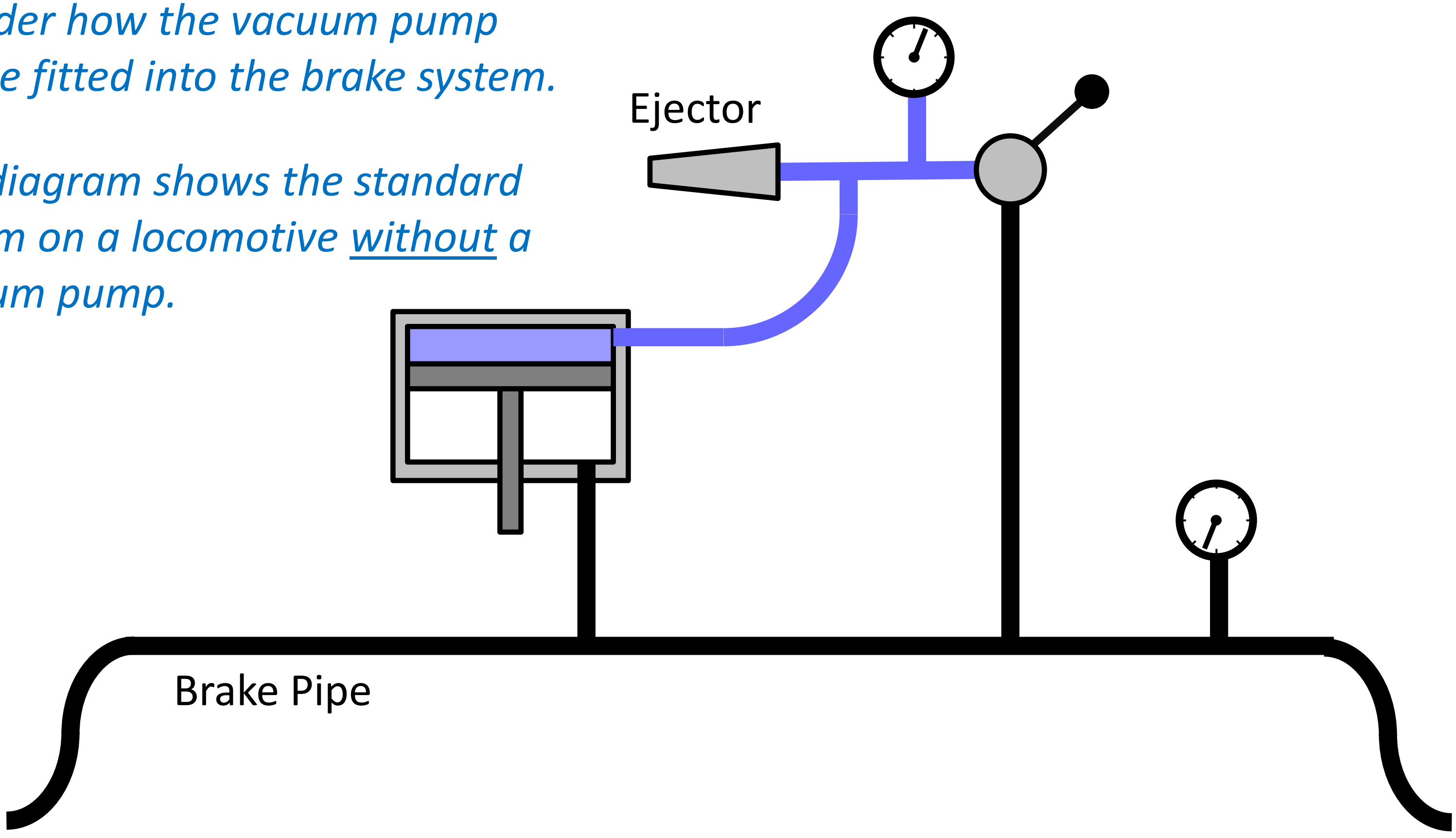


The upper non-return valve at this end of the cylinder allows the air drawn from the brake pipe on the previous stroke of the piston to now escape to the surrounding atmosphere.

Vacuum brakes

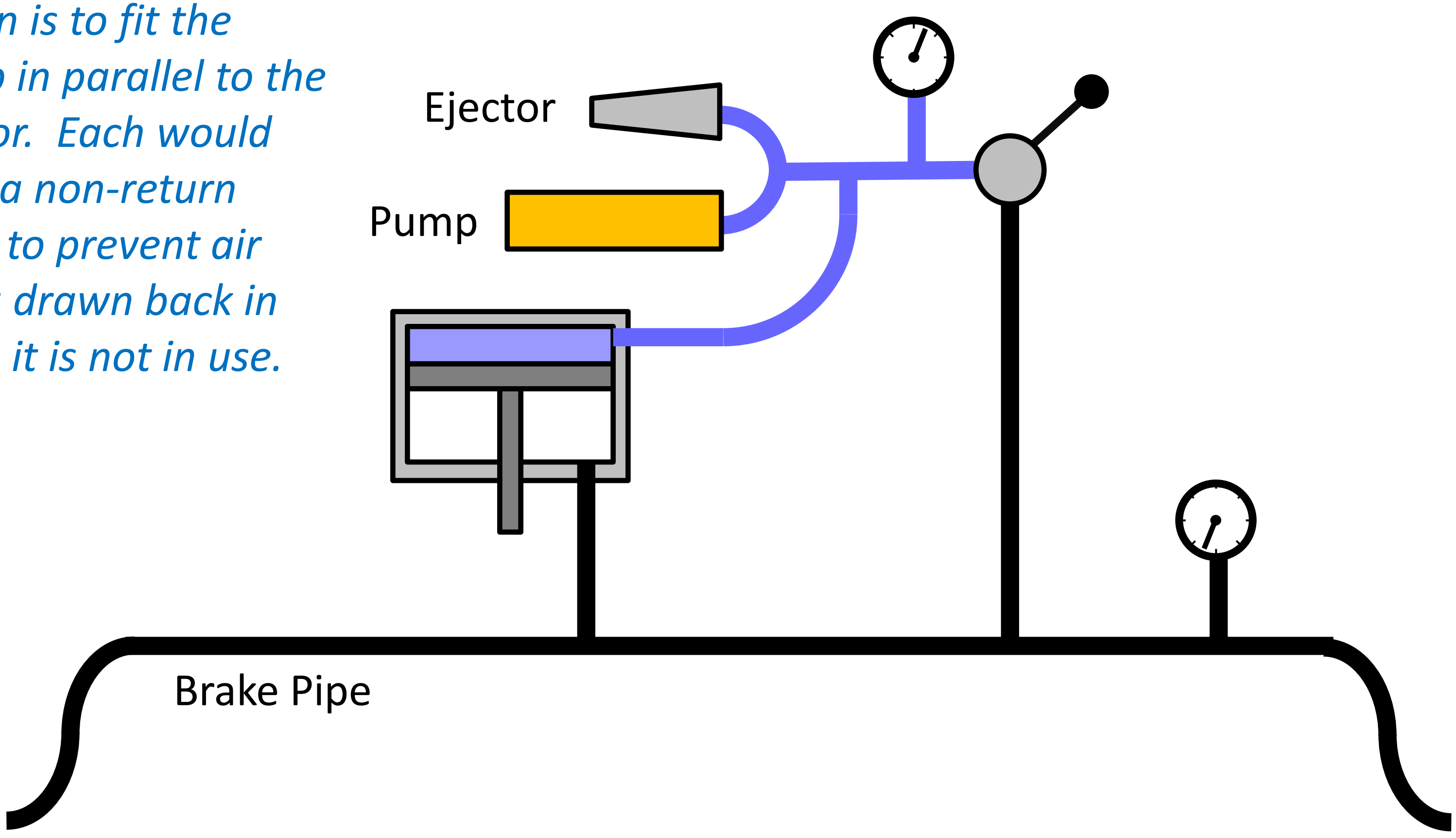
In the next few diagrams we will consider how the vacuum pump can be fitted into the brake system.

This diagram shows the standard system on a locomotive <u>without</u> a vacuum pump.



Vacuum brakes

A straightforward option is to fit the pump in parallel to the ejector. Each would have a non-return valve to prevent air being drawn back in when it is not in use.



Vacuum brakes

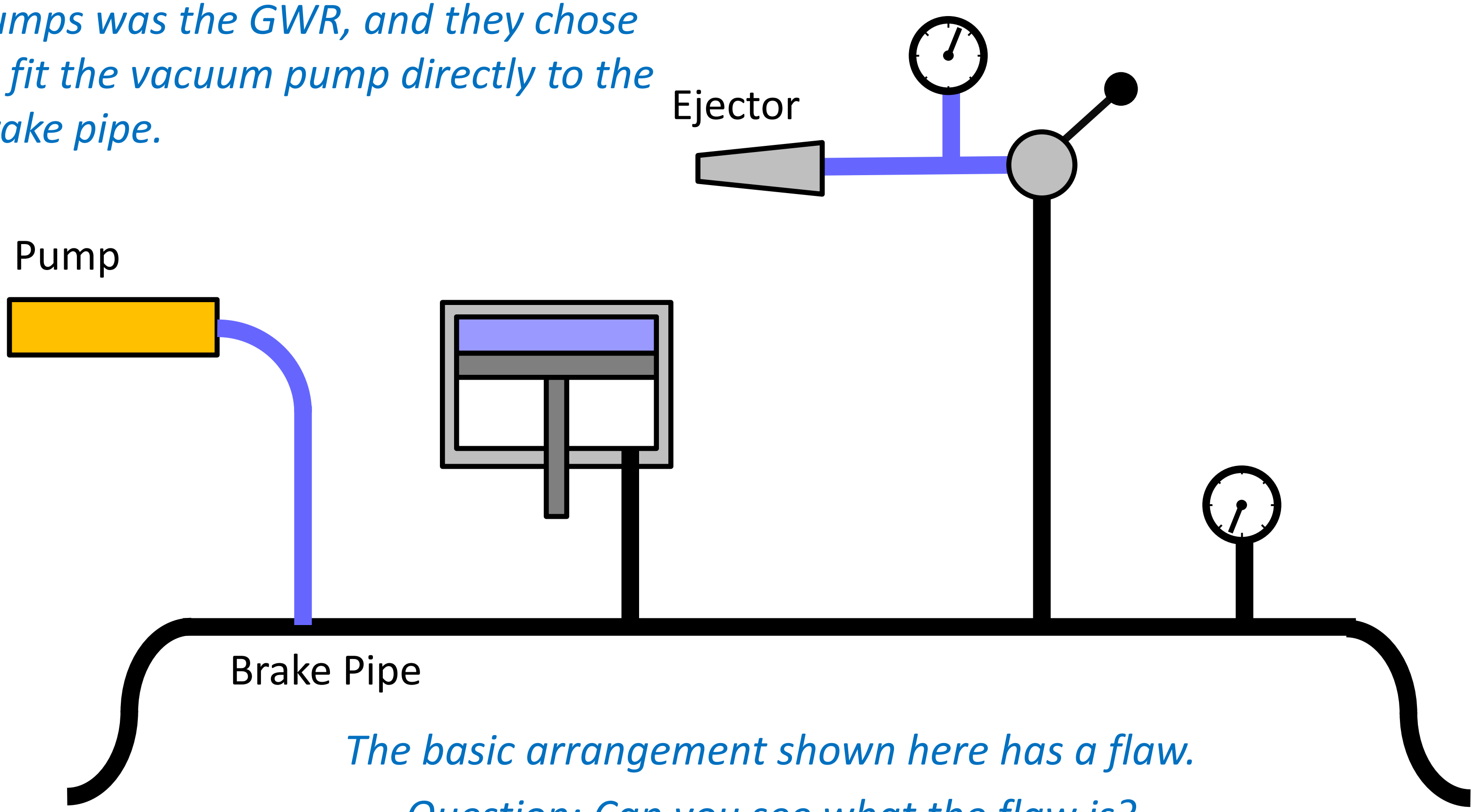
The vacuum pump can complicate the operation of the brakes, because it behaves differently to a steam powered ejector. An ejector provides a constant suck at all times, whereas a vacuum pump provides a greater suck when the locomotive is moving faster.

Therefore, the feel of the continuous type of controller (i.e. no lap position) would be different when the train is moving faster (when the suck is greater). At slow speeds there may be very little suck and operation of the ejector could be required to release the brakes. At high speeds the controller may have to be operated harshly (a greater movement of the handle) to allow the incoming air to beat the suck of the pump.

The arrangement illustrated on the previous slide would work better with a controller comprising a lap position. Such a controller would physically disconnect both the ejector and pump from the brake pipe during braking. However, the operation of the controller and the ejector could get confusing.

Vacuum brakes

Britain's greatest advocate of vacuum pumps was the GWR, and they chose to fit the vacuum pump directly to the brake pipe.



The basic arrangement shown here has a flaw.

<u>Question:</u> Can you see what the flaw is?

Vacuum brakes

<u>Answer:</u>

The vacuum pump will fight the brake application made by the driver's control valve. The effect of this will be worse the faster the train is moving.

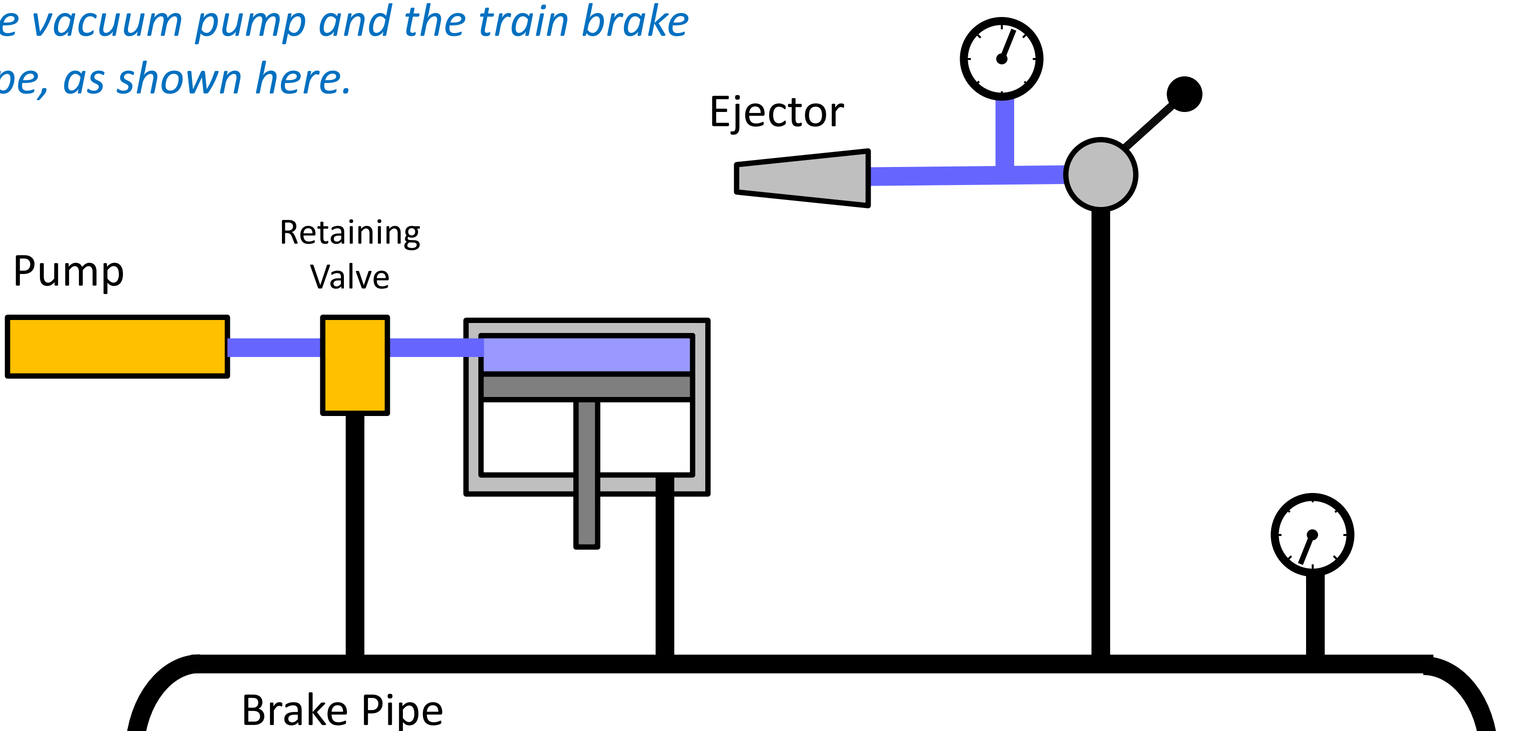
As the train moves faster, the vacuum pump moves faster and pumps a greater volume of air from the train brake pipe.

This would create an additional difficulty for the driver, who would have to operate the brake control more severely at higher speeds. Also, if double heading, there would be two vacuum pumps fighting the brake application, further complicating the whole situation.

Therefore, the GWR fitted an additional component, known as the retaining valve...

Vacuum brakes

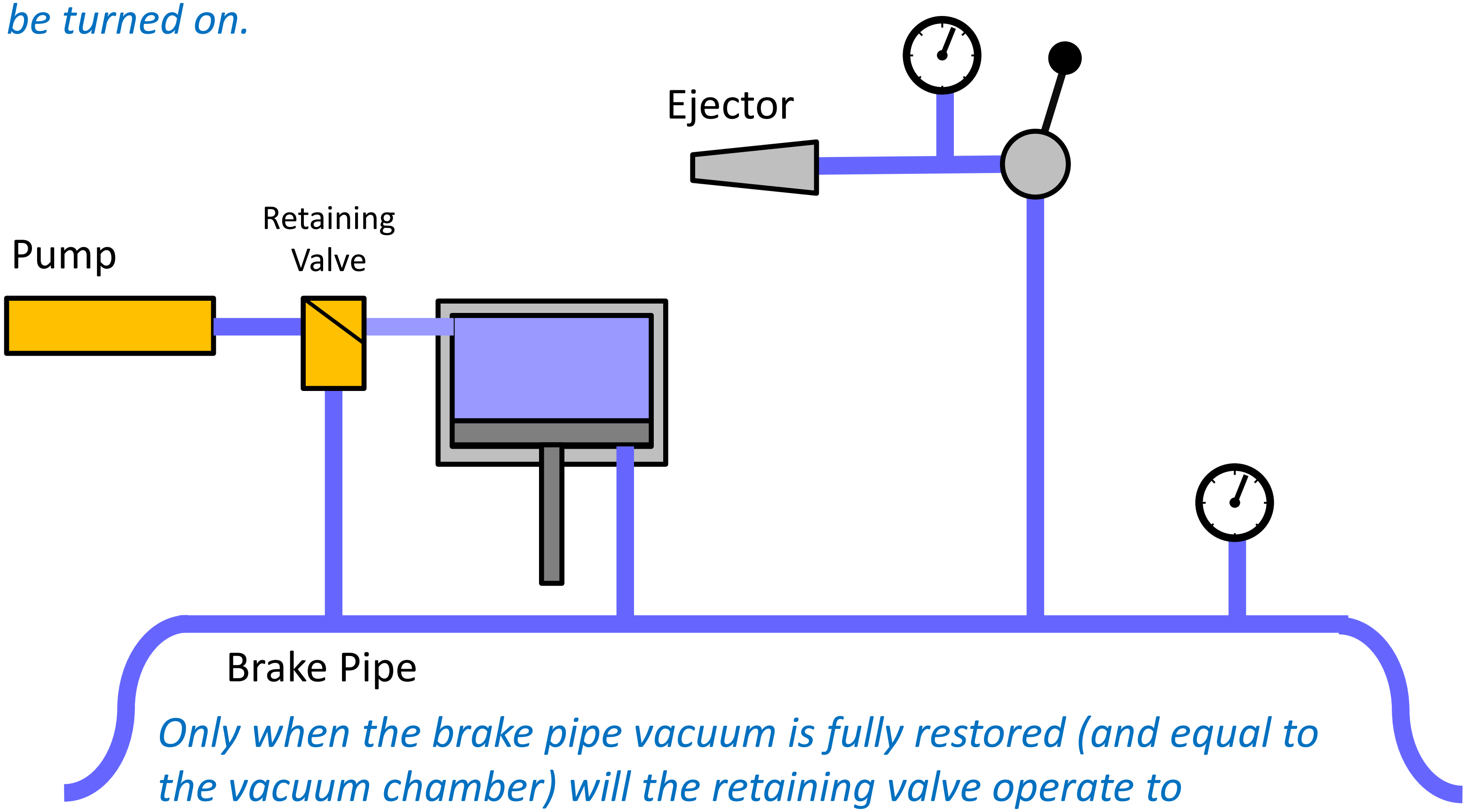
The retaining valve is fitted between the vacuum pump and the train brake pipe, as shown here.



The retaining valve redirects the suck of the vacuum pump to the vacuum chamber when the train is braking. The retaining valve is automatic in its operation.

Vacuum brakes

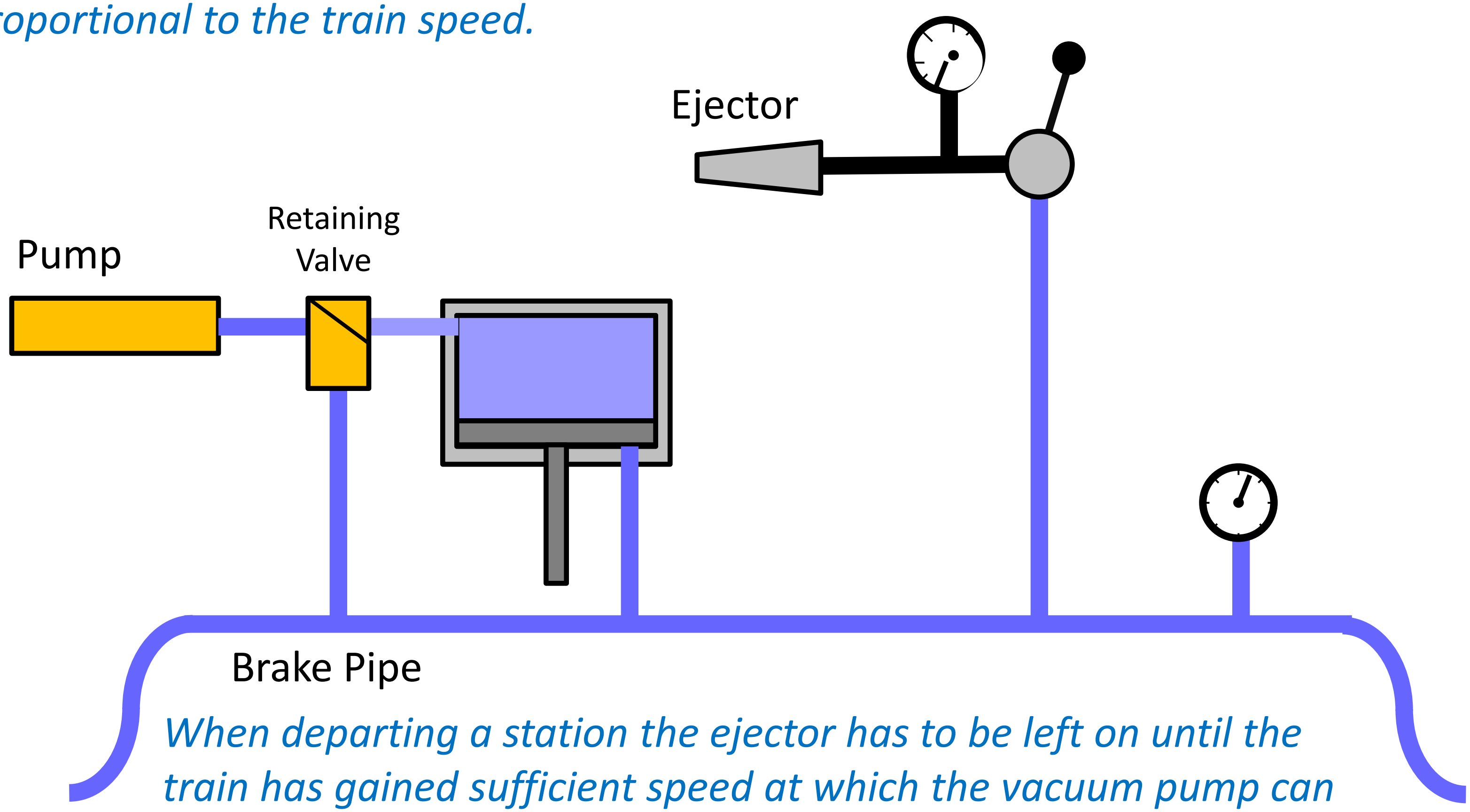
To release the brakes the ejector has to be turned on.



Only when the brake pipe vacuum is fully restored (and equal to the vacuum chamber) will the retaining valve operate to reconnect the vacuum pump to the brake pipe.

Vacuum brakes

The suck of the vacuum pump is proportional to the train speed.



When departing a station the ejector has to be left on until the train has gained sufficient speed at which the vacuum pump can maintain brake pipe vacuum. Then the ejector can be turned off.

Vacuum brakes

Vacuum Pump – Operation

The operation of the vacuum brake controller on former GWR locomotives is different to convention because of the retaining valve. When the controller is moved to make a brake application, the vacuum pump becomes isolated indefinitely. This means that if the controller is held in the application position the brake pressure will eventually build up to maximum.

To hold a partial brake application, the controller must be returned to the running position, which is now a lap position. Having made the initial reduction of brake pipe vacuum, no air will be drawn from the brake pipe.

To increase the braking force, the controller would be momentarily moved to let more air in and then returned to the running (lap) position. To ease the brake, the ejector has to be turned on to suck air from the brake pipe.

Vacuum brakes

Vacuum Pump – Operation continued

During shunting operations, the ejector is typically left running. This is because the slow speed of shunting operations is insufficient for the vacuum pump to maintain the vacuum.

Depending on the type of locomotive, the GWR had two different arrangements. Some locomotives had separate ejector and brake control handles. Other locomotives were arranged with one control handle, which included ejector, lap and brake application positions.

On locomotives fitted with separate ejector and brake control handles, when the ejector is running continuously the brake controller will operate more conventionally like a dreadnought. The more the handle is pulled towards the apply position, the greater the severity of the brake (i.e. there is no lap position).

Vacuum brakes

Vacuum Pump – Hazards

The retaining valve only operates when it senses the initial inrush of air, and only returns when the brake pipe vacuum is fully restored.

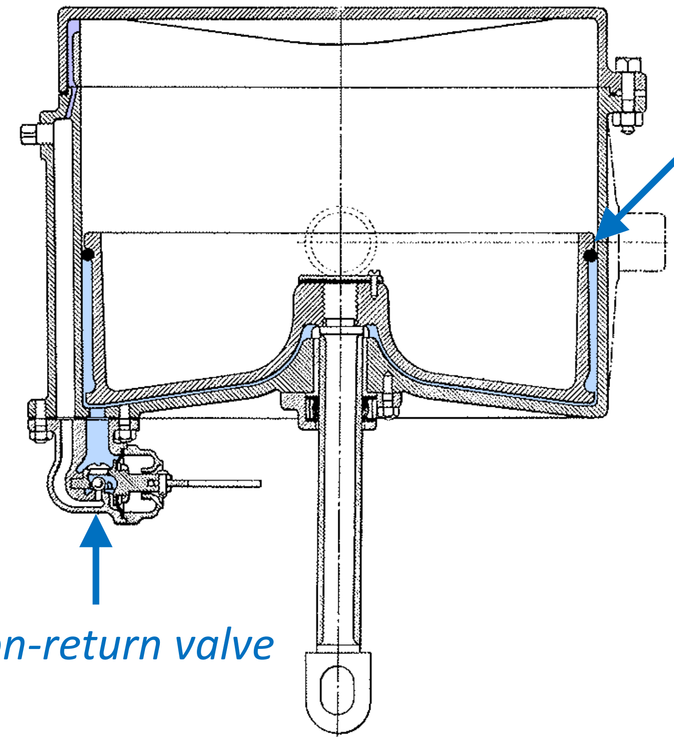
There is a myth that the retaining valve will prevent a strong vacuum pump (when operating quickly) from preventing a brake application. This is not the case. The brake controller fitted to the locomotive must be able of admitting enough air into the brake pipe to partially destroy the vacuum sufficiently for the retaining valve to operate.

An interesting scenario would be the coupling together of a train of locomotives, each with vacuum pump, and trying to make a brake application whilst all these pumps are drawing air from the brake pipe. It would not be surprising if the GWR had specified reduced speed limits when hauling locomotives!

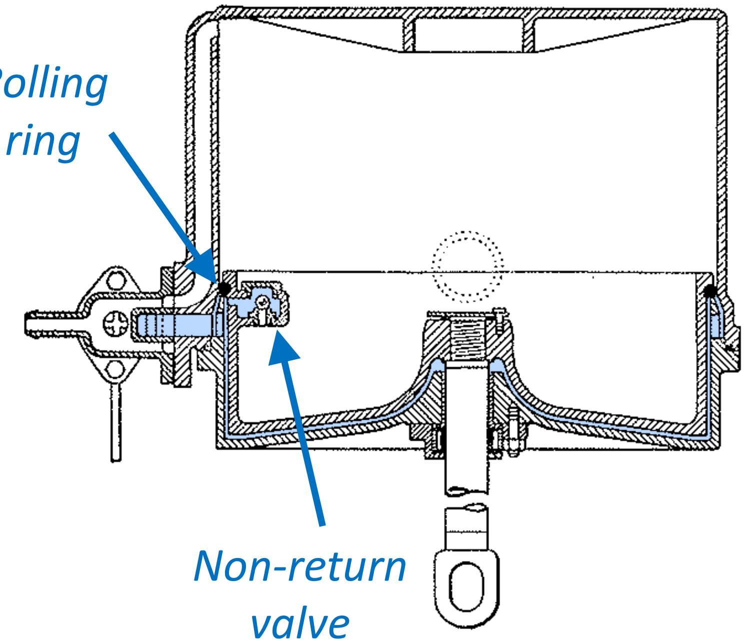
Vacuum brakes

[Piston Head Non-Return Valve]

These diagrams are explained on the next slide.



Separate non-return valve



Piston head non-return valve

Vacuum brakes

Piston Head Non-Return Valve

When a brake application is made, the piston is forced up the cylinder and there is a pressure difference between the brake pipe and vacuum chamber. The higher pressure of the brake pipe will try to leak into the vacuum chamber and the pressures gradually equalise. Eventually the brake force will be lost. The better the seal between the brake pipe and vacuum chamber, the longer the brake is maintained.

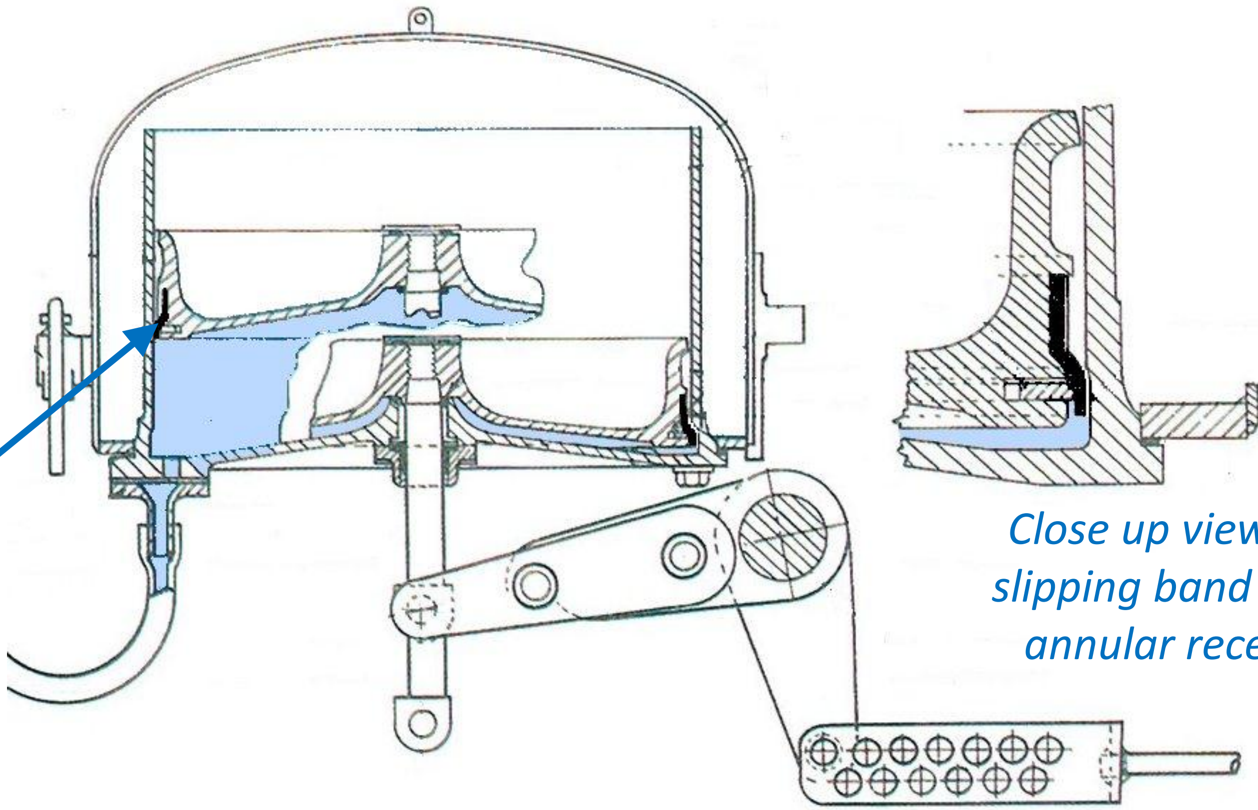
In the brake cylinder shown on the left, the non-return valve is mounted on an external bracket. When a brake application is made there are two areas for a leak to occur. One is the rolling rubber ring seal around the piston and the other is the metal non-return valve.

In the brake cylinder on the right, the non-return valve passes to the upper side of the rolling ring when a brake application is made. Therefore the non-return valve is isolated from the brake pipe and the only leak source is the rolling rubber ring.

Vacuum brakes

Slipping Band Piston Seal

This diagram is explained on the next slide.



Vacuum brakes

<u>Slipping Band Piston Seal</u>

This type of seal is arranged so the higher pressure will tend to push the band outwards against the cylinder walls and thus improve the seal.

If air pressure is greater on the upper side of the piston it will tend to push the band inwards and force its way around the outside. In effect, the band forms a non-return valve. To assist this process, there is an annular recess in the cylinder that allows excess air to pass the slipping band when the piston is at the bottom of the cylinder (i.e. the brakes released position).

There is no separate non-return valve required with this type of brake cylinder.

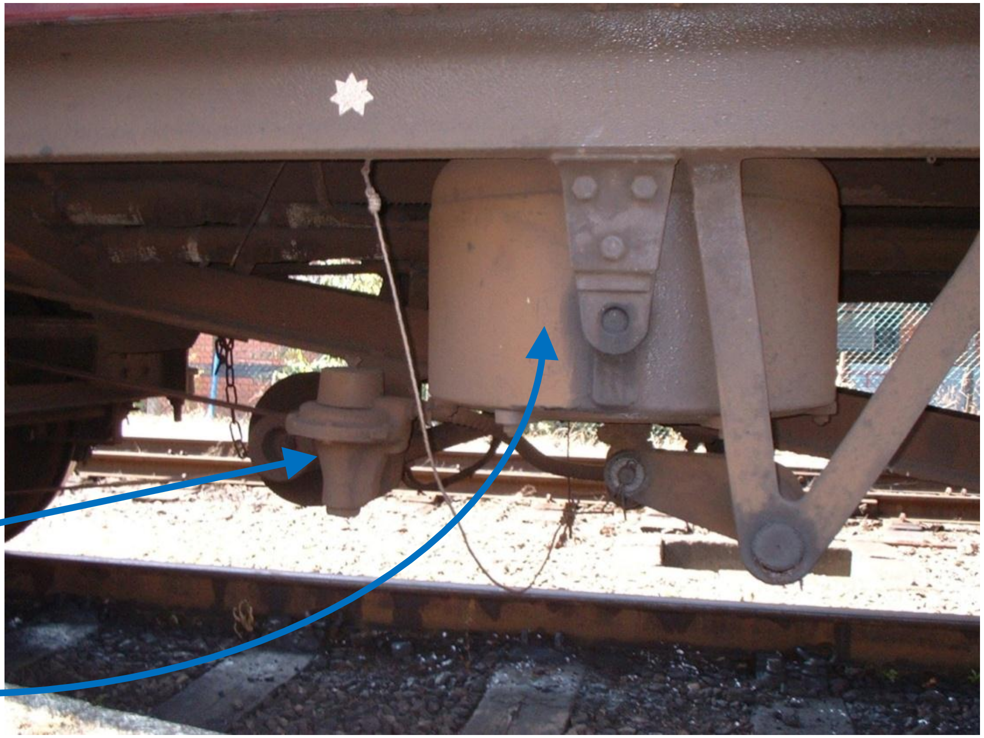
It was used by the Great Western Railway and in many respects is similar to the seal used in air brake cylinders.

Vacuum brakes

<u>Direct Application Valve</u>

The previous section (operation questions and answers) highlighted how many problems are caused by the slow propagation of atmospheric air along the long brake pipe.

These problems can be largely overcome by the fitting of direct application valves. These valves are mounted next to the vacuum brake cylinders.



Direct Application Valve

Vacuum Brake Cylinder

Vacuum brakes

<u>Direct Application Valve</u>

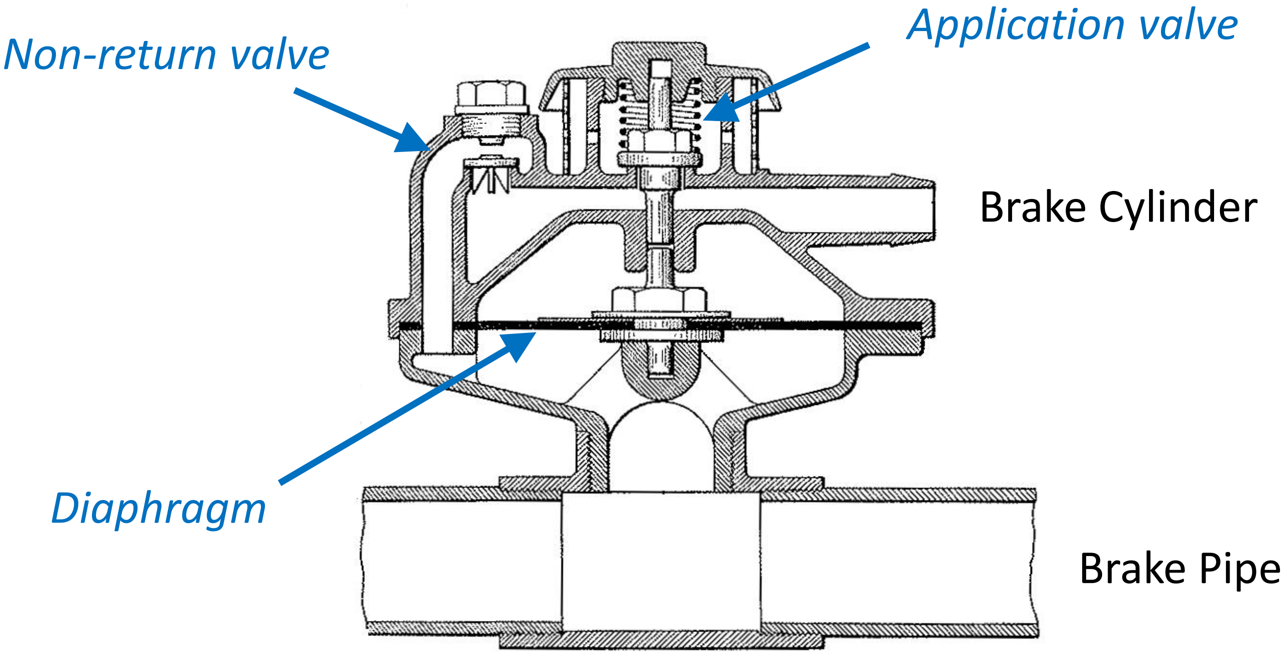
The direct application valve operates automatically when the brake pipe pressure increases. It admits air to the brake cylinder directly from the surrounding atmosphere. This means that the air pressure in the brake pipe is not required to fill that particular cylinder and can pass straight on to the next vehicle of the train.

The direct application valve uses the natural reservoir of air around the train to fill the brake cylinders, rather than all the air having to enter at the driver's control valve. The result is faster propagation of the brake demand along the length of the train. The more direct application valves are fitted in a train, the quicker the brake propagation.

<u>Note:</u> easing of the brake will not be speeded up, all the air still has to be drawn out of the brake pipe by the locomotive's ejector.

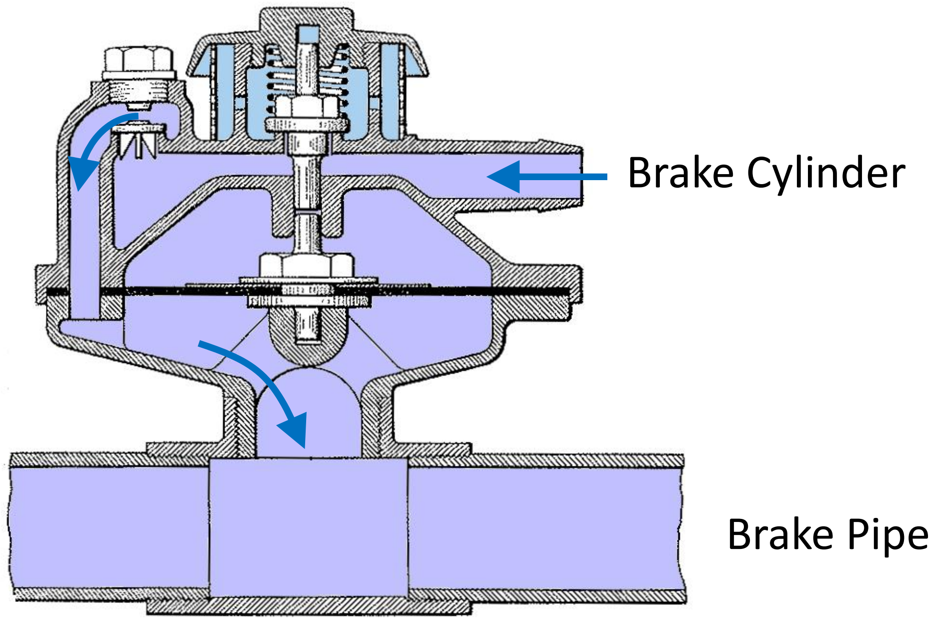
Vacuum brakes

Here follows an explanation of how one type of direct application valve works.



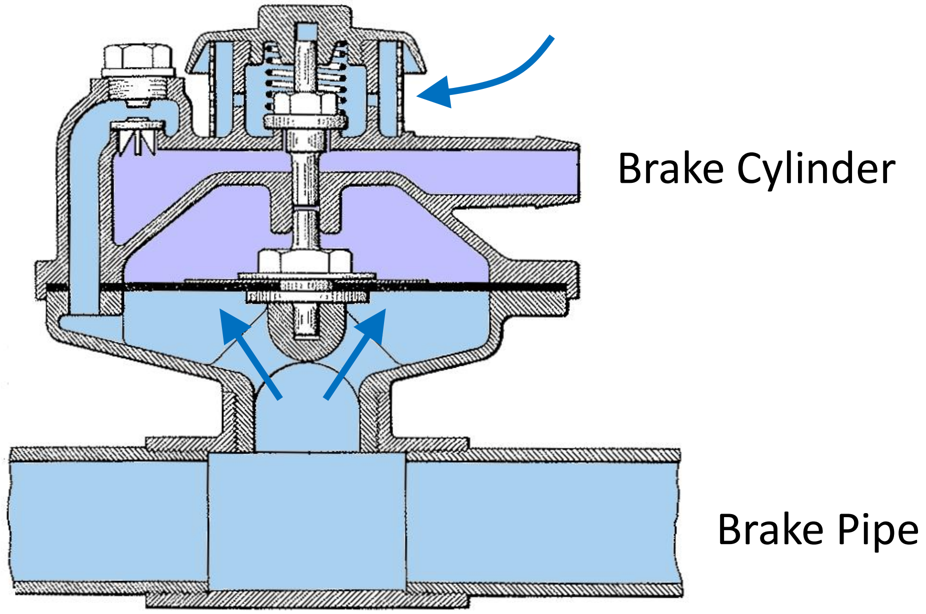
Vacuum brakes

When air is drawn out of the brake pipe, it is also drawn past the non-return valve from the brake cylinder, as shown below:



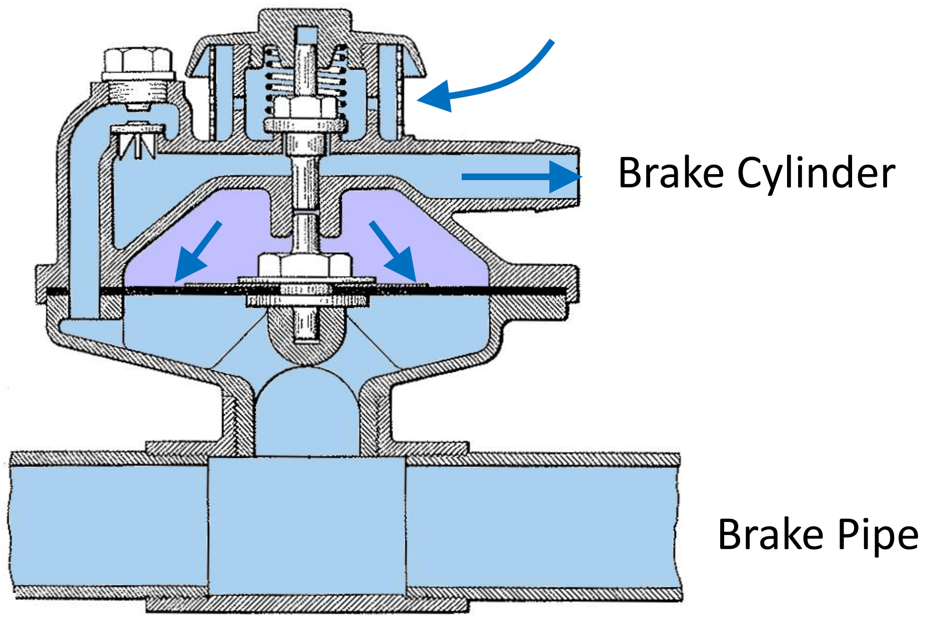
Vacuum brakes

When air enters the brake pipe, it cannot pass through the non-return valve. The pressure builds up on the underside of the diaphragm and forces open the application valve, allowing air from the surrounding atmosphere to enter the brake cylinder:



Vacuum brakes

As air enters the brake cylinder, it seeps into the chamber above the diaphragm, destroying the vacuum in this chamber:



Vacuum brakes

When the pressures above and below the diaphragm are equal, the spring closes the application valve. The air pressure admitted to the brake cylinder is equal to the pressure in the brake pipe.