**Vaccum Brake System**

The **vacuum brake** is a braking system employed on trains and introduced in the mid-1860s. A variant, the **automatic vacuum brake** system, became almost universal in British train equipment and in those countries influenced by British practice. Vacuum brakes also enjoyed a brief period of adoption in the USA, primarily on narrow gauge railroads. However, its limitations caused it to be progressively superseded by compressed air systems starting in the United Kingdom from the 1970s onward. The vacuum brake system is now obsolete; it is not in large-scale usage anywhere in the world, supplanted in the main by air brakes.

Moving train contains energy, known as kinetic energy, which needs to be removed from the train in order to cause it to stop. The simplest way of doing this is to convert the energy into heat.

The conversion is usually done by applying a contact material to the rotating wheels or to discs attached to the axles. The material creates friction and converts the kinetic energy into heat. The wheels slow down and eventually the train stops. The material used for braking is normally in the form of a block or pad. Vacuum brakes were a big step forward in train safety.

**Overview**

In the earliest days of railways, trains were slowed or stopped by the application of manually applied brakes on the locomotive and in brake vehicles through the train, and later by steam power brakes on locomotives. This was clearly unsatisfactory, but the technology of the time did not easily offer an improvement. A chain braking system was developed, requiring a chain to be coupled throughout the train, but it was impossible to arrange equal braking effort down the length of the train.

A major advance was the adoption of a vacuum braking system in which flexible pipes were connected between all the vehicles of the train, and brakes on each vehicle could be controlled from the locomotive. The
earliest pattern was a simple vacuum brake, in which vacuum was created by operation of a valve on the locomotive; the vacuum actuated brake pistons on each vehicle, and the degree of braking could be increased or decreased by the driver. Vacuum, rather than compressed air, was preferred because steam locomotives can be fitted with ejectors, which are simple devices that create vacuum without the use of moving parts.

However, the simple vacuum system had the major defect that in the event of one of the hoses connecting the vehicles becoming displaced (by the train accidentally dividing, or by careless coupling of the hoses, or otherwise) the vacuum brake on the entire train was useless.

How they work:

The brakes themselves are in the form of metal shoes which press against the train's wheels creating friction which slows the train down.

On a train equipped with vacuum brakes, every wagon or coach is equipped with at least one set of brakes. The default position of each brake shoe is on and the brakes are spring-loaded so that without vacuum, there is pressure applied. Behind each brake shoe is a vacuum cylinder which contains a piston, which draws the brake shoe forwards or backwards, or into the on or off positions.

An airtight pipe runs along the entire length of the train. The air is pumped out of this pipe by a pump in the locomotive to form a vacuum. As a vacuum forms in the vacuum cylinder behind the piston, the piston is pushed backwards by atmospheric pressure, thereby drawing the brake shoe backwards into the off position.

The brakes will automatically move forward to the default "on" position if the vacuum is broken. The train driver can apply the brakes by opening a valve which lets air into the pipe thus breaking the vacuum. If the train breaks up or the pipe develops a leak, the vacuum will again be broken and the brakes will come on.

The vacuum brake was considered preferential to the air brake in railroad applications largely because it was cheaper to install on a steam locomotive.
Air brakes required a steam-powered compressor - bulky, noisy, unsightly and using a lot of power, while the vacuum ejector used to generate vacuum was a much simpler device, having no moving parts.

MAINTENANCE AT WORKSHOP:-

During POH all components of the brake gear system shall be examined, repaired and replaced as necessary. The pins and bushes shall be examined for wear and replaced if the radial clearance exceeds 0.75 mm. Following items should receive particular attention during POH:

i) Safety brackets provided for brake gear components should be in accordance with the approved drawings and shall be examined for proper condition and secured according to the prescribed method.

ii) Vacuum cylinders and their trunnion brackets, vacuum reservoirs and train pipes, rubber hose & syphon pipes, alarm chain apparatus including the chain, disc and locking arrangement, brake beams, hangers, and brake blocks shall be secured as prescribed. All brake gear pins (should be chromium plated) shall be secured with washers and split cotters.

iii) Vacuum gauges shall be properly tested and adjusted using master
gauges before being fitted.

**How the automatic brake works:**

Vacuum brake cylinder in running position: the vacuum is the same above and below the piston. Air at atmospheric pressure from the train pipe is admitted below the piston, which is forced up. In its simplest form, the automatic vacuum brake consists of a continuous pipe -- the train pipe -- running throughout the length of the train. In normal running a partial vacuum is maintained in the train pipe, and the brakes are released. When air is admitted to the train pipe, the air pressure acts against pistons in cylinders in each vehicle. A vacuum is sustained on the other face of the pistons, so that a net force is applied. A mechanical linkage transmits this force to brake shoes which act by friction on the treads of the wheels.

**The fittings to achieve this are therefore:**

- a train pipe: a steel pipe running the length of each vehicle, with flexible vacuum hoses at each end of the vehicles, and coupled
between adjacent vehicles; at the end of the train, the final hose is seated on an air-tight plug;
- an ejector on the locomotive, to create vacuum in the train pipe;
- controls for the driver to bring the ejector into action, and to admit air to the train pipe; these may be separate controls or a combined brake valve;
- a brake cylinder on each vehicle containing a piston, connected by rigging to the brake shoes on the vehicle; and
- a vacuum (pressure) gauge on the locomotive to indicate to the driver the degree of vacuum in the train pipe.

> The brake cylinder is contained in a larger housing—this gives a reserve of vacuum as the piston operates. The cylinder rocks slightly in operation to maintain alignment with the brake rigging cranks, so it is supported in bearings, and the vacuum pipe connection to it is flexible. The piston in the brake cylinder has a flexible piston ring that allows air to pass from the upper part of the cylinder to the lower part if necessary.

> When the vehicles have been at rest, so that the brake is not charged, the brake pistons will have dropped to their lower position in the absence of a pressure differential (as air will have leaked slowly into the upper part of the cylinder, destroying the vacuum).

> When a locomotive is coupled to the vehicles, the driver moves his brake control to the "release" position and air is exhausted from the train pipe, creating a partial vacuum. Air in the upper part of the brake cylinders is also exhausted from the train pipe, through a non-return valve.

> If the driver now moves his control to the "brake" position, air is admitted to the train pipe. According to the driver's manipulation of the control, some or vacuum will be destroyed in the process. The ball valve closes and there is a higher air pressure under the brake pistons than above it, and the pressure differential forces the piston upwards, applying the brakes. The driver can control the severity of the braking effort by admitting more or less air to the train pipe.

> In a vacuum brake system, depressing the brake pedal opens a valve between the power cylinder, which contains a piston, and the intake
manifold to which the power cylinder is connected. When you apply the brakes, air is exhausted from the cylinder head of the piston. At the same time, atmospheric pressure acts on the rear side of the piston to exert a powerful pull on the rod attached to the piston. When the brake valve is closed, the chamber ahead of the piston is shut off from the intake manifold and is opened to the atmosphere. The pressure is then the same on both sides of the piston; therefore, no pull is exerted upon the pull rod. The brakes are released and the piston returned to its original position in the power cylinder by the brake shoe return springs. Hydrovac is a trade name for a one-unit vacuum power-braking system. It combines a hydraulic control valve, a vacuum power cylinder, and a hydraulic slave cylinder into one assembly. This assembly (fig. 3-50) is connected to both the master cylinder and the wheel brakes and eliminates the need for mechanical connections with the brake pedal. Pressure on the brake pedal forces fluid from the master cylinder through the check valve to the slave cylinder and to the wheel cylinders. Also, the foot pedal pressure, acting through the master cylinder, acts also against the slave cylinder piston to help the vacuum pistons and pushrods to press against the brake shoe

**Practical considerations:-**
The automatic vacuum brake as described represented a very considerable technical advance in train braking. In practice steam locomotives had two ejectors, a small ejector for running purposes (to exhaust air that had leaked into the train pipe) and a large **ejector** to release brake applications. Later Great Western Railway practice was to use a vacuum pump instead of the small **ejector**.

> The driver's brake valve was usually combined with the steam brake control on the locomotive.

> Release valves are provided on the brake cylinders; when operated, usually by manually pulling a cord near the cylinder, air is admitted to the upper part of the brake cylinder on that vehicle. This is necessary to release the brake on a vehicle that has been uncoupled from a train and now requires to be moved without having a brake connection to another locomotive, for example if it is to be shunted.

> In the United Kingdom the pre-nationalisation railway companies standardised around systems operating on a vacuum of 21 inches of mercury (533.4 Torr), with the exception of the Great Western Railway, which used 25 inches of mercury (635 Torr). An absolute vacuum is about 30 inches of mercury (760 Torr), depending on atmospheric conditions.

> This difference in standards could cause problems on long distance cross-country services when a GWR locomotive was replaced with another company's engine, as the new engine's large ejector would sometimes not be able to fully release the brakes on the train. In this case the release valves on each vehicle in the train would have to be released by hand. This time consuming process was not infrequently seen at large GWR stations such as Bristol Temple Meads.

> The provision of a train pipe running throughout the train enabled the automatic vacuum brake to be operated in emergency from any position in the train. Every guard's compartment had a brake valve, and the passenger communication apparatus (usually called "the communication cord" in lay terminology) also admitted air into the train pipe at the end of coaches so equipped.
When a locomotive is first coupled to a train, or if a vehicle is detached or added, a brake continuity test is carried out, to ensure that the brake pipes are connected throughout the entire length of the train.

**Limitations:-**

The progress represented by the automatic vacuum brake nonetheless carried some limitations; chief among these were:

- the practical limit on the degree of vacuum attainable means that a very large brake piston and cylinder are required to generate the force necessary on the brake blocks; when a proportion of the British ordinary wagon fleet was fitted with vacuum brakes in the 1950's, the physical dimensions of the brake cylinder prevented the wagons from operating in some private sidings that had tight clearances;
- for the same reason, on a very long train, a considerable volume of air has to be admitted to the train pipe to make a full brake application, and a considerable volume has to be exhausted to release the brake (if for example a signal at danger is suddenly lowered and the driver requires to resume speed); while the air is traveling along the train pipe, the brake pistons at the head of the train have responded to the brake application or release, but those at the tail will respond much later, leading to undesirable longitudinal forces in the train. In extreme
cases this has led to breaking couplings and causing the train to divide.

- the existence of vacuum in the train pipe can cause debris to be sucked in. An accident took place near Ilford in the 1950's, due to inadequate braking effort in the train. A rolled newspaper was discovered in the train pipe, effectively isolating the rear part of the train from the driver's control. The blockage should have been detected if a proper brake continuity test had been carried out before the train started its journey.

A development introduced in the 1950's was the **direct admission valve**, fitted to every brake cylinder. These valves responded to a rise in train pipe pressure as the brake was applied, and admitted atmospheric air directly to the underside of the brake cylinder.

American and continental European practice had long favoured compressed air brake systems, the leading pattern being a proprietary Westinghouse system. This has a number of advantages, including smaller brake cylinders (because a higher air pressure could be used) and a somewhat more responsive braking effort. However the system requires an air pump. On steam engines this was usually a reciprocating steam pump, and it was quite bulky. Its distinctive shape and the characteristic puffing sound when the brake is released (as the train pipe has to be recharged with air) make steam locomotives fitted with the Westinghouse brake unmistakable, for example in old films.

In the UK, the Great Eastern Railway, the North Eastern Railway, the London Brighton and South Coast Railway and the Caledonian Railway adopted the Westinghouse system. It was also standard on the Isle of Wight rail system. Inevitably this led to compatibility problems in exchanging traffic with other lines. It was possible to provide through pipes for the braking system not fitted to any particular vehicle so that it could run in a train using the "other" system, allowing through control of the fitted vehicles behind it, but of course with no braking effort of its own.

**Dual brakes:**

Vehicles can be fitted with dual brakes, vacuum and air, provided that there is room to fit the duplicated equipment. It is much easier to fit one kind of brake with a pipe for continuity of the other. Train crew need to take note
that the wrong-fitted wagons do not contribute to the braking effort and make allowances on down grades to suit. Many of the earlier classes of diesel locomotive used on British Railways were fitted with dual systems to enable full usage of BR's rolling stock inherited from the private companies which had different systems depending on which company the stock originated from.

Air brakes need a tap to seal the hose at the ends of the train. If these taps are incorrectly closed, a loss of brake force may occur, leading to a dangerous runaway. With vacuum brakes, the end of the hose can be plugged into a stopper which seals the hose by suction. It is much harder to block the hose pipe compared to air brakes.

**Twin pipe systems**-

Vacuum brakes can be operated in a twin pipe mode to speed up applications and release.
Air versus vacuum brakes:-

In the early part of the 20th century, many British railways employed vacuum brakes rather than the air brakes used in America and much of the rest of the world. The main advantage of vacuum was that the vacuum can be created by a steam ejector with no moving parts (and which could be powered by the steam of a steam locomotive), whereas an air brake system requires a noisy and complicated compressor.

However, air brakes can be made much more effective than vacuum brakes for a given size of brake cylinder. An air brake compressor is usually capable of generating a pressure of 90 psi (620 kPa) vs only 15 psi (100 kPa) for vacuum. With a vacuum system, the maximum pressure differential is atmospheric pressure (14.7 psi or 101 kPa at sea level, less at altitude). Therefore, an air brake system can use a much smaller brake cylinder than a vacuum system to generate the same braking force. This advantage of air brakes increases at high altitude, e.g. Peru and Switzerland where today vacuum brakes are used by secondary railways. The much higher effectiveness of air brakes and the demise of the steam locomotive have seen the air brake become ubiquitous; however, vacuum braking is still in use in India, in Argentina and in South Africa, but this will be declining in near future.

Vacuum Brake Evacuator:-

Vacuum Brake Bleeder/EvacuatorThe Mityvac MV6830 Vacuum Brake Bleeder/Evacuator was developed for the automotive service professional. This portable unit operates on compressed air, and includes accessories for vacuum bleeding automotive hydraulic systems. It also functions well for evacuating fluids from small tanks and reservoirs. The MV6830’s compact, 1.9-quart (1.8 liter) reservoir allows the operator to perform multiple bleeding jobs without emptying, thereby reducing downtime. The unit bleeds at a rate of up to two quarts (1.9 liters) per minute for increased productivity and features a variable thumb throttle to maintain desired flow rate. The MV6830 has a swivel air inlet to prevent kinks in the air hose during
movement and a hook that allows the unit to be hung out of the way during use. The reservoir and lid feature large, coarse threads to reduce cross threading, and the bench-mountable, molded base keeps the unit secure while removing or replacing the lid. The MV6830 has an automatic shutoff valve to prevent overfilling and a convenient quick-disconnect coupler for fast accessory changes.

**Features:**
- Large capacity reservoir reduces operator downtime.
- Bleeds up to two quarts (1.9 liters) per minute for greater productivity.
- Variable thumb throttle holds desired flow rate.
- Swivel air inlet for flexibility of movement.
- Large coarse threads reduce cross threading.
- Bench mountable molded base for securing unit.
- Automatic shutoff valve prevents overfill.
- Quick disconnect coupler for quick accessory changes.

**Applications:**
- Brake bleeding
- Hydraulic clutch bleeding
- Evacuating fluids from tanks or reservoirs

**Specifications:**
- Weight: 4.8 lbs. (2.2 kg)
- Working Pressure: 60-150 psi (4.1-10.3 bar)
- Vacuum @ 90 psi (6.2 bar): 26 in. hg (88
kpa) Air Consumption @ 90 psi (6.2 bar): 4.3 cfm (2.0 l/s) Flow Rate @ 60 psi (4.1 bar) 50 oz/min (1460 ml/min) @ 90 psi (6.2 bar) 70 oz/min (2100 ml/min) @ 150 psi (10.3 bar) 70 oz/min (2100 ml/min) Inlet Thread Size: 1/4" NPT.

Comment:-

The vacuum brake was not widely popular outside the UK and UK inspired railways, but it has the advantage of being simple in design and of having the ability to get a partial release, something the air brake could not do without additional equipment. The vacuum brake was not as effective as the air brake, it taking longer to apply and requiring large cylinders to provide the same brake effort as the air brake. It was also slow to release and requires additional equipment to speed up its operation.

Present-day use of vacuum brakes:-

Today's largest operators of trains equipped with vacuum brakes are the Railways of India and Spoornet (South Africa), however there are also trains with air brakes and dual brakes in use. South African Railways (Spoornet) operates more than 1 000 electric multiple unit cars, which are fitted with electro-vacuum brakes. The electro-vacuum system uses a 2 inch train pipe and basic automatic vacuum brake system, with the addition of electrically-controlled application and release valves in each vehicle. The application and release valves greatly increase the rate of train pipe vacuum destruction and creation. This, in turn, greatly increases the speed of brake application and release. The performance of electro-vacuum brakes on SAR EMUs is equivalent to electro-pneumatic braked EMUs of a similar age.

Other African railways are believed to continue to use the vacuum brake. Other operators of vacuum brakes are narrow gauge railways in Central Europe, the largest of which is the Rhaetian Railway.

Vacuum brakes have been entirely superseded on the National Rail system in the UK, although they are still in use on most heritage railways. They are also to be found on a number (though increasingly fewer) main line vintage special trains.
Iarnród Éireann (the national rail operator in the Republic of Ireland) ran vacuum-braked British Railways Mark 2 stock on passenger trains until the end of March 2008 and still operates vacuum-braked revenue freight (at least in the case of Tara Mines ore traffic).