Kent & East Sussex Railway

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Valves and Pistons

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The steam locomotive is the means of converting the heat energy contained in the fuel into useful work by driving the pistons, the reciprocating motion of these being converted into the rotary motion of the driving wheels by the piston rod, connecting rod and cranks. When the regulator valve is opened, steam generated in the boiler passes through the internal steam pipe (and superheater when fitted), through the external steam pipe to the steam chest, where the supply of steam to the cylinders is regulated by the action of the valves, In the cylinders the steam expands and does useful work on the piston before escaping into the atmosphere.

The locomotive valve of any kind must, in conjunction with the valve gear, so control the valve that the following events take place in succession in the cylinder:

(a) A period of admission of live steam up to a point of cut-off.

(b) A period of expansion up to a point of release.

(c) A period of release for the used steam.

(d) A period of compression after the valve has closed.

(e) A brief period of pre-admission of live steam before the piston commences its working return stroke.

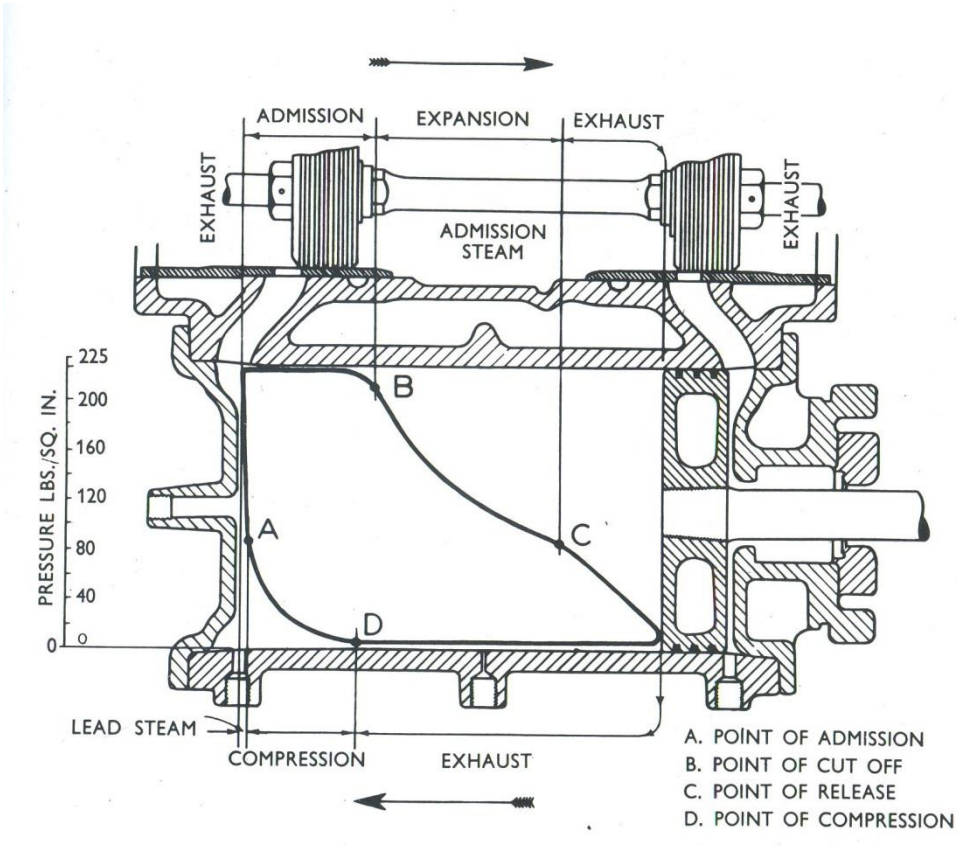
In the events just indicated the valve has three distinct duties to perform:

(a) to close both steam ports when in its central position;

(b) to admit steam to only one end of the cylinder at one time;

(c) to open to exhaust at one end of the cylinder as soon as it opens to admit steam at the other.

During the steam cycle in the cylinders the period of admission can be altered to edit the point of cut-off. When starting trains away, longer cut-offs are required but as the energy required to keep the train moving is lesser than the energy required to start it moving, the engine can be “notched” or “linked” up to a shorter cut-off. This allows a longer period of expansion, resulting in the steam being used more efficiently with savings in the reduced amount of coal and water used.



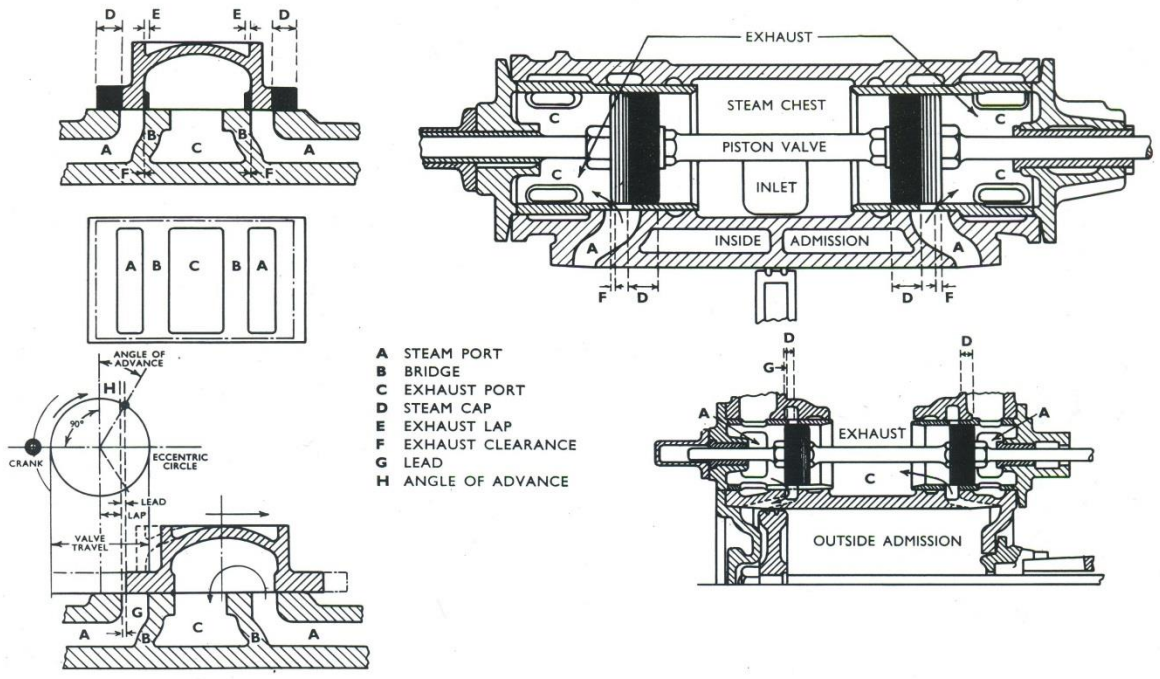
The face on which the valve slides has three ports, the end ports lead one to each end of the cylinder, the larger centre port leads to the exhaust passage.

It will be noted that the slide or piston valve controlling the admission and exhaustion of steam to and from the cylinders has its face of such breadth that when the valve is in mid position it completely closes both steam ports. Two more important items have to be considered now-the "lap" and "lead" of the valve. "Lap" is the amount by which the valve overlaps each steam port at the middle position of each valve.

There are actually two kinds of lap: "steam lap" is the amount by which the valve overlaps the port on the live steam side; similarly, the "exhaust lap" is the amount by which the valve overlaps the port on the exhaust side. "Exhaust lap" is generally given to slow-running locomotives, i.e. those designed for shunting duties, the effect being to delay the exhaust and derive the maximum work from the expanding steam in the cylinder.

"Negative exhaust lap", or as commonly termed "exhaust clearance" is the amount the port is open to exhaust when the valve is in mid-position, and this is used on many fast-running locomotives to give a free exhaust. The amount seldom exceeds 1/16 in. when exhaust clearance is given; the cylinder on both sides of the piston is open to exhaust at the same time when the valve is passing through the mid-position, which is only momentary when running.

The "lead" of the valve is the amount by which the steam port is open when the piston is static at front or back dead centre. Pre-admission of steam fills the clearance space between the cylinder and piston and ensures maximum cylinder pressure at the commencement of the stroke. "Lead" is particularly necessary on locomotives designed for high speeds, under which conditions the valve events are taking place in rapid succession.

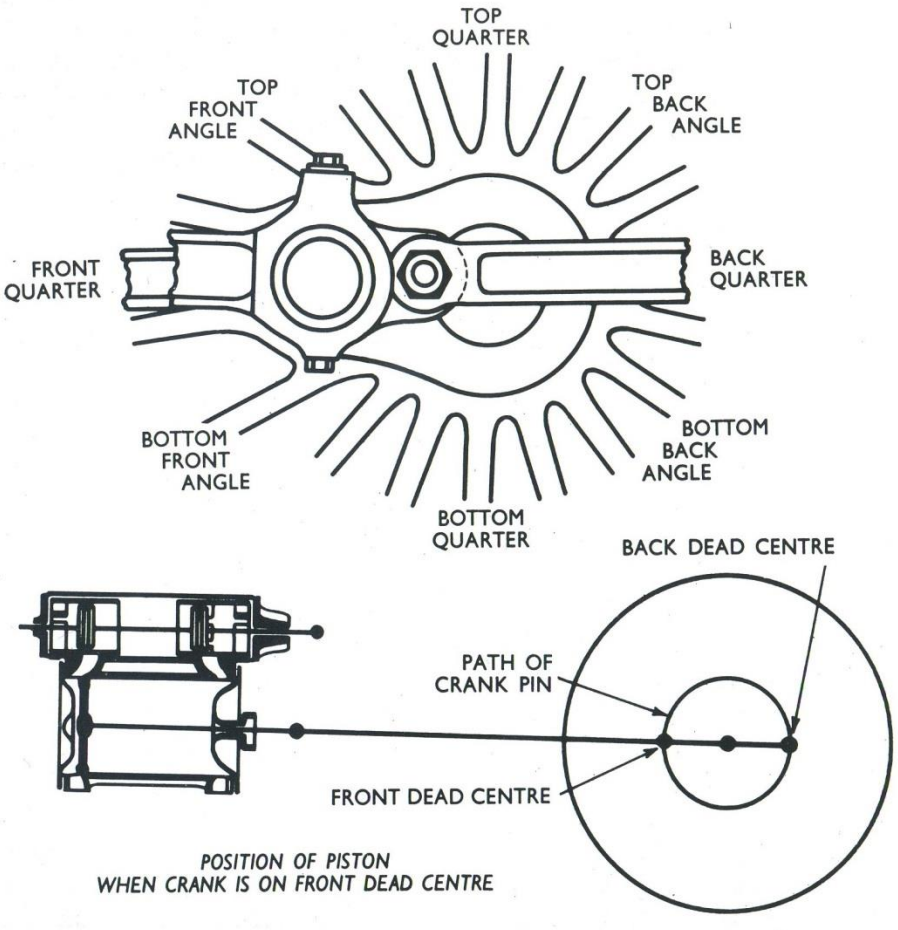


The eccentric is used to convert the rotary motion of the crank axle into the reciprocating motion required to operate the valve. If we imagine a "D"-type slide valve without "lap" and not given "lead" it would, when the piston is at the end of its stroke, just cover the steam ports and be in the central position, i.e. midstroke. The eccentric operating the valve would also be in mid-position and set at 90° (a right-angle) in advance of the crank. From this position the valve would commence to open.

The eccentric is equivalent to a small crank, the length of whose arm is the same as the distance between the centre of the eccentric sheave and centre of shaft. The length of this arm is called the eccentricity of the eccentric, and the valve travel is equal to twice the eccentricity. The return crank gives an equivalent movement to that of the eccentric and describes a circle of radius equal to distance between the centre of the shaft or axle and the centre of the return crank pin.

If "steam lap" is added to the valve it would overlap the port by the amount of "lap" and if the eccentric were set as described above, steam would not be admitted to the cylinder until the piston had travelled some distance from dead centre and the engine would not work properly. To overcome this difficulty and to admit steam through the steam port to behind the piston immediately it moves from dead centre, the valve must be set ahead of the crank by 90° plus the "steam lap" It is necessary also, as we have previously stated, to provide "lead" and this is done by moving the eccentric still further in advance of the crank; the eccentric has therefore been moved through a total of 90° plus "lap", plus "lead", the angle in excess of the right-angle being known as the "angle of advance"

It should be remembered that only the "lap" is apparent on the valve, the "lead" being a portion of the port opening, but both the "lap" and "lead" are apparent on the setting of the eccentric. From mid-position the travel of the valve is equal to the "lap" plus the steam port opening, this being equal to the throw of the eccentric or the radius of eccentricity. Twice the throw of the eccentric will be equal to the full travel of the valve, just as twice the throw of the main crank equals the stroke of the piston. Whilst the "lead" affects the angular advance of the eccentric it does not affect the travel of the valve.



POSITION OF PISTON WHEN CRANK IS ON FRONT DEAD CENTRE

The piston valve consists of two circular pistons fixed the necessary distance apart on a spindle; the whole assembly reciprocates in a cylindrical steam chest. The valve heads are each fitted with rings to maintain a steam-tight fit in the steam chest. Piston valves can be adapted for inside or outside admission of steam to the cylinders. With inside-admission piston valves the live steam is contained between the two heads and is admitted to the steam ports at the inner edges of the valve heads, being exhausted at the outer edges into separate exhaust passages which combine to communicate with the blast pipe.

With outside-admission piston valves the steam is contained outside the valve heads with a common exhaust chamber between the heads, steam entering the ports at the outer edges of the valve heads and being exhausted at the inner edges.

With this arrangement the valve spindle glands are subjected to high-pressure steam at high temperature in the case of superheated locomotives and for this reason modern locomotives are almost invariably of the inside-admission type.

With inside-admission piston valves the travel of the valve is opposite that of the slide valve and outside steam admission piston valve; thus, to admit steam to the front port the valve must be moved forward to allow steam to pass the inside edge of the front valve head, i.e. in a direction opposite to that of the cylinder piston.

When using a direct-acting link motion with inside-admission piston valves the eccentric requires to be set an additional 180° in advance of the crank to that used for outside admission, which position is actually following the crank by 90° minus "lead". Inside-admission piston valves actuated by means of a rocking shaft, which reverses the direction of travel of the valve motion, require the eccentrics to be set as with direct motion with slide valves. The maximum travel of the slide or piston valve is twice the "steam lap" plus twice the port openings. The minimum travel is twice the "lap" plus twice the mid-gear "lead".

The term "long travel" actually refers to a "long lap" valve, the increased steam lap being greater in proportion than the increase in valve travel. The chief advantage derived from long-lap valves is greater exhaust freedom and earlier cut-off working, the valve moving a greater distance for a given angular movement of the crank. The initial movement of the valve is accelerated, being the valve events of admission, expansion, exhaustion and compression more sharply defined. The port opening to steam is increased and both the exhaust and compression delayed, at the same time the greater port opening to exhaust provides a free exhaust at high speed and a decrease in back pressure.

The slide valve has an advantage over the piston valve in that it will lift off the port face to release water which may have accumulated in the cylinders when standing, and although pressure relief valves are fitted to the cylinders of locomotives fitted with piston valves, they are not designed to deal with large quantities of water.

Cylinder drain cocks are fitted to drain away any accumulation of water from the cylinders and steam chest. Three drain cocks are fitted to each cylinder casting, one at each end of the cylinders and one connected to the steam chest. Cylinder cocks should always be open when the locomotive is standing or at any time when there is an indication of water in the cylinders. Steam-operated cylinder cocks are fitted to some of the B.R. standard locomotives and automatic cylinder cocks fitted to some continental locomotives like the SR USA tank engines.

Most locomotives with piston valves are fitted with one or more anti-vacuum valves (also known as “snifting” valves) which automatically admit air to minimise the partial vacuum created in the cylinders and steam chests when coasting with the regulator closed. Under these conditions the valves and pistons in the cylinders act like pumps, tending to induce air from the steam chest, which action rapidly creates a partial vacuum inside the steam chest, the amount being further increased by the cylinders during what would be the normal "expansion" portion of the stroke, with the result that when the valve opens to exhaust, smokebox gases and possibly ashes may be drawn down the blast pipe to destroy the vacuum. Additionally, during the compression portion of the pistons stroke very high temperatures are reached which cause lubrication difficulties. These can further be eliminated with the use of anti-vacuum valves. It will be appreciated that these valves are more effective at slow speeds and long cut-offs, i.e. when the expansion and compression periods of the stroke are the shortest. It is not satisfactory, however, to run at high speeds with the valve gear in full travel, nor would the anti-vacuum valves admit sufficient air to be effective. When coasting under these circumstances a breath of steam should be supplied to the steam chest by cracking the regulator, i.e. slightly opening and placing the reversing gear in the best position for the type of locomotive.

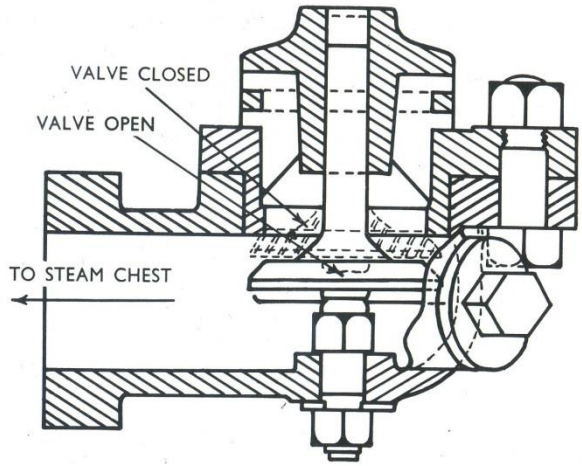


Fig. 38 ANTI-VACUUM VALVE MOUNTED ON STEAM CHEST