The Heart of the Locomotive

The Reason for the "Grasshopper" Valve Motions Seen on Modern Locomotives

By C. H. Claudy

THE human heart controls the circulation of the life blood. The valves of a steam engine control the circulation of its life blood—steam. If the valve acts well, the engine is prompt, economical, precise,

Walschaerts valve gear diagram.

From the return crank *N* the connecting rod *M* works the link *L* in which the block at the end of the rod *E* slides. This block is raised and lowered by means of the reverse lever *K*, and the rods *H* and *F* and the joint *G*. The valve *A* and the valve rod *B* are worked jointly by the return crank motion and motion obtained from the cross-head through the rods *D* and *C*. The travel of the valve *A* is governed by the position of the block in the link, which is under the control of the engineer through the lever *K*. The lead of the valve is constant, and obtained through the motion of the cross-head.

powerful. If the valve is faulty, the engine lacks power, limps on its way, and allows its energy to run to waste.

At first glance it might not seem to the casual reader that there was anything very difficult in the making of a proper valve motion. But the locomotive designer has much to contend with that the stationary engineer has not. When it is considered that with an engine running at speed, the valve opens its ports or steam ways by less than half an inch, that a valve may operate ten times in a second, that a whole valve motion weighs from one to more than two tons, and that the least change in its exact working will affect both speed and power and coal consumption, and that it must work equally well in a yard at low speed or at high speed upon a rough track, then its making does not seem so simple.

A few years ago constant travelers noted, often with curiosity, that the trim American engine with which they had long been familiar had grown a new set of rods and cranks. The general public asked what this "grasshopper" was which had suddenly begun to appear among the familiar working parts of the engine. They called it "grasshopper", because, in motion, this valve gear, the real name of which is the Walschaerts, from its inventor, has ungainly rods and sharp-angled joints in operation.

It is more familiar now, as railroad after railroad has specified it on new equipment, and replaced the older or Stephenson valve motion or gear with this foreign invention. But its working and the reason for the change remain a sealed mystery to the man on the street, simple as these real reasons actually are.

It may be something of a shock to know that it is not a new valve motion, this gear with the peculiar name, and that for more than half a century it has

been common in Europe. It seems strange that a country which has led the world in railroading should follow so long after Europe in this vital matter.

But the reason is not far to seek. Most foreign engines are "inside connected," that is, their cranks, pistons, cross-heads all work between the wheels and not on the outside of them, as with us. Hence, there was less space between the wheels for extra mechanism, and a valve gear which could be applied outside the wheels had a powerful argument in its favor.

That is one of the reasons why American locomotives, particularly the larger ones, now have these strange steel "grasshoppers" on either side. The space between our wheels, too, is getting valuable. The familiar four eccentrics take up room. That room is needed for bracing, with the increase of weight and size of boilers. Hence, an outside gear made its appeal to American builders.

But matters of space and convenience are not all the arguments which have displaced the familiar "Stephenson link" gear with the Belgian machine shop foreman's peculiar device. To understand these other reasons is to understand something of what the heart of a locomotive really is and does.

Everyone knows that steam makes an engine go by being allowed to enter a cylinder in which is a piston. The pressure on the steam pushes the piston, which is connected by means of rods to the wheels, and so they turn. Most people will understand without being told that the steam is allowed to enter first one end of the cylinder and then the other, so that the piston is first pushed forward and then pushed back again.

There must also, of course, be some way of letting the used steam out of the cylinder.

The letting the steam in and out again is the work

of the valve. In the cylinder are two admission ports, through which steam flows from the steam chest into which it comes from the boiler. The exhaust steam comes out through these same ports, but not back into

Stephenson valve gear.

Two eccentrics *A* and *B* are connected with a link *O*, which can be raised and lowered by means of the link hanger and the arms *EE* and *F*, the latter leading to the reverse lever in the cab. The block *G* is fixed to the end of the rocking arm *H* from the top of which the valve rod *I* leads to the valve in the steam chest. The travel of the valve is under the control of the engineer, by means of the reverse lever, but the lead of the valve varies because raising and lowering the link has the same effect as slightly increasing or decreasing the amount of angular advance of the eccentrics. The lead is greater, in forward motion, the more the link is raised toward the central or neutral position. Extreme cut off, then, gives extreme lead, which is not always desirable. This feature is obviated in the Walschaerts motion, in which the link is pivoted and the block raised, lead being obtained not by the position of the eccentrics but from the cross-head.

the steam chest, of course. Exhaust steam travels through the steam port not being used for letting steam into the cylinder, and out into the open air *via* the

smoke stack, because the valve directs it, forces it to take that course. The valve, which, in its simplest form, is like the letter *D* laid on its side, and its upright taken away, covers first one port and the exhaust way, then the other port and the exhaust way. The valve works in the steam chest or valve chest, and is constantly surrounded by steam, so that the life blood of the engine is always pressing for admission to the cylinders.

The valve in the Stephenson gear is worked forward and backward by means of eccentrics on the driving axle. If an engine had only to go forward, one eccentric would be enough. But because an engine must go either forward or backward, there are two eccentrics for each "slide valve." These are connected by rods to what is known as the "link," a curved, oblong frame, and in the link is a block, connected to the valve rod. The connection is made through what is known as a rocker arm, but it is not important in understanding the principle or function of the valve. When the link is down, one eccentric works the valve. When the link, by means of the reversing lever in the engineer's cab, is pulled up, the other eccentric works the valve and the engine goes the other way.

The theoretical position for the eccentric is at 90 degrees to the crank, so that, when the piston is at the exact end of its stroke,

(Concluded on page 86.)

Typical American express locomotives. Upper view an "American" or 4-4-0 model, with Stephenson valve gear. The other views show opposite sides of the "Pacific" models (4-6-2) fitted with the Walschaerts gear.

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The Heart of the Locomotive

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the valve will be in the exact middle of its stroke. The least motion forward or backward, then, tends to make the valve admit steam to one end or the other of the cylinder. Such a construction would begin to admit steam to the cylinder only after the piston had started on its stroke.

But practically this will not work out. It is found that steam should be admitted to the cylinder before the piston finishes one stroke in one direction and begins a stroke in the other. It must do this for several reasons. One is to furnish a cushion of steam, a pressure in the cylinder, to help take up the jar and shock of stopping the piston and piston head, before it starts in the reverse direction. Another is to allow the piston to have something to compress, so that when the valve port opens full, the cylinder pressure and the boiler pressure are already about the same, and the tiny interval of time which would otherwise be necessary to bring the cylinder pressure up is saved.

There are other reasons, but these will suffice. The "angular advance," or amount by which the eccentric is in front of its theoretical position, gives the valve what is known as its "lead." The "lead" of a valve makes everything which occurs in the cylinder, that is, admission of steam, cut off of steam, expansion of steam, exhaust of steam, admission of steam to the other end, cut off of that steam, etc., occur earlier than would otherwise be the case. But the matter is complicated by the necessity of what is known as "lap" on the valve, that is, the extra length or face of the valve which permits early "cut off" without too early pre-admission of steam to the cylinder.

"Cut off" means what it says, the cutting off of steam. The shorter the travel of the piston during the time steam is coming in, the less steam is used, of course, and the more economy in coal. Early "cut off" allows the steam to expand and use this expansive force which is wasted when the engine is running in full gear without much "cut off."

Here is the real reason for the two eccentrics. If a valve had no lap, and the eccentric was at exactly 90 degrees with the crank, so that the valve had no lead, one eccentric would do for either forward or backward motion, changing from one to the other by a simple link motion. But, in practice, valves do have and must have both "lap" and "lead," and so two eccentrics are necessary (at least in the familiar Stephenson motion), one arranged or set for forward motion and one for reverse.

But the inventors of the Stephenson motion builded better than they knew when they designed the "link" and the two eccentrics. For it was found that the use of the reversing lever, which raises the link through its entire throw, was not confined to reversing the engine. When the link is raised exactly half way, each eccentric has an opposite effect upon it, and the valve has but a slight movement. The more the link is raised or lowered beyond this point, the greater becomes the travel of the valve until it is working in full gear.

The engineer thus has at his hand a method of increasing or decreasing the travel of the valve, which, of course, gradually increases or decreases the size of the effective steam opening into the cylinder. Because the economical use of steam demands that its expansive force be utilized, this is of great service to the engineer. The familiar expression, met with even in railroad fiction, of "hooking her up," comes from the use of the reversing lever to shorten the travel of the valve, and this gives the steam a chance to use its expansive power in the cylinder.

But, because of questions of space under a locomotive, eccentric rods cannot be made of infinite length; and with the short eccentric rods, the familiar "hooking up" operation gradually increases the "lead" of the valve, as its travel is shortened. Too much "lead" is as bad as too little—some engineers say worse. And, for this reason, a valve gear which should never change the "lead," no matter how it was

"hooked up," has been the aim and end of thousands of inventors.

The peculiarity of the Walschaerts gear is found in the fact that it has only one eccentric, which is in the form of a "return crank" from the main crank on the main driver, and that this one eccentric or return crank does all the work of the valve gear as far as determining the travel of the valve is concerned. It operates a rocking link which does not move up or down, and in which the block, connected to the valve, is moved up and down by the reversing gear. The "lead" is given to the valve by bringing in a motion obtained from the "cross-head," a "lead" which remains constant, regardless of the position of the block in the link. Hence, the engineer can "hook her up" all he wants, but the "lead" of the valve remains constant.

But the advantages of the Walschaerts valve gear are not confined to a mere matter of constant "lead." Its accessibility commends it highly to engineers who must have the care and oiling and inspection of it. Because it does not take up valuable under-boiler room it commends itself to the designer, who also finds in its much lighter weight a great blessing. The Walschaerts gear transmits its motion from driving wheel and cross-head to valve in almost a straight line, which avoids the errors of distortion found sometimes in the Stephenson gear, which gains its motions from eccentrics between the wheels, and transmits it to a valve considerably to one side. The Stephenson "link," acting under the forces from two eccentrics, moves through a wide angle. A wedging action on the block takes place at high speeds, and this, together with the difficulty of oiling large eccentrics properly and continually, makes the gear sometimes collect "lost motion." Lost motion in a valve gear is about as welcome as a cat at a mouse party, and does about as much damage in the long run. Finally, the Walschaerts gear is said by master mechanics to be more "foolproof" than the ordinary gear. There is less opportunity to "tinker" with it, to experiment in changes in eccentric positions, and its cost of maintenance is less than that of the older, heavier, clumsier mechanism.

It may be of interest to remember that Egide Walschaerts, to whom the railway world owes so much, died near Brussels fourteen years ago, at the ripe age of eighty-one. It is true that he was first a mechanic, lived a mechanic and died a mechanic, that his position in life was always that of a workman, a foreman in the workshops. But Walschaerts was a foreman from choice, not necessity. He hated red tape, thought reports and investigations and office work a bore, and wanted nothing more than a blue print in his hand, a shop to work in, and some engines to work on. As a boy, he had been fascinated by the then brand new idea of railroading. Born at Malines, in Belgium, the connecting of that town by railroad with Brussels in 1835 determined his career. Though he worked on improvements in steam vessels, and stationary as well as marine engines, it was the locomotive which he loved and on which he spent most of his time. He met with great appreciation from the State railways of his country; later all Europe adopted his valve gear, and now the United States is using it as fast as it can be applied.

So it is that a Belgian "grasshopper" is to be found on most modern United States engines, and the traveler who casts a curious glance at the queer rods and joints which give a constant "lead," no matter what the "hook up" or cut off, which make a light mechanism do the work of a heavy, and which tends to strength in the engine by giving space for bracing, should not grudge a moment's thought to the Belgian boy who was content to wear overalls all his life, though he had the capacity to become a wealthy business man, because of his love for the horse of the iron rail, and his never-ending investigations into the mechanism, the mathematics and the physics of that greatest triumph of steel and iron, the locomotive.

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Modifications of the Walschaerts gear have appeared and are apparently successful, but they all contain the basic principles of the original.

The Thermaphone

A RECENT report from Amsterdam described a Dutch invention which promises to revolutionize the telephone industry. The discovery was made by Mr. P. de Lange, a native of the Netherlands, at the University of Utrecht. The discovery is the more wonderful that it comes announced at the time when Europe is terror-ridden by this disastrous war.

The thermaphone is the name of the new telephone and consists of a telephone receiver and transmitter which is so small that it can be carried in the vest pocket and is no larger than a watch. The magnet and the diaphragm of the ordinary receiver are replaced by a loop of an exceedingly fine platinum wire and a disk of aluminum perforated with fine holes.

The American Consul at Amsterdam, Mr. D. I. Murphy, who writes that he has witnessed a demonstration of the thermaphone at the University of Utrecht, describes it as follows:

"The receiver and transmitter are so small they may easily be carried in the vest pocket, taking up no more space than the ordinary watch. The cost of manufacture is estimated at 30 American cents.

"Notwithstanding its diminutive size, the 'thermaphone'—for so the inventor has named it—appears to have the advantage over the telephone of transmitting messages with perfect clearness and distinctness, vocalization being especially good, and there being no confusion of vowel sounds, letters, or figures. In the thermaphone the magnet and diaphragm of the telephone are eliminated, there being substituted a loop of exceedingly fine platinum wire within a small aluminum cover pierced with minute holes. Currents passing through the wire cause changes in temperature, alternating from heat to cold with great rapidity, the consequent expansions and contractions of the surrounding air becoming evident as sound."

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Interlocking Steel Construction

A SYSTEM of fastening steel beams together without the use of rivets was recently tested at Columbia University with results that were surprisingly favorable. The webs and flanges of the beams were slotted or recessed and then they were interlocked in such a manner as to reinforce one another. The purpose of this construction is to dispense with the cost and labor of riveting in steel work.

In the accompanying engraving, Fig. 1 shows how a floor beam *E* may be secured to a column *D*, a slot *F* being cut in the column to receive the beam. A pair of clips *G* fit snugly over the upper flanges of the beam *E* and between the flanges of the column *D*, leaving a slot between them to receive column *H*.

Fig. 2 shows the construction of a bent such as would be used in a mine. A little study will show how the legs *A* fit into recesses in the beam *B* and are held from sliding out by clips *C*. The last are fitted on the beam *B* before it is slipped into place on the members *A*. The roof beams interlock with the clips *C*. The legs *A* are anchored in base-blocks as illustrated. Of course, the details of the joints will vary to meet the particular requirements of different structures.

The structure tested at Columbia University was such as would be used on a four-tube subway.

Wait's interlocking steel is constructed by various ways of recessing the web and flanges of both the I and H beam to the necessary form of usage to which it is to be adapted; in so doing each joint reinforces itself, whether for subway, bridges or mining, and erections of buildings. The same basic principle is applied in each different construction, but necessitating various forms of locks independent of beams to unite the various angles or lines in construction.

The test of May 29th at Columbia University was a form for subway construction of a four-tube subway.

The test was a great surprise to all that were present. This section was formed of 4-inch H-beam columns and 6-inch I-beam girders. The second story was interlocked by one set of lock sections for continuing column supports. The I-beam indicated an equal stress on the beam to nearly 150,000 pounds before the giving away of the web of the upper I-beam. At 153,000 the stress was discontinued so as not to destroy the beam totally.

The lock or the columns did not show any failure and remained perfectly true in form. The damaged sections could be replaced in five minutes. The tapping of a 4-pound hammer was all that was necessary to remove them. A 6-inch I-beam is supposed to fail completely at 100,000 pounds where the flanges are not supported. As these were not supported, the 53,000

pounds of extra pressure indicated must have been distributed throughout the out-members constituting the complete unit. This would indicate that a construction of interlocking steel is one third stronger than where rivets are used.

A Submarine Catcher

THE illustrations show a new method and apparatus for catching submarines, differing in many features from those previously described. Comparatively narrow channels to harbors are usually protected from submarines by mooring strong steel nets across the channel from shore to shore. Such protection, however, is not

System of steel construction that dispenses with rivets.

so well suited to large bodies of water, as bays and open roadsteads.

The device shown, submitted to us by Mr. Jesse W. Reno of New York city, appears to have considerable merit, and would be useful in discouraging submarine attack upon ships passing through extensive bodies of water. The plan is to drop overboard from a small cruiser several hundred of these "catchers" and leave them free to float back and forth with the current. It would be impossible for the enemy to locate them from the conning tower of a submarine, and therefore their presence in such waters would exert a powerful moral influence to prevent the free access of this terrible engine of destruction.

There can be little doubt that a submarine will be put out of commission if it enters, or even strikes a glancing blow against, the submerged ring of the "catcher." This ring, made of light gas pipe or angle iron, is 24 feet in diameter, and is suspended freely by chain to a float which is nearly submerged. Attached to the ring are eight $\frac{3}{4}$ -inch ropes about 100 feet long with looped ends. The ropes are continuous in pairs and the attachment to the ring is such that it will easily break away and thus permit about 200 feet of rope to wrap around

the propeller blades and shaft when the loop is caught. Inasmuch as all submarines have twin propellers, located at a considerable distance from each side of the keel, the chance that both propellers will be simultaneously entangled in the trailing ropes is almost certain. The action of twin screws is to cause a powerful in-sweep of the water currents some distance forward of the stern, which would aid in bringing the ropes in contact with the blades. The "catcher" would have little or no effect upon the ordinary ship, the bow of which, if coming in contact with it, would not engage; in fact, the bow wave would probably push the "catcher" to one side, permitting it to drift astern. Assuming that a submarine has been caught in the manner described, her distress and location can be signaled by a simple device also invented by Mr. Reno, which will be clear from the following description.

A slack wire or lanyard is strung from the lower edge of the "catcher" ring and continued through a hole in the upper edge of the float. The float is provided with a conical hole through which the lanyard is passed, leading to a Coston signal flare contained in the upper end. As the submarine enters the ring it pulls the lanyard, setting off a delayed action fuse which will fire the flare, say one minute later, thus giving time for entanglement of the rope with the screws. The Coston signal can also be supplied with a substance producing a dense brown smoke visible for ten miles in daylight.

A day and night signal of this character would enable a small cruiser or torpedo boat to capture or sink a submarine whose propellers were entangled and could not be operated.

The Interstate Commerce Commission and the Shipment of Natural Gas Gasoline

IN the final rules of the Interstate Commerce Commission regarding the shipment of natural gas gasoline it is suggestively stated that the commission has not deemed it best "at this time" to prohibit the use of good wooden barrels in shipping inflammable liquids with a flash point below 20 deg. Fahr. (—7 deg. Cent.), while requiring that liquefied petroleum gas must be shipped in metal barrels, drums or tank cars of a certain specification. We say suggestively stated, because the tendency appears to be toward the metal container exclusively and inventors or manufacturers of such containers or those contemplating such manufacture may well consider the possibility of improvements either in the product itself with a view to cheapening or improving the product itself or the process of its manufacture.

Catching submarines with ropes.