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Valve Motion.

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The duties which a locomotive valve gear has to perform are exacting in the extreme, as it has to control the distribution of steam to the cylinders with almost perfect precision through a wide range of cut-offs in forward and reverse direction. There is no apparatus on a locomotive upon which the economical working depends so largely, and when we consider that at diameter-speed the movement of the distribution valve is reversed 672 times a minute, we can appreciate with what care the design must be undertaken.

From the point of view of economical steam distribution, valve motion design has today reached a point where it cannot be greatly improved upon, and the chief attention of the designer has for the last few years been taken up with questions of accessibility and low maintenance cost, his aim being to apply a gear which would run and keep square from shopping to shopping with the minimum of attention. Considered from the stand-point of steam distribution alone, I doubt if a well designed and properly set Stephenson gear has ever been excelled, but owing to inaccessibility, high maintenance cost and its great liability to get out of square due to the springing of parts and development of lost motion, the Stephenson gear has become a back number, and I shall only refer to it for purposes of comparison.

For several years past practically every locomotive built in this country has been equipped with an outside gear, the vast majority with Walschaert's, and to this gear I shall devote most attention. Of all locomotive valve gears made, Walschaert's is the simplest to understand, to design and to set, and when this gear has been well designed and correctly set, it will keep square for an indefinite length of time. The simplicity of the gear lies in the fact that the valve receives its motion from two sources, first from the crosshead through the combination lever, and second from the eccentric through the link, and each of these sources of motion can be dealt with separately without considering the influence of the other, both in designing and setting.

The motion derived from the combination lever is equal to the steam lap plus the lead and it attains its maximum travel when the engine is on the dead centers, it is not affected in any way by the reverse gear but remains the same in all position of the lever. The motion derived from the link is simply a symmetrical motion front and back of the center line, and is increased or decreased according to the distance of the link block from the center of the link. When the link block is exactly in the center of the link, there is, of course, no motion from this source and as the block gets by the center the motion is reversed. When the engine is on the front or back dead center the link assumes such a position that the reverse lever can be moved backward and forward through the entire travel without imparting any motion to the valve, and the distance the valve is off center is entirely due to the position of the combination lever which is at its maximum travel at these points.

The proportioning of the length of the combination lever is a simple matter when we have decided on the steam lap and lead required. The length of the combination lever from the radium bar connection to the union link connection must bear the same proportion of its length from the radius bar connection to the valve stem crosshead connection as does half the stroke of the piston to the lap plus the lead plus 1/64 in. The 1/64 in. is added to the lap plus the lead to take care of lost motion. Care must be taken that the length of the combination lever adopted will bring the lower end of the lever to the correct level to connect up with the union link, especially if the union link is connected directly to the wrist pin, which is the practice generally adopted unless the Ripken Kingan main rod arm is used.

I have seen various rules as to the length of the radius bar and eccentric rod, but they are for the most part worthless, as our problem is to apply a gear to a locomotive; we are not permitted to design a valve gear and then build an engine around it. The best rule we can adopt therefore is to make both the radius bar and the eccentric rod as long as circumstances will permit and with ordinary wheel bases this will invariably give satisfactory results. The radius of the link slot center line is of course determined by the length of the radius bar, and the preferred location of the link support bearings is such that the horizontal center line is on a level with the radius bar connection to the combination lever. This location may be varied within reasonable limits, without affect the valve events to any appreciable extent; for instance, on a locomotive with a very large cylinder the steam chest center line and the cylinder center line are of necessity quite a distance apart, and in this case the link support is sometimes lowered an inch or two, to bring the link tail nearer to the horizontal center line of the axle. The angle through which the link rocks should not exceed 45°, and if it can be kept lower so much the better.

The eccentric rod connection to the link tail should be kept within 3 in. or 4 in. of the horizontal center line of the axle, in order to keep the angularity of the eccentric rod within limits, and owing to this angularity of the rod, it will be found necessary to offset the tail connection of the link in order to give it the same angular travel on either side of the central position. I have heard men with a good deal of experience state that an approximately correct offset is all that is required, but as it is just as easy to make this offset correct as otherwise I always prefer to make it dead right. The eccentric crank must be set so that it brings the link dead on its central position when the engine is on either front or back dead center, and the throw of the eccentric pin must be such that, acting in combination with the radius of the link tail, it will give the required angular travel to the link. The reverse shaft location, length of arm, and swing link are very important considerations, and unless great care is exercised in the arrangement of these details the efficiency of the motion may be considerably reduced. The arc which the reverse shaft arm describes should be so arranged as to reduce the link block slip to a minimum in all positions of the reverse lever, special attention being paid to the running position in fore gear. It is impossible to avoid link block slip altogether, but it can be kept pretty low, and if this is not carefully looked after the effect will be seen in the valve events and also in the wear on the link and link block. The steam chest center line should be outside the cylinder center line far enough to permit of bringing the whole motion into practically a straight line, thus eliminating the necessity for rockers, and doing away with the twisting effect and lost motion which the use of rockers involves.

All road locomotives equipped with Walschaert gear should be so arranged that the link bottom is in the bottom half of the link for fore gear, the eccentric of course following the crank pin. The advantages of this arrangement are that the wear on the link support bearings is diminished and the link block slip in running position may be kept very small, as the swing link describes an arc which is very similar to the arc struck by a point in the bottom of the link, the concave side of both these arcs being uppermost. It is very important that the design of this gear should be as good as it is possible to make it, for, if it is faulty, it is impossible for the valve setter to correct its faults. With a badly designed Stephenson gear, a good valve setter could often get very fair results in running position, by sacrificing the other positions of the reverse gear, but with a Walschaert gear this is out of the question, as it is squared on the dead centers, and, if the design is good, all the valve events naturally come within very close limits of being square, but if they do not there is practically nothing the valve setter can do to correct them.

It must be borne in mind that the chief aim of the designer is to obtain as nearly as possible a perfect steam distribution, but the most important consideration with the valve setter is to get four level beats up the stack. A perfect steam distribution will of course give a perfect exhaust, but a perfect sounding exhaust does not necessarily mean a perfect steam distribution, by any means. The steaming properties of the boiler, and the fuel economy, depend very greatly on the evenness of the exhaust, and if the exhaust is ragged, the vacuum in the smokebox is unsteady and the fire is soon pulled in holes, resulting in a