Discussion on Valve Motion.

The paper on valve motion. by F. Williams, Mechanical Designer, Canadian National Rys., Moncton, N.B., which was published in Canadian Railway and Marine World for April, was discussed by Canadian Railway Club members, before whom it was read. Following are the principal remarks:—

W. A. Booth, Engineer of Locomotive Construction, G.T.R.:—The paper states that the Stephenson link motion is a back number, and I think we all agree with that. On account of the increased size of the locomotives now being built, it is not likely that any more motion of this type will be applied.

O. W. Young, Young Valve Gear:—The dynamic operation of a locomotive steam engine is accomplished by four essential acts; steam admission, expansion, exhaust and compression. Admission is the act of directing steam pressure against a piston. It is the motive agent employed for revolving the wheels. The duration of the admission period must be subject to control by the locomotive man. At his option it should be possible to admit steam to the cylinders during nearly the entire piston stroke, in order to ensure positive starting reliability and maximum power for initial train movement. The maximum cut-off must therefore be late. After starting a train it must then be possible to manually shorten cut-offs (the admission period), because less power is required to keep a train moving than is necessary to start and accelerate it, and because, also, small volumes of steam must be used, on account of difficulty of rapid exhaust after speeds become considerable, and further because it is impracticable to design locomotives with proper ratios between boiler capacity and cylinder volume, to permit the use of full cylinder capacity only at low speeds. In addition, late cut-offs are uneconomical since they preclude effective expansion. The range of duty required by a locomotive in starting, accelerating, attaining and maintaining high speed, is so great that it necessitates a wide range of cut-offs subject to control by a locomotive driver. The admission period must begin as early as the beginning of a piston stroke. It may, and usually does begin before the completion of the piston's return stroke and that portion of its period is called pre-admission. Steam is then admitted against a piston, tending to check movement, and cushion its momentum. The pre-admission period should not commence before the crank pin is practically on a dead center, when working in late cut-offs, and consequently slow speed. But it may, and it is desirable that it should, begin considerably earlier, when in early cut-offs (high speed position), because piston velocity is then greater, and greater cushioning power needed to absorb the shock of checking and reversing the direction of piston movement. It is desirable that during the admission period steam flow should be unobstructed, in order that there may be but little drop in pressure against a piston up to the point of cut-off. Any valve actuating mechanism tending to increase the widths of steam port openings is therefore for that purpose basically sound.

Expansion is the act of prolonging steam pressure against a piston after admission ceases. A mass of steam then in a cylinder cut off from further replenishment from a boiler, continues to expand and propel a piston with decreasing pressure until it is permitted to escape to the atmosphere. All piston movement during this process causes rotative impulse to the driving wheels, without further drain on a boiler, and is in the direction of fuel economy. The expansion period should therefore embrace the greatest practicable portion of piston movement. In all successful valve gears, the relative duration of the expansion period increases with shortened cut-offs. Expansion should be continued as late in the stroke as possible, and any valve gear that permits this, is in this respect desirable, provided it does not introduce objectionable features affecting other events in the cycle.

Exhaust is the act of relieving a cylinder of pressure. Its period may be divided into two stages. First, after expansion has been carried as late in the stroke as practicable, all steam tending to propel a piston should be permitted to escape to the atmosphere. Unobstructed means should be provided for escape to the lowest obtainable pressure by the time a piston has reached the end of a stroke, so as to ensure the least possible initial back pressure during the return stroke. This is particularly desirable at high speed, because it is not only then more difficult to accomplish, but the piston speed is then so great that it precludes material lowering of back pressure ahead of the advancing piston, during this, the second exhaust stage. A valve gear therefore that causes rapid valve opening during the first exhaust stage, and maintains liberal opening during the second stage, not only increases effective cylinder pressure, but the increased power is produced economically because of lower negative pressure.

Compression is the act of building up pressure to cushion a piston at the end of its stroke. Compression, together with pre-admission, serve to fill the clearance space between the piston when at either extreme position its nearest cylinder head and valve. These together ensure high initial pressure. All steam pressure remaining in a cylinder at the beginning of compression, together with 15 lb. atmospheric pressure, are concentrated into smaller space and should then approximate steam chest pressure. Compression and pre-admission blend into a common pressure. Compression costs only to the extent that it retards wheel revolution. Pre-admission costs in addition the amount of steam it draws from a boiler. Therefore, the terminal pressure should be largely caused by compression. That is, terminal compression should be so high that it will require but little if any additional pressure from pre-admission to build up a pressure equal to that in a steam chest. Compression should and does in all successful valve gears begin earlier at high speed (in short cut offs) than at low speeds. But at low speed terminal compression is lower and the influence of pre-admission more pronounced and expensive. At high speed it is difficult to avoid excessive compression, and any valve gear tending to lower initial compression logically accomplishes some economy.

That Mr. Williams knows human nature is most evident when he said in introducing his subject, that he hoped he might get on some of our pet theories. He did. Conceding that "valve motion has today reach a point where it cannot be greatly improved upon" does it follow that we cannot consider the constantly increasing cylinder sizes which demand the rapid handling of greater volumes of steam and, consequently, more liberal means of handling this volume? When 20 in. cylinders were the maximum in service the valve travel was 6 in., which was thought sufficient. An analysis of numerous tests with which I am familiar showed excellent steam distribution in 20 in. cylinders with 6 in. travel and 12 in. piston valves. That combination is therefore used as a basis for the arguments herewith presented.

The first duty required of a locomotive in train operation is the start. To ensure this, it is capable of demonstration by an analysis of main rod angles, and it is further proved by actual experience, that the maximum cut-off must be approximately 88% of the piston stroke. If of less than that percentage, a locomotive will frequently fail to start, even though coupled to a comparatively light train, without first slacking back, and not only reducing the initial load resistance, but also changing the crank and rod angles to more favorable leverages. In order to provide for 88% maximum cut-off, the sum of lap and lead must not exceed 19% of valve travel. A valve setting in the following tables is therefore so arranged, the figures representing inches.

Cylinder diameters.	Sq. inch piston area	Valve travel.	Lap and lead 19% of travel.	Lap.	Lead.	Valve Diameter.
20	314	6	1 9-64	57-64	¼	12
25	491	7	1 21-64	1 5-65	¼	17
30	707	7	1 21-64	1 5-64	¼	24

Port length.	Port width 25% c.o.	Port area 25% c.o.	Maximum cut-off.
28.7	9-32	8	88%
42	19-64	12.3	88%
60	19-64	17.7	88%

It will be noted in the table that for 20 in. cylinders the piston area is 314 sq. in., the valve diameter 12 in. with 28.7 in. port length exclusive of bridges, valve travel 6 in., lap 57/64 in., lead ¼ in., maximum port opening in 25% cut-off, 9/32 in. which causes 8 sq. in. steam port area. This is equal to 1/40 of the piston area. Assuming that a ratio of piston area to port area in 25%, cut-off of 40 to 1 is necessary for rapid steam flow into a cylinder during admission, and assuming that the valve travel for larger cylinders is increased to 7in. with valve lap of 1 5/64 in. and lead ¼ in., then for 25 in. cylinders with 491 sq. in. piston area the port area should be 12.3 sq. in. This would require a valve 17 in. in diameter with ports 42 in. long exclusive of bridges. 30 in. cylinders with 707 sq. in. of piston area, 7 in. valve travel, 17.7 in. port area require valves 24 in. diameter with ports 60 in. long. Twenty-five per cent. is considered in the foregoing, because that is the desired running cut-off, as all valve events then combine to produce the best economy and efficiency.

Valve travel of only 7 in. is mentioned, for the reason that with the Walschaert gear greater travel involves such acute angles in the movement of certain members of the gear that designing engineers have been reluctant to introduce them.

It is clearly shown that so far as the admission period is concerned, cylinders of 25 to 30 in. diameters require valves of 17 in. to 24 in. diameter to produce as free steam flow as 20 in. cylinders re-