mediate signals, must be carefully avoided, as this introduces the possibility of additional delay which would materially reduce the capacity.

If the above reasoning is correct, that is that the necessity for following or permissive movements is due to running trains of different speeds on a division, then the advisability of putting in signals between passing tracks is dependent on the proportion of high speed trains to slow speed trains on a division, and therefore proportional to the amount of tonnage loss due to the inability of slow trains to get away from the passing tracks quickly, after having been passed by a high speed train.

This loss in tonnage means a loss in possible revenue, and when this potential loss in revenue is equal to the cost of maintenance and operation of the signals necessary to eliminate this tonnage loss, plus the interest on first cost and depreciation, then the point has been reached when the introduction of signals can be justified economically.

The average freight earnings on Canadian railways for 1913 was 0.753 cts. per ton mile; of this 70% was expended in cost of operation, leaving as net revenue 0.227 cts. per ton mile. Assuming that an automatic signal will cost $800, and that the cost of operation and maintenance will be $150 per year, the yearly charge for an automatic signal would be: Interest at 5%, $40; depreciation at 7%, $56; maintenance and operation, $150; a total of $246 per signal per year, or 67.4 cts. a day, as the cost per signal. If we divide this amount by 0.227 cts. we will get the ton miles over the division that must be added to the capacity of the line to justify the installation of one signal. This is $\frac{67.4}{0.00227}$=296.9 ton miles, or in tons for the district illustrated in the above $\frac{296.9}{25}$=11.8 tons per signal in the 24 hours. It has been shown above that the tonnage lost due to this inability to follow was, on this district 7,730 tons, enough tonnage to pay for 65 signals on 24 miles of track.

The question naturally arises how many signals could be used economically? It is quite evident that if the slow speed train is to get away as soon as possible after the fast train has passed, that the first block out from the passing train must be short enough to permit the entrance signal to assume, at least, the 45 degree position, in the least possible time, bearing in mind that the minimum length of block must not be less than the braking distance of the maximum speed train, and that the next block length would be such as to allow the high speed train to pass the outgoing signal of the block before the following train has reached the outgoing signal of the first block.

As an illustration, assuming the speed of the fast train is 30 m.p.h., and that the braking distance for the maximum train, at its maximum speed, is 2,000 ft., the signal marking the end of the first block would be located 2,000 ft. out from the siding, the entrance signal of this block being located just beyond the siding switch, this 2,000 ft. would be run in 0.76 mins.

The train which has been passed can now head out and will pass the entrance signal at 45 degrees. Assuming that it takes this train 6 mins. to open the switch and head out on to the main line and close the switch, and an additional minute to run to the next signal, or 7 mins. in all, the fast train would have run 3½ miles, and therefore if the slow train is to be given a clear signal, the fast train must have passed two signals, or the block lengths succeeding the first block out would be about 9,200 ft. in length. This would determine all succeeding block lengths, except that in order to facilitate meets the distant signal indication for the next passing track should be set as close in to the passing track as possible, or it would be probably located out a distance equal to the maximum train length plus its braking distance. This would be approximately 3,500 ft. The above is illustrated in figs. 9 to 11.

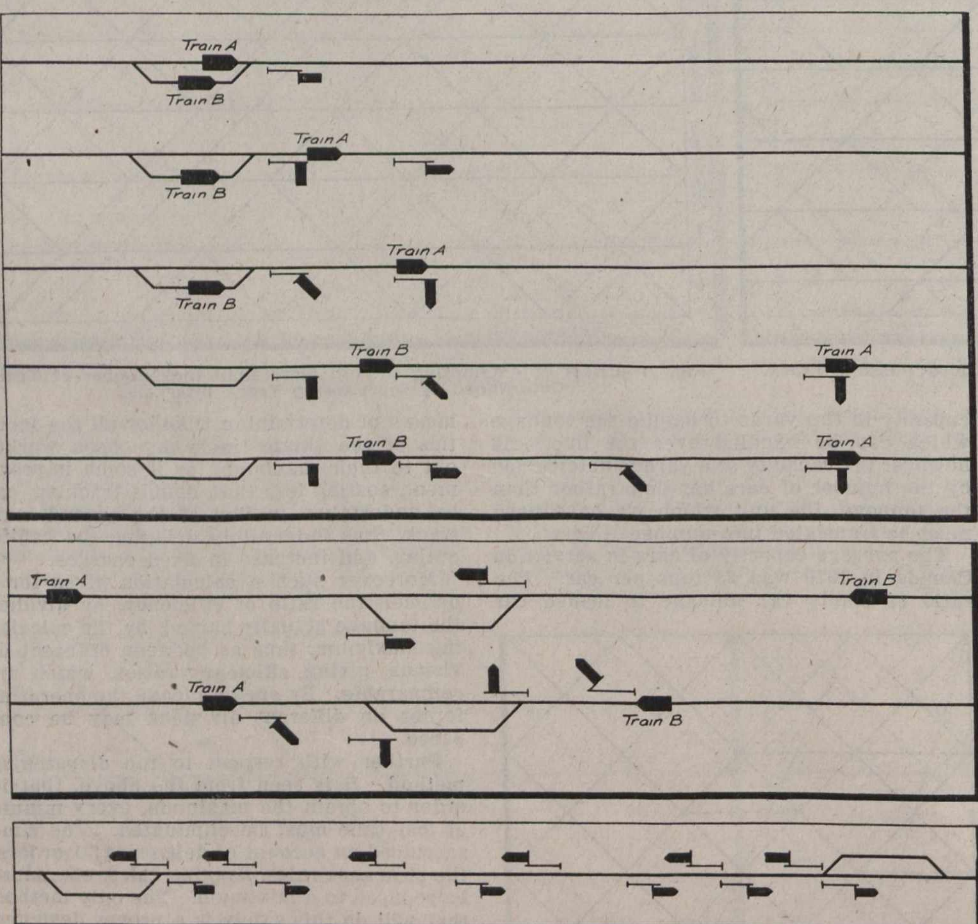

Fig. 9.—Fast Train Passing Slow Train at Siding. Fig. 10.—Trains Meeting at Siding. Fig. 11.—Distribution of Blocks between Sidings.

Now if we summarize the different values in tons lost for the different elements which we have considered we can approximately show the relative value of each.

	Tons.	%
Operating:		
Clearance rules	8,136	20.5
Lack of ability to follow	7,730	19.5
31 orders	10,260	25.5
Irregularly spaced passing tracks	10,896	27.0
Passenger trains	3,112	7.5
		100.0

65.5% of the tonnage loss on this line is due to the method of operation, 27% is due to the irregularity of the passing track spacing and 7.5% is due to the passenger train service. The introduction of automatic signals on this line would apparently have the greatest effect in increasing the tonnage, spacing of the passing tracks being next in order, assuming that the terminal yards are sufficient to take care of the tonnage when increased.

The tractive effort of the locomotive is found from the formula $T=\frac{O8Pds}{D}$ where T is the tractive effort; P, boiler pressure; d, diameter of cylinders; s, stroke; and D, the diameter of the locomotive driving wheels.

In working out the data for the profile here shown, I assumed that the class of locomotive being used on the district was of the following dimensions:—

Weight on drivers	131,200 lbs.
Locomotive and tender	152 tons.
Boiler pressure	185 lbs.
Cylinders	22 x 26 ins.
Dia. of drivers	63 ins.

The tractive effort of this locomotive with full cut off would be 31,400 lbs. When however the locomotive reaches a certain speed the cut off must be changed, so as to admit less steam to the cylinders, and this will cause a reduction in the tractive effort of the locomotive. The point where the cut off will be modified is a function of the speed, and will be found by the formula, Speed factor $=\frac{56.02\ V\ s}{D}$ The speed factor is given in revolutions per minute of the driving wheels. Up to a value of 250 the locomotive will be operated with full ports; above this the cut off is reduced, and there is a rapid drop in the tractive effort of the locomotive. Fig. 13 gives the tractive effort curve for the locomotive above. The tractive effort curve is a straight line to 10.8 m.p.h., the rest of the curve is a hyperbola, that is the product of the ordinates and abscissae is constant, in the case of our locomotive this product is 339,120. This curve gives the theoretical tractive effort, but the actual tractive effort which it is possible to utilize at low speeds is dependent on the friction between the drivers and the rails. Using 0.2 as the coefficient of friction, and with 131,200 lbs. as the weight on the drivers, the actual tractive effort available is 131,200×0.2=26,240 lbs. This value is shown on fig. 13, the balance of the curve being found by drawing a tangent from this point to the curve already found. This curve then gives the tractive effort of the locomotive from 10 to 40 m.p.h.

The resistance which the locomotive must