gear, we shall have to analyze the situation a little further and go into the question of starting tractive effort. We all know that the worst starting position for a locomotive is when she is standing with one side just past the cut-off point. In this case the whole starting effort has to come from the other cylinder where the crank has not yet reached the point of maximum leverage. Fig. 3 shows the position of the crank pin of this locomotive at the point of cut-off, the full line indicating position with normal setting and the dotted line with the variable lead setting. It is evident that, when the locomotive is standing in this position, we shall get the minimum starting effort, as all the turning moment has to come from the other crank, which will be either at B b or C c, according to whether A a represents the right hand crank or the left. The effective length of the crank, which is doing the work, is 10 in. for nominal setting and 10⅝ in. for the variable lead setting, or a difference in favor of the variable lead of 6¼%, so that we may say that the minimum starting effort of this locomotive is increased 6¼% by this setting. I do not wish to convey the impression that this locomotive can be improved 6¼% by this means, as the maximum tractive effort is not affected in any way, and the only advantages are that the maximum tractive effort is available through a very slightly wider range of positions, and in the very worst starting position the tractive effort is increased by 6¼%. As soon as the locomotive has turned a wheel the advantage almost entirely disappears, the slight delay in the release and closure points may result in a slight improvement during the early stages of acceleration, but on notching up the two settings are practically identical.

Fig. 4 shows a diagram plotted for one of our mikado locomotives. This locomotive has a 27 x 30 in. cylinder, 14 in. valve, 6½ in. valve travel, ⅛ in. constant lead, 1 in. steam lap and no exhaust clearance. The chief difference from the passenger locomotive settings are reduced lead, reduced steam lap, and elimination of the exhaust clearance.

We have already seen that reducing the lead will give us a later cut-off in starting position, and have decided, I think, that this is an advantage when starting the load. Reducing the steam lap has the effect of lessening the period of expansion, but by reducing the exhaust clearance the period of expansion is lengthened and thus the ill effect of cutting down the steam lap is neutralized. The reduction or total elimination of the exhaust clearance lengthens the period of expansion by delaying the release, and this in itself is a good feature, but it has also the effect of advancing the closure point and the question naturally arises as to why it should be permissible to eliminate exhaust clearance and thus advance the closure point on freight locomotives and not on passenger locomotives. The first reason is that in running position the passenger locomotive is generally notched up to a much earlier cut off than the freight locomotive—about 25% of the stroke instead of 50%—and the second the piston speed of the passenger locomotive averages much higher than that of the freight locomotive.

The passenger locomotive, under consideration, has a piston speed of 1,136 ft. a minute when making 50 miles an hour, or over 40% higher than that of the freight locomotive at 30 miles an hour, and the higher the speed the higher the compression will be, provided that all other conditions are equal. It is a mistake to think that compression always starts from the closure point; it does at very slow speeds, but as the speed increases the compression begins earlier, owing to the fact that the piston has to sweep a considerable volume of steam through a port opening which is narrowing down for the closure, in an increasingly short space of time. By giving this locomotive exhaust clearance, we not only delay the closure point, but also give a greater exhaust port opening, thus allowing the exhaust freer access to the atmosphere, and the result is a freer running locomotive.

You may say that when the locomotive is working at a short cut off less steam is admitted to the cylinder, and, therefore, the piston has less to sweep out on the return stroke, but if we consider for a moment we shall realize that the exhaust begins with the release, and by the time the return stroke has begun there is very little difference in the amount of steam left in the cylinder, whether running on long or short cut off.

When dealing with the question of compression we have to look into the matter from several different view points. From the point of view of economy of steam consumption per unit of power developed, the higher the compression the greater the economy, provided we do not run the compression higher than boiler pressure. This is on account of the clearance volume, and we can readily understand that, the higher the compression the less steam has to be supplied from the boiler to build up the initial pressure, and if the compression reaches boiler pressure there is no steam drawn from the boiler until the piston actually starts its working stroke.

The next thing to consider is the power required, as it is no use trying to run on a very fine thread of steam if we cannot get the tractive effort necessary to keep the load moving. From this aspect of the question, compression is negative effort, and a high compression curve seriously cuts down the area of an indicator diagram and the mean effective pressure, thereby reducing the power delivered.

The third and most important consideration is machine friction, and this generally limits the compression in practice. When the compression is too high, it can generally be detected in the cab, as the locomotive will jig, and ride badly at high speeds, and the effect on the rods and other running gear will be disastrous if this condition is allowed to continue. If we compare fig. 1 and 4 we find that the closure takes place at 76% of the stroke for the passenger locomotive in running position; with the freight locomotive running at the same cut off the closure takes place at 73%, but if we eliminate the exhaust clearance on the passenger locomotive we shall advance the closure point from 76% to 68% of the stroke. This goes to show how much the closure point is affected by the amount of exhaust clearance. For my own part I do not think the actual closure point is of very much importance, but that the exhaust port opening has a great deal more influence on the compression than the actual position of the closure point. I contend that if we pay proper attention to the exhaust port opening, the closure point will take care of itself.

There is no purely mathematical means of determining the most desirable exhaust port opening, and this, like so many other problems in locomotive work, has had to be determined by practical experiments. It is here that we find the chief difference between passenger and freight locomotive setting, and, still referring to figs. 1 and 4, we see that the maximum exhaust port opening in running position for the passenger locomotive is just over 1⅝ in., whereas that of the freight locomotive is just over 1 9/16 in., when running at 50% cut off, while if we notch up the freight locomotive to the same cut off as the passenger locomotive we have a maximum exhaust port opening of only 1¼ in. This maximum port opening is only maintained for a few inches of the stroke, and it is easy to understand that when this port opening begins to narrow down it will form quite a choke for the exhaust, at a high piston speed, and will build up quite a little compression before the closure point is reached.

We all realize that a locomotive exhaust has to be choked to a certain extent, to obtain a high velocity jet up the stack, which will induce a proper draft through the grates, but this choking should be done by the exhaust pipe tip and not by the valve. Any choking which is effected by a correct exhaust pipe tip can build up but very little back pressure in the cylinder, whereas the throttling of the exhaust by the valve builds up considerable back pressure, and its effect on the draft is only detrimental. The area of the bore of the exhaust pipe tip on the passenger locomotive under consideration is about 23 sq. in., and on the freight locomotive 29 sq. in., and the valve displacement necessary to give a port opening equal to the area of the tip will be approximately 11/16 in. for the Pacific locomotive, and ⅞ in. for the mikado. This 11/16 in. port opening you can see from the diagram is maintained for 53% of the stroke on the Pacific locomotive, but on the mikado the ⅞ in. port opening is only maintained for 36% of the stroke when notched up to the same cut off as the Pacific. When the mikado is running at a 50% cut off, which is approximately her running position, the ⅞ in. exhaust port opening is maintained for 58% of the stroke, which compares favorably with the Pacific. I think that this gives us the chief reason why the Pacific setting is found to be more suitable for high speeds and short cut offs, while the mikado setting is better on the slower speeds and long cut offs.

We will now sum up the chief differences between passenger and freight locomotive settings, and as far as possible the reasons for the variation. The passenger locomotive has a greater lead, which gives an unrestricted supply of steam to the cylinder at the beginning of the stroke, and reduces the wire-drawing of the steam at high piston speeds. It has also the effect of increasing the exhaust port opening, which we will at once realize when we consider that the exhaust port opening at the end of the stroke must always be equal to the sum of the steam lap, plus the lead, plus the exhaust clearance, so that the greater any of these three properties are, the greater by that amount is the exhaust port opening at the end of the stroke. The freight locomotive has a smaller lead, in order to get a slightly later cut off, which will increase the