by .04 inch the machine worked very freely. A further increase of the lap produced a decrease in the efficiency, even when working in full gear.

A still more remarkable result was first obtained in 1880 on a standard freight locomotives which, at .03 cut off, and with Allen valve, had a linear lead of from .018 to .03 inch, and in spite of the remarkable increase of efficiency it did not exceed in any of the principal dimensions those of the old freight engines, although it did burn somewhat more coal than they did. In this case the outside lap was increased about .09 inch, and since that time has done better work than the standard locomotives.

These results gave occasion to test the valve motions of all of the old passenger and freight locomotives on the Hanover railways. In many cases the lead was found to have been .08 inch, the decrease of which, according to the use of valve necessary, being from .01 inch to .03 inch for plain valves, has invariably made an improvement in the working of the engine.

It is difficult to determine the most suitable dimensions for the width of the lead opening in the valve. It passes without further comment, that work will do no assistance, since they do not mark the forward motion of the neighborhood of the dead points, or the internal frictional resistance of the machine. These mistakes are frequently made through an imperfect understanding of the case, since good admission lines can always be obtained by increasing the lead. As illustrating this statement it may be said that the first standard freight locomotive with an Allen valve and a large lead gave faulty admission lines, while the opposite arrangement of locomotives with the common valves gave cards with the admission line falling off very rapidly.

The inadequacy of the indicator lines to furnish sufficient data for the determination of a satisfactory valve motion must be taken into account in the answering of the second portion of the question. It is, therefore, necessary to guard against accepting an indicator card as an evidence of the good action of the steam and the satisfactory operation of the valve motion. In this matter we must rely upon practical investigation alone in order to obtain trustworthy information.

That the width of the lead opening is a matter of very great importance will be clear, if we consider, that, as it is increased, the lead angle increases at the same time, and the entering stream of steam will also be increased in two directions.

In Fig. 1 the valve motion of the standard freight locomotive is shown in twice its natural size for a cut-off as one-quarter stroke, in the valve circle II, for an outside lap of .08 and .06 inch, and in II, for a lap of .05 and a lead of .08 inch. We see that the angle of opening BOD in case I, is twice as much as it is in case II. The triangle enclosed by the lap circle, the valve circle and the line ODB, which we may call the lead surface, is at least four times as large in case I, as in case II. We must then acknowledge that the action of the lead of the entering steam varies almost as the square of its width. Hence its very marked importance.

In a further consideration of Fig. 1, it is necessary that the following points should be taken into account in order to correctly understand it. For a given outside lap, the valve circle is definitely fixed by the lead, the intersection with AO, the point of cut-off in the line ON, and the center O, on the principle of three points determining a circle. The lead circle used in the making of this figure is the point of cut-off in the circle of steam distribution is determined for every point of cut-off, as has also been shown by Richter. As the link motion must be so designed as to produce this valve, the lead is an important factor. From a comparison of the two valve circle I and II, all of the variations in the action of the steam can be deduced thereby. From further trouble. By diminishing the lead opening to that shown in II, the following changes are made in the original valve motion I: (1) The maximum opening in the admission line is somewhat lessened; the cut-off at ON, takes place somewhat more slowly. (2) The expansion will be prolonged from b to b', since the