so as to describe a looped curve. The nature of this devintion will become very evident if we suppose the parallel motion to be altogether detached from the piston-rod, and the motion of the parallel bar and link carried to its extreme, as in the following figures, 154, 155. A pencil being used to trace the motion of the middle point, *p* will describe, not a straight line, but the curve *p x y.* When we carry the rods up to the position represented in the first of the following figures, where the bar *g s* comes into the straight line with the link *g g,* the point *p* deviates from the straight line by a quantity equal to *p',* and this is reversed in the opposite extreme. In the next figure the deviation is much greater when the link *g g* comes into the same line with the other bar *g* s, and is also reversed in the position at the bottom of the figure. By the time the links have been returned to their primitive position, they have described the curve

It is important to diminish the amount of this deviation, which increases more rapidly than the square of the length of the stroke. Having ascertained the amount of greatest deviation at the end of the stroke, and also the amount at ½th part of the stroke from the middle, bring the centres ***s*** and *s* each nearer to the other by a quantity equal to the deviation at the said 8th part, and the amount of the greatest deviation will now be reduced to less than one quarter of its former amount : the curve will now become a line of the sixth (eighth?) order.

The parallel motion of one point having thus been se cured, it is easy to transfer it to any other point. This is most commonly done by a jointed parallelogram. Thus, to transfer it to a point in connexion with *s g* prolonged

to *t*, (figs. 158 to 158) take a second link *tq,* equal to *g g,* and a second bar, called the parallel bar *g q,* equal to *g t,* the corner *q* of the parallelogram will give a motion *t q*

similar to *p.* Figs. 159, 160, show the parallel motion transferred to a point still farther from the original point.

Another form of Mr Watt's invention consists in placing two bars in the same direction, with such a difference in their length, that the excess of the continuance of the one above the other may afford the means of compensation. Suppose that the point *p*, fig. 161, is to be guided to move in the straight line *p g g’ ; s s'* are pointe on the same side of the required direction of motion, and *s g* ***s'*** *g'* are the differential bars connected by a link *g, g,*

which is prolonged to *p.* The dotted Iines of the figure show the bars in different positions. The line described by the point *p* is not a straight line, but a curve, like figs. 154, 155. The motion of the point *p* may be transferred to a distance, as in the former instance, by a jointed parallelogram *g p t q,* fig. 162. All these parallel motions may be inverted, and, indeed, generally are inverted in steamboat engines. For practical examples of them, the reader may consult the plates.

All these motions are imperfect; that is to say, the motion of the end of the piston-rod does not take place in a perfectly straight line, but possesses high curvature. Various plans have, from time to time, been adopted for the purpose of remedying the evil. In American steam engines Watt's parallel motion has been to a great extent abandoned, because in them long strokes and long cranks are preferred ; and in such cases the deviations of the point *p,* that is to say, of the piston-rod, from a straight line, become excessive. Watt and his assistants and followers were perfectly aware of this, and hence were led to construct beams, and connecting-rods, and parallel motions, of *very great length,* so as to diminish the evil as far as possible. This has, of course, the effect of rendering the whole engine both bulky and expensive, and is, therefore, in many cases inexpedient.

The American engineers, therefore, use the sliding parallel motion ; that is, they have substituted for the radius bars of the parallel motion of Mr Watt, a sliding bar or groove in which the top of the piston-rod is guided.

The head of the piston-rod *p,* figs. 163,

164, is enclosed between two flat surfaces, or between two parallel iron bars, which are kept in the vertical position by means of stiff framing: on these it slides, or to diminish the friction a wheel may be added ; but there are reasons why this wheel does not in practice work very well, and the plain slide is therefore preferred.

In fig. 163 we have represented this motion as applied to an engine of the simplest form, and in fig. 164 to a beam engine.

Another species of parallel motion was, we think, first adopted in America, but it has also been used in this country. It is the engine with vibrating pillar.