cylinders are made to act on cranks at right angles to each other.

The whole of this calculation is summed up in the following formula:

Let *r* be the radius of each crank, *x* the effective leverage of one,

.∙. √r2—*2* is the effective leverage of the other, and *x* + *√r2—a2* the sum of the pressures, from which we obtain, by differentiating

*r — √r2—x2* in the case of a maximum, and when *x* = 0, the sum *x* + √r2—*x2* becomes = r

or when *√r2—x2* = 0, .*x* + *√r2—x2* becomes *— r* and when *x =* *√r2—x2, √r2—x2* becomes= 2*r/√2r =* 1.411

Hence the point of greatest pressure is at 45° from the minimum, and the minimum sums at the termination of each quadrant, the maximum being to the minimum as the square root of 2 to unity.

It is obvious then, in conclusion, that with two engines the variation above the mean, amounts to about 12,6— 141 = 15 in 126, or about eleven per cent, and that the decrease below the mean amounts to twenty percent.

It is a matter of some difficulty to decide at what angle the cranks should be placed in a double engine, so as to give the best effect. If we place them at a greater angle than 90° apart, the minima become small, and the maxima, however, are by no means sudden. If we place them at a less angle, the maxima become excessive ; and although the minima be larger, the maxima are also larger. The following diagrams, 137, 138, show the effect of these two methods.

When a lever intervenes between the crank-rod and the piston-rod, new irregularities are introduced. The variation in the direction of the connecting link, and in the position of the lever-ends from a straight line, introduces modifications of these effects of a serious nature, hut not of a large amount. It is worthy the attention of practical men to consider these variations, and the manner in which they affect the uniformity of the pressure. They affect it by way of increase at the beginning and end of the stroke. By proper arrangements these very obliquities may he rendered very considerable improvements in the working of the engine. It should also he observed that the stroke of the piston and crank will not remain of the same length.

The agency of the crank in transmitting a force parallel to the piton rod has been repre­sented by the curve of sines, as in fig.l39.

But if we represent, in a similar way, the pressures produced by the obiquity of the crank rod, we shall find the form become that given in the following figures.

Fig. 140 represents the variation of pressuro with a crank-rod of four times the length of the crank, fig. 141 with a crank-rod of double the length of the crank, and fig. 142 with a crank-rod equal to the length of the crank.

It is obvions, that with the shortening of the crank rod, the irregularity of the motion becomes very great. Two maxima rapidly succeed each other, and these are wide apart from the next pair. Thus two violent pressures succeed at a short interval, and a long pause intervenes, when the force is very small.

By the same system of curves we may proceed to ex amine the pneumatic equalizer of Mr Buckle. Let the rotative pressure of the crank be again represented, as for­merly, by the curve in fig. 143. And let the rotative

pressure of the pneumatic crank of the equalizer be re presented by the curve in fig. 144, lying on alternate sides of the axis, so as to show the alternate coincidence with, or opposition to, the action of the steam-crank. Then if we place the two axes as in fig. 145, the lines between the two curves will represent the sums of the pressures ; and if we set off these intercepted parts in a third curve, we shall get the line representing the variation of the resulting force, corresponding to the sums and differences of the former ordinates. The values of these are given in columns of figures on the right through one quadrant. The mean value 03 is in this case exceeded by 19 per cent, and is receded from below by nearly 20 per cent. The deviation from the mean pressure is not, therefore, greater than 20 per cent, and the equalization produced by Mr Buckle’s pneumatic equalizer is as sufficient as a pair of engines, and much less complicated and expensive.

Still, however, it is to he noticed, that as there is a variation of force amounting to about 20 per cent above or below the mean, with a pair of engines as well as with the pneumatic reservoir of power, it is obvious that the combination of a flywheel with either of these systems of arrangement, would be required to obtain the nearest possible approximation to uniformity in cases of delicacy.