the nosing from unbalanced weights was not noticeable, and in a paper before the Northwest Railway Club, in 1896, I advocated a rule in which the unbalanced weight was increased in proportion to the length of the engine as well as to its weight. This rule was defective, as it increased the longitudinal vibrations on a long engine as compared to a shorter one of equal weight, and as the longitudinal vibrations are those which render an engine rough riding, it could not, and no rule could increase the unbalanced weight beyond a certain amount without being objectionable.

It is true that engines balanced by it rode satisfactorily, but that was because it started with a short engine with $\frac{1}{400}$ of the weight unbalanced, and on the longest engines it was applied to, did not increase the unbalanced weight beyond $\frac{1}{360}$, which is an amount that does not, as a rule, lead to criticism by the men.

Although this rule was not of much practical value, it recognized one point, namely, that the nosing motion was not as important as the longitudinal, and when investigating the counterbalancing of some engines on the Canadian Pacific, in which the counterbalances were off-set so as to increase the longitudinal, and decrease the nosing movement, it occurred to me that by allowing an increase in the nosing movement, a decrease in the amount of overbalance could be obtained without increasing the longitudinal movements.

This can be done by means of off-set counterbalance weights, but as they have a serious objection, the same result can be obtained by means of supplementary counterbalance weights placed at right angles to the cranks. This arrangement is shown on Fig. 5, S_1, S_2, indicating the supplementary counterbalances and the arrows the direction of the forces.

Neglecting the difference in the distances, centre to centre, of the balance weights and the pistons, which it is not necessary to consider here, it will be seen that the forces at O_2 and S_1 both tend to drive the engine forwards as against that of P_2 driving it backwards; in place of a force $P_2—O_2$ driving it backward as in Fig. 4, the force is, therefore, reduced to $P_2—(O_2 + S_1)$ on the other hand, the force $P_2—O_2$ still tends to throw the front of the engine to the right, and it is assisted by S_1.

The net result therefore is, an engine that is balanced longitudinally as an engine would be with an overbalance $O_2 + S_1$, and balanced transversely as though its overbalance were $O_2—S_1$. To put this into figures, suppose the engine weighs 160,000 lbs., and the reciprocating parts weigh 1,300 lbs. a side; the permissible unbalanced weight at $\frac{1}{400}$ of the weight is 400 lbs., leaving 900 lbs. to be balanced, or 300 lbs. per wheel, if the engine has six drivers; if the weight per wheel is 20,000 lbs., this overbalance is 1.5 per cent. of the weight on the wheel, and the variation in pressure at the maximum speed is 12,000 lbs. or 60 per cent.

This would not be an unusual case, in fact it would be an ordinarily well-balanced engine. Now, if we place a supplementary balance weight of 100 lbs. on the opposite wheel, and reduce the overbalance to 200 lbs., this 200 lbs., and the 100 lbs. from the other wheel, make up the 300 lbs. to balance the engine longitudinally, but for transverse balance the 100 lbs. has to be deducted from the 200 lbs. overbalance, so that only 100 lbs. is balanced in each wheel, or 300 lbs. altogether.

Taking 300 from 1,300, leaves 1,000 lbs. unbalanced transversely, or $\frac{1}{160}$ of the weight, and we, therefore, have an engine that longitudinally has $\frac{1}{400}$ of its weight unbalanced, but transversely $\frac{1}{160}$ unbalanced. The overbalance has been reduced from 300 to 200, but the reduction in the effect on the track is not quite as great as this; the greatest effect of S_2 and O_2 is not when O_2 is vertical, but it equals $\sqrt[2]{(O^2_2 + S^2_2)}$ or, for the two weights in question 222 lbs., a reduction of 78 lbs., or 3,120 lbs. at the maximum speed.

I am not entirely prepared to say how far this system can be carried, but from the experiments so far, it would appear that an engine having $\frac{1}{400}$ of its weight unbalanced longitudinally, and entirely unbalanced transversely, is entirely satisfactory as far as its riding qualities are concerned. This would mean that the supplementary balance was equal to the overbalance, and in that case the effect on the track would be 71 per cent. of that of an ordinary overbalance giving the same longitudinal effect, and this reduction can be accomplished without detriment to the ordinary qualities of the engine, or without introducing any objectionable troubles.

It is true that the nosing must be prevented by the pres-

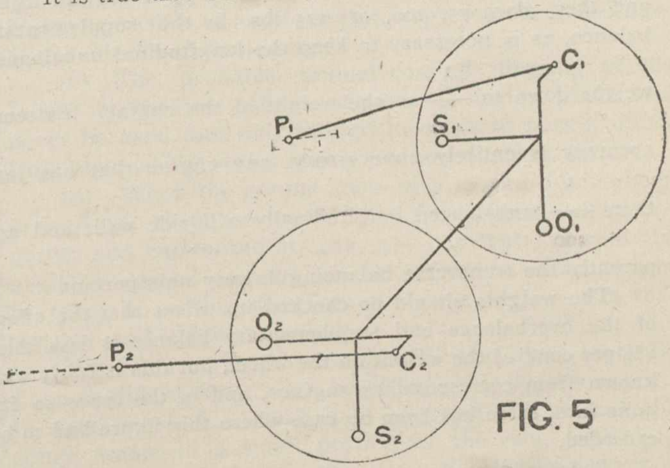

FIG. 5

sure on the hubs of the wheels, but against this, it must be remembered, that when balance weights are distributed amongst three or four wheels that the effect of the overbalance on the boxes of all except the main wheels is just the same as it is on the track, and that the steadying effect on the engine is obtained at the expense of wear in the boxes. The wheel base on an engine is so long, compared to the distance from the centre of the engine to the centre of the cylinder, that a very small pressure on the hub is able to overcome a nosing motion much better than a balance weight, and probably with less wear.

We are not, however, leaving engines entirely unbalanced transversely except as an experiment, but are leaving from $\frac{1}{100}$ to $\frac{1}{150}$ of the weight unbalanced transversely, and $\frac{1}{400}$ unbalanced longitudinally with extremely satisfactory results; one passenger engine has been entirely balanced longitudinally and entirely unbalanced transversely. It is reported to be a "perfect riding engine," and its balance is exactly the