DISCUSSION.

Mr. Norman Selfe, in opening the discussion, said:—

The author had certainly brought before the members a very important and interesting subject—one which should be of the greatest value to our junior members because the literature relating to it was widely scattered, and so far as he knew there was no complete handbook in existence on such matters. In view of the extended application of balancing to marine engines and to electric motors and other land engines, it was rather a pity that the title of the author's paper was so restricted as to be limited to inside cylinder locomotives, because, as it was fairly extensive, it left but little room for saying more within such narrow lines, and the day to see an outside cylinder was not yet. As an illustration of the computations which were involved in designing the balancing of an inside cylinder engine on the commonly accepted system, the paper was very complete. The ordinary engineer should have no difficulty in following the figures given and in understanding the application of the principles involved to other classes of engines. As regarded the question of balancing the revolving weights in an engine there was not much to be said. Perhaps in order to make it easier to read, it would have been better to have started with weights that would have worked out without involving fractions, as they made the equations look more complex. With regard to the question of balancing the reciprocating weights, however, it was certain that there was much which could be said arising out of the paper; in fact, it would provide material for another paper altogether. In Mr. Scoular's reply to the discussion it would be very interesting if we could have his opinion of a system introduced by Mr. Stroudley, of the L. and B. Railway, some years back. In this arrangement the inside and outside cranks of coupled engines were made co-incident with, instead of opposite to, one another, and thus required a great deal heavier balance

weights than in the ordinary system, but with the advantage that the wear and tear of driving axle bearings were said to be reduced. In speaking of the blow on the rail given by a balance weight in the wheels, the author said: "It should be borne in mind that it was given gradually and more especially with lune or crescent shaped weights." He also said: "It was doubtful if any locomotive engineers balance more than two-thirds of the reciprocating weights as a maximum." It was of course a fact that many engines were now made with the balance weights lune shaped, instead of just being square blocks between the arms of the wheels, and it was highly probable that the lune form was better in some respects for the wheel; but it would be most interesting if the author could show us how it did affect the rail surface, seeing that the centre of gravity of the weights, whatever their outline form, must be on the same radial line in either case. The author might have pointed out that the balancing of the reciprocating parts of engines by means of revolving weights at all was absolutely wrong in principle—merely setting up one evil against another one; but that the locomotive as a whole being only a series of compromises, owing to the many special conditions involved, which did not apply to fixed and marine engines, it was used because the only method thought of by locomotive engineers up to a recent date had been the addition of more weight to the counterbalances in the wheels which were required to neutralise the effect of the revolving parts. When a stationary engine installation of, say, a 1000 horse power, with its immense engine and boiler house, foundations, chimney shaft, and massive machinery, was compared with a locomotive of the same power, which latter was restricted in height and width within very narrow limits, was required to burn its fuel on one tenth of the grate surface given to the land boiler, and to do its work while running over rails at 60 miles an hour, in all conditions of wind, rain and dust storm, then after such comparison, it would be realised that the locomotive designer had anything but a free hand, and that the continuous demands which had been made upon him year after year for more and more tractive power, had prevented the more perfect balancing of the recip-

rocating parts of his engine from receiving that attention which it might otherwise have done. This was the more so, because the compromise made by putting the additional weight in the wheels where its effect was to pound the rail bed out of shape, had answered so far fairly well for the engine, and generally another engineer without any interest in the engine, per se, had had to put the road, which the engine knocked to pieces, in order again. With marine engines, however, there had on the other hand been of late years a most extraordinary development in the counterbalancing of the reciprocating parts; and also in the reduction of vibration, which vibration at one time threatened the destruction of vessels at certain speeds. Many papers, by such authorities as Macfarlane Gray, A. F. Yarrow, Schlick and others were distributed over the technical literature of the past few years. Experimental apparatus had been constructed to test a system of bob weights which had been introduced; the relative position of the cranks had been made the subject of special investigation, that now a system had so developed that a perfection was attained which at one time was deemed impossible. It would almost seem that the steam locomotive had now reached its practical limit, for power and speed, in the great quadruple cylinder compound and double bogie engines recently built on the continent of Europe; and it might therefore be possible for locomotive engineers to return to the duplex principle first introduced on the Australian State railways by Mr. Haswell, and shown at the Great London Exhibition in the year 1862. These engines had two outside cylinders on each side, with double cranks on the driving wheels, and their pistons moving in opposite directions. There was with them no setting up of a series of additional disturbing forces in order to partly neutralise those already existing, but the separate reciprocating parts, as well as the revolving parts, mutually balanced one another. No doubt there was still room for improvement in these engines, besides presenting serious difficulties in the application of the system to coupled wheels; and locomotive superintendents naturally fought shy for a long time of having four engines to keep in order instead of only two; but the principle in-

volved in the duplex system was a correct one—the mor so that the contrary and opposing forces were so nearly in the same plane, merely separated by the length of a crank pin. The importance of such a condition of things had been twice forcibly brought home to the writer with vertical saw-frames—where a very heavy sash, driven at a high speed from a crank, was counterbalanced by a weight in the fly wheel between the shaft bearings, these machines were always carrying away their main bearings or breaking the shaft; and one had been thrown out as a failure. He took all the weights out of the fly wheel and removed the crank, substituting for the latter a counterbalanced disc, with the result that they had now worked satisfactorily for years. Duplex sawframes having two sashes with their cranks 180 deg. were balanced in themselves and worked well, and their success no doubt led may engine builders of late years to make pairs of engines with their cranks opposite to one another in the same way. He had often wondered why "Bob" weights, as proposed for marine work, had not been tried on locomotives where there seemed to be no obstacle to their introduction. It would also be interesting to hear from Mr. Scoular whether the cranks themselves were ever extended for balancs, as in land and marine engines. It seemed possible that many of the troubles which occurred to a certain class of locomotive might be modified by the addition of another pair of secondary guide bars on each side, and the connection of sliding weights to the outer crank pins. As a matter of fact, this had recently been accomplished in Europe (where every opportunity for the improvement of the locmotive seemed to be availed of) on a German express engine. If this discussion was rather outside the limits of this paper, he hoped he would not decline to follow it, because it arose out of the very interesting questions he had opened up. If it be possible in the near future to construct a steam turbine with the full efficacy of Mr. Parsons' invention, and, with the additional qualification of reversing, then we might expect to see the end of the old locomotive, a machine that had done so much since its first practical form by Trevithick and others, and in the past half century especially to open up the ends of

the earth to the people thereof. Direct rotary motion successfully applied to a locomotive would perhaps mean the doubling of the life of the permanent way that carried it.

Mr. Scoular, in his reply, ably touched upon the points referred to, and promised in a future paper to treat the balancing as applied to an outside cylinder.