curve, and in the other almost a straight line. With regard to the difference in the consumption of coal, he thought the Appendix to the Paper clearly showed the opinions expressed by the Authors on that point to be well founded. It had been suggested that it would be better to drive the drums of the instruments from the axle of the carriage or locomotive, in order to more readily locate the faults. Undoubtedly they would get a better idea of the position of any particular disturbance if such a course were adopted; but he had always understood that Professor Milne regarded it as a great feature in his apparatus that it was portable, and capable of being used in any carriage or on any locomotive without special fixing. When once they came to drive the drums from the axle, it was necessary to have a specially constructed carriage, and the nature of the instrument was entirely altered. Mr. Mills.

Correspondence.

Mr. JOHN A. F. ASPINALL took exception to the statement of the Authors that the economy of fuel was due to balancing; more probably it was to be ascribed to the mere presence of an inspector or investigator watching the experiments. Perhaps 10 per cent. of the fuel could be saved on any of the best locomotive engines in England, without spending a farthing on additional mechanism, by sending an inspector to travel on the engine for a month. Knowing they were watched, the men would take more care. The wear of tires was affected by so many different things that it was most unwise to deduce any argument from so small a number as the Authors had tried. Mr. Aspinall.

Mr. D. K. CLARK could confirm the opinion of the writers of the Paper, that a proper equilibration of the engine was not only conducive to economy of maintenance, but was beneficial also in reducing the resistance on the rails at high speeds, and economising fuel. Mr. Le Chatelier, about forty-one years ago, experimented with an outside-cylinder goods locomotive on the Orleans railway. The engine had originally been unbalanced, and vibrated when running with considerable oscillatory movement. The wheels were afterwards fitted with counterweights so distributed as to effectually extinguish the oscillation. The following average quantities of fuel were consumed during three months, the engine Mr. Clark.

Mr. Clark. being in each case under the charge of the same driver, and doing the same kind of work:—

	Coke per Mile. Lbs.	
1848. December . .	49·5	Without counterweights.
1849. January . .	50·3	
„ February . .	42·3	Average of twelve trips, of which ten only were made with counterweights.

This showed an economy of about 8 lbs. of coke per mile, or 15 per cent. Mr. Clark, in 1854, designed some outside-cylinder locomotives for the Great North of Scotland Railway, with a complete system of balancing. They ran at all speeds with perfect steadiness, and he believed that they were the first outside-cylinder engines so fitted in this country. In his Paper on locomotives, read before the Institution in 1856,[1] Mr. Clark gave the results of an experiment in balancing the "Canute" single outside-cylinder express engine, which had previously been fitted with balance-weights of 85 lbs., one to each driving-wheel. These were replaced by a weight of 186 lbs. for each wheel, balancing the whole mass at the crank-pins. The engine ran so much more steadily and freely with this alteration as to take the engine-driver by surprise, for on the first day of trial after the new weights were applied, the train considerably overshot the stopping-stations. The economy of fuel thus effected was at least 10 per cent. This trial was made on the London and South-Western Railway. The effective equilibration of locomotives, whether with inside-cylinders or outside-cylinders, was now thoroughly understood.

Mr. Cowper. Mr. E. A. Cowper said that apparatus of the kind described in the Paper was calculated to assist railway companies and managers in making improvements in the running of engines and carriages. Some years ago he had given a good deal of attention to the subject, and his first idea was to have a fair-sized cannon ball hung in the centre of a square box by a spring above, and a spring below, and four other springs, north, south, east, and west. Then, to prevent extreme and continued oscillations there must be resistances or frictions introduced, say in the form of "cataracts," that would give resistance and no recoil. The motions of the ball were to be communicated by means of levers to pencils, so that one pencil should record the vertical motion, one the side motion, and one the fore-and-aft motion of a carriage. A very good form of apparatus (modified by "cataracts") would be the "seismograph," that he

[1] Minutes of Proceedings Inst. C.E., vol. xvi. p. 18.

submitted to the committee on Earth Tremors at the British Association, though the atmospheric support for the weight, for vertical motion, would hardly be necessary in the case of railway carriages. Of course, in testing a line of railway, the instrument should first be tried several times over a good piece of road, to establish, so to speak, the pattern of vibrations on a good road; then, with the same carriage and instrument, the doubtful road should be run over. And *vice versâ*, in testing engines or carriages, they should be compared with a good sample, and always over the same piece of road, the instrument occupying always a corresponding position in a train. He trusted railway engineers would institute experiments on their lines, in the interests of the public. Mr. Cowper.

Mr. GEORGE HODGKINSON desired to ask if any, and what notice was taken of atmospheric influences likely to bear on the result at the time of the trials and experiments; such as the velocity of the wind, and its direction in relation to the motion of the train, the state of the weather at the time, and whether the diagrams were taken after a long spell of wet, or in fine weather. The fact of being in a cutting or on a bank, although having a certain effect on any one particular diagram, would, with an instrument which would indicate the locality, give comparative results only, both as to the state of the permanent way and the working of the locomotives. A systematic gauging of the wind would assist much in arriving at a satisfactory conclusion, and his mentioning the "Tay Bridge Disaster," would, he thought, give force to his argument. Reference was also made to "swaying" locomotives in the Paper; this also would be greatly affected by the direction and velocity of the wind. Mr. Hodgkinson.

Mr. J. C. PARK thought great credit was due to the Authors for having devised an apparatus so simple and sensitive, and yet so reliable in its action. The instrument would, no doubt, record faithfully all inequalities in the rolling-stock due to imperfections of the springs, as well as any defects in the permanent way. With these diagrams the permanent-way engineer would be able to justify himself when the condition of the road was questioned by other departments. With regard to the unsteady running of locomotives, although the present method of balancing the disturbing forces by calculation and verifying the same by running the engine suspended in slings gave satisfactory results in practice, this instrument would be useful in checking the correctness of the old method of balancing at different speeds. Again, the difficulty in determining the proper strength of springs for carriages of new construction and large carrying capacity would be more readily Mr. Park.

Mr. Park. overcome with the help of the vibration recorder. As to its value for traffic department purposes, he was of opinion that it would only be useful for experiments.

Prof. Perry. Professor PERRY regretted his unavoidable absence from the discussion on his friend's Paper, but he was glad to think that Mr. Bracebridge Mills had added so much valuable matter to the information given by the Authors, and had also been able to answer the inquiries made during the discussion. He thought that the significance of the new departure had been greatly neglected in the discussion. Here was a small instrument which could be carried in any part of a train or placed on any part of a bridge, and it would record with wonderful exactness the actual motion. Hitherto engineers had depended on their illusory sensations, or on records of the relative motions of different parts of a structure, made by most expensive and large contrivances which could not be altered in position. Sir Frederick Bramwell had referred to Mr. Payne's pedometer as an anticipation of the Author's vertical vibrator, and in the same way it might be mentioned that the Author's fore-and-aft and lateral vibrators were pendulums and that pendulums had been used as seismoscopes for many years. This was all quite true, but as Sir Frederick admitted, there was a difference between making a record of a jolt, and recording accurately the motion during a jolt. The instruments exhibited were not mere jolt indicators or counters; in every detail they had been worked out on scientific principles so that there should be packed in a small box one or more recording bodies, whose own vibrational periods should be very slow, so that the pencils would remain nearly at rest whilst the paper moved underneath them with the motions to be recorded. Mr. Dawson had referred to a ball controlled by springs of which he had had experience, and from that experience he seemed rather to doubt the usefulness of Milne's vibration recorder. Professor Perry ventured to question any deductions made from Mr. Dawson's experiments, or from experiments with any apparatus which could set up vibrations of its own. It could not be too well remembered that this instrument was the outcome of fifteen years' expensive experimenting with all kinds of vibrating bodies used in Japan as seismoscopes. An ordinary vibrating body would record a jolt, but the record would be large or small, according to all sorts of chance circumstances. The problem solved by the present instrument was the recording to scale of all the vibratory motions. If engineers were satisfied that this was the case, there could be no question as to its usefulness. The remarks made by Mr. Aldridge and others showed that in modern rail-

Prof. Perry.

way carriages the motions of different parts differed very greatly, and surely, to any one accustomed to engineering calculations, it must be evident that a complete knowledge of these motions was absolutely necessary if they were ever to escape from a mere rule-of-thumb method of design. At present they only assumed that they knew the forces to which different parts of carriages were subjected. Any one who looked at these instruments making their records would see that his own sensations were quite unreliable in giving evidence of the motion of the carriage. He was glad to see that Mr. Aldridge welcomed the instrument as a thing indispensable to the carriage builder. As a detail that would have been improved long ago by the use of the instrument, he might mention the springs, which were now made usually of the commonest Bessemer steel, although it was well known that good spring steel was six times better for such a purpose, a cubic inch of spring steel having six times the resilience of the material of which carriage springs were now usually made. Of course the instrument gave different kinds of records when placed in the middle of a Pullman car or at one end; but in either position, the fore-and-aft record showed in very plain writing the balance or want of balance of the engine; and the up and down record showed in equally plain writing the state of the permanent way. In either case the engineer got information about his engine and the permanent way, and if, besides this information, the largeness or smallness of the writing gave him other information more interesting to carriage builders, he would not find this an objection. If, however, he was in doubt, let him keep the instrument always in the same relative position in the carriages. Mr. Moir seemed to doubt the usefulness of the instrument until a specimen could be placed in a guard's van, making a record every journey, the record giving distances as well as times, and no hitches being possible in its working. Although Professor Perry agreed with Mr. Moir that the vibration-recorder might be improved up to such perfection as this, he ventured to think that not only in its present state, but even in the state in which it was two years ago, when he first tested it, the instrument was a useful one, for which there was a demand among engineers, and any engineer who knew his line thoroughly must be delighted to watch the record a-making at his side. A stranger was not astonished to see a great up-and-down motion on a bridge, nor even the great sidelong motion which one was sorry to find recorded on some bridges in London; but he might be astonished to discover on every journey, through a particular cutting, at a

Prof. Perry. particular place, a considerable up-and-down motion. But the engineer of the line knew, or ought to know quite well, what the record indicated. It was his opinion that after a little companionship with one of these machines on his journeys, an engineer would be able to read its writings with very much clearer eyes, and that even in the guard's van, making its locked-up diagram, it would not have a more useful function than it might have had two years ago at the side of the engineer. Furthermore, he did not think that Mr. Moir, or the Authors of the Paper, could tell to what uses such instruments would be put. They recorded actual motions, and therefore in the construction of roofs, bridges, and ships, and all large structures, they would be useful. Of smaller size, they might be of great assistance in the balancing of machinery in general. Until seismographs on similar principles were invented by Professors Ewing and Milne, everybody made the most absurd assumptions as to the motions of the earth and of buildings during an earthquake; whereas now there was certainty on those points. It seemed to him that certainty as to the nature of vibratory motions was more to be desired at the present time by engineers than almost anything else.

Sir William Thomson. Sir WILLIAM THOMSON said that when Mr. Milne was last in England he explained the instrument invented and worked out by himself and Mr. McDonald for registering the three components of oscillation, or of change of motion, of a railway train, and showed it in action on a railway journey from Largs to Glasgow. Sir William Thomson was much interested in it, and in the principles which had been worked out, as it seemed to him, with great ability, and to a result of great practical utility, in this instrument. He believed that even for an ordinary timekeeper on ordinary goods and passenger trains, the instrument would be very valuable in the economy of railway management. For the all-important engineering questions of balancing and other details of the locomotive, and of the condition of the line in respect to the rails, and the stability or elasticity of their supports, and the character of the roadway itself, especially on bridges, the instrument might be found largely useful.