Correspondence.

Mr. Menges. Mr. C. L. R. E. MENGES observed from the diagrams, *Figs. 23, 24,* and *25*, that the speed of the engine, when running light, was about 7 per cent. above the speed at maximum HP. Now, he thought such variations in speed during the use of the large welder C, *Fig. 22*, would make it at least difficult to use at the same time the small welder A, the more so as the current varied even in a greater ratio than the speed. That might be of no consequence in this temporary installation, but in a workshop all machines should be, of course, quite independent of each other. A 7 per cent. variation in speed was by no means too much for a steam-engine, and especially in such cases as this one, where the power was suddenly thrown off. He should never advise the adoption of a more sensitive, that was a more astatic, governor, for then the engine would certainly hunt. For a like reason, any of the common kind of electric regulators, such as Richardson's, Willans', the Porte-Manville, and others, would be useless; they would hunt or would be too slow. In this application of electricity, which depended upon the heat developed by the current, which was proportional to the square of the current, it was obvious that sudden variations in the speed would have a detrimental effect upon the quality and the quantity of the work. He wished, therefore, to direct the attention of those interested in electric welding to his electric governor.[1] It would exceed the limits of discussion to give here a full description of his method; as, however, many people object to the use of any complicated apparatus in a blacksmith's work, he might mention that his method consisted in a special manner of applying the current in an exceedingly simple apparatus, and that by this method variations in speed might be prevented. This was impossible with all the common kinds of regulators, because their action depended upon the variation in speed. A good regulation in this case gave still another more direct advantage. According to the Paper, pp. 25 and 31, the engine was running light during more than two-thirds of the time to make a weld, and for pieces of more difficult form, this ratio would, of course, be much greater. A reduction in speed of 7 per cent. during more than two-thirds of the time that the

[1] Elektrotechnische Zeitschrift. Berlin, 1887, p. 171; and *The Electrician* vol. xix. p. 482.

engine was at work, would thus give a saving in steam, fuel, wear and tear, &c., which was by no means to be neglected. For large welders he should like to go a step further, by using for each welder a separate steam-dynamo, governed by his method so as to run at 10 per cent., or even more below the normal speed when running light, and to get up to full speed immediately the current was switched on. Mr. Menges.

Professor SILVANUS P. THOMPSON remarked that the Author had so well and so thoroughly explained the methods adopted by the inventor for transforming electric energy, from the condition of small current at high-pressure (or potential) down to the condition of large current at low pressure, that no further explanation of this problem of practical engineering was needed. He had, however, taken the opportunity of making a number of electrical tests upon the apparatus installed at Fanshaw Street, and upon the currents supplied by the generating machine to the welding machine during the operation of welding. In these tests it was desired to measure the amount of power actually supplied electrically to the welding machine. The instruments were, therefore, inserted between the generating apparatus and the welding machines, and did not measure any of the power wasted in the belting, shafting, or bearings of the running plant. Neither did they measure any of the power wasted by magnetic friction, nor by the production of eddy-currents in the moving parts, nor that part of the power which was employed in driving the separate exciting machine, and expended in maintaining the magnetic field of the alternate current generator. The only power measured was that which passed across and entered into the primary wire of the transformer in the welding machine. Such measurements of power supplied electrically were not always easy nor simple in the case where alternate currents were used. For in this case power could not be accurately reckoned by multiplying together the two simple factors of current and potential. The custom, so familiar to all engineers, of calculating mechanical power by multiplying together the two factors, force and speed, had its electrical analogue in the two electrical factors of current and potential (or electric pressure). But engineers knew also that if the force measured were not a force exerted in the same line as the motion that was measured, but at some angle with that motion, the proper factor to employ was not the whole force, but its resolved part along the line of motion. Or, in other words, the product of the apparent values required to be reduced to its true value by being multiplied by the cosine of the angle between the two factors. Electrically, Professor Thompson.

Professor Thompson. a similar distinction had to be observed between the apparent value and the true value of the product, whenever alternating currents were employed. For, in the case of alternating currents, the waves of positive and negative current which resulted from the application in the circuit of alternating electromotive pressures, suffered a retardation of phase, the waves of current coming to their maxima after the waves of electromotive force (or pressure) had passed their respective maxima. The maximum pressure was not acting on the circuit at precisely the same instant as the maximum current was flowing; hence the apparent product obtained by multiplying together the two maximum values would be in excess of the maximum value of the true product; and the product of the two average values would be in excess of the average value of the true product. As in the mechanical problem so in the electrical, the true value was to be obtained from the apparent value by multiplying by the cosine of the angle between them; the angle in the electrical case being the angle of phase of lag of the current; the current being assumed, like the tides, to rise and fall periodically in the manner known as "simple-harmonic." Now, in measuring the power supplied by an alternate-current dynamo to a system of conducting wires, it was clear that if an ampere-meter of suitable type was inserted in the main conductor to measure the current, and if a volt-meter of proper construction was applied across the mains to measure the difference of potential or electric pressure between them, there would still be required a third instrument to measure the angle of phase between the waves of current and the waves of pressure. And, if three such instruments were set up in the system, it would be needful to take three simultaneous readings in order to evaluate the power supplied at any time. But in the case of the operations of welding, which lasted for but a few seconds, and in which by the very nature of things the power was continually increasing or decreasing, it became impracticable to take such sets of readings. Resort must be had to some simpler method, even though it might not be susceptible of so great refinement. It was known that when a transformer of alternate currents was used, the retardation of phase of the currents behind the electromotive forces was at its maximum when the transformer was doing no work; and that on the other hand the retardation became practically zero when the work done by the transformer was at or near its maximum. Hence, it was fair to take, as a sufficient approximation for most purposes, the assumption that the retardation of phase would be small enough to be neglected, whenever power above a certain

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value was being supplied to the transformer. Further it was possible to construct instruments in which the difference of phase between current and pressure was actually taken into account; such an instrument being existent in the watt-meter of the late Sir William Siemens. A watt-meter, specially adapted to the purpose, by having its fine-wire circuit arranged to offer a very large resistance, in proportion to its electric inertia, was therefore employed in the Hoxton tests. The thick wire coil was inserted in the main circuit, and the fine wire coil, augmented by suitable resistance coils, was inserted as a shunt across the mains. With such an apparatus it was possible to obtain four or five readings of power during the operation of a single weld. He was present, and made electric tests, during the eighty weldings conducted for the Author of the Paper. He would, therefore, speak first of these welds. They were all made on $1\frac{1}{8}$-inch wrought-iron; and the power required was found to vary somewhat with the rate at which the operation was conducted. If only moderate power was applied, more time was required to heat up the joint, than if more power was applied. The time during which the current was actually on (not including the re-heating before using the swage) was noted, and the average duration was actually only thirty-two seconds and one-tenth for each weld. The average power supplied electrically during this time (the average being taken for the whole eighty welds) was 13·17 kilo-watts, or 17·5 HP. When the operation was conducted more rapidly the power rose. The last ten welds were made more quickly than the average, their average duration being twenty-eight seconds and a half, and the power applied electrically was 13·34 kilo-watts, or almost exactly 18 HP. But in the first ten welds which were made more slowly, taking on the average thirty-three seconds and seven-tenths, the power supplied was 12·82 kilo-watts, or 17·1 HP. In another individual case a single similar weld conducted in thirty seconds, required 17·01 kilo-watts, or 22·8 HP. In the re-heating of the eighty welds, the average power expended electrically was 15·19 kilo-watts, or a little over 20 HP., for an average duration of twelve seconds and nine-tenths. In welding $\frac{3}{4}$-inch round steel bars the average power employed was 11·4 kilo-watts, or 14·2 HP. for sixteen seconds. In welding some larger wrought-iron bars of rectangular section, about $2\frac{1}{2}$ by $1\frac{1}{8}$-inch in the sides, there was required an average power of 24·98 kilo-watts, or 33·4 HP. for a duration of twenty-eight seconds and a half. He did not think that any proportion could be drawn between cross section and power required for welding, as the main expenditure of energy was due to the

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escape of heat from the surface. More power was required to weld square bars than to weld round bars of equal section and similar material. He had also made some tests upon the electric conductivity of joints thus electrically welded; these showed that the conductivity of joints was scarcely inferior to that of the solid material, if at all. It was to be hoped that the Postal Telegraph Department of the British Government would not be slow to adopt an electric method of welding its line wires instead of using the present comparatively clumsy modes of jointing them. As doubts might arise concerning the safety of such apparatus as the electric welder, he might state that more than once during a welding, he had grasped the two clamps with both hands, and could not feel the slightest sensation. The parts of the machine where the high-pressure circuit came in and went out were amply protected, so that any part of the apparatus might be handled without its giving a shock. Doubtless it might be possible to apply to welding in some similar way the direct electric current instead of the alternating one, though the direct current, whether supplied from dynamo machines or from accumulators would be far less convenient to regulate and control than was the alternating current. One phenomenon of high interest to engineers could be shown in perfection by means of the welding machine; namely, the recalescence of steel. If a steel file was placed in the machine, and gently heated up, a sort of dark wave might be perceived passing over its surface as the critical temperature was reached and surpassed. Then if the file was taken out and allowed to cool, a wave of brighter red light might be noticed to move gently from the ends toward the middle as the critical temperature was again reached during cooling. Lastly, he should like to point out the triply automatic nature of this most ingenious process. Not only was the heat produced just at the place where it was wanted, because the greatest resistance to the electric flow was there; but directly any portion of the metal was heated sufficiently, it flowed aside under the application of pressure, and fresh parts of the joint were brought into the path of the current. As the joint grew more perfect it necessarily conducted better, and more current flowed, so automatically keeping up the heat over the greater area. And not only so, but this action must necessarily take place precisely at that temperature which was needful for welding, simply because so soon as that temperature was reached the softened portions moved aside, and colder portions were brought up to be heated. It was seldom that such advantage could be taken of the facts of nature, rendering them simultaneously *automatic in a single industrial process, the very simplicity of* which attested its intrinsic merit as a great invention. Professor Thompson.

Mr. S. Alfred Varley observed that, as a pioneer in electro-dynamics, he took considerable interest in any electrical advance. He desired to ask whether the Author could state the actual ampere current necessary to weld a given section of iron. The conclusion at which he had arrived from a close study of electro-dynamics now for more than thirty years, was, that what was described as hysteresis was simply attributable to the inertia inherent to all electrical conductors. Inertia was opposed both to the setting up electrical motion and also to the cessation of such electrical motion after it had been set up in a conductor, much in the same way as matter resisted a sudden change from a condition of rest to a state of motion, or from a state of motion to a condition of rest; and, as active magnetism was developed in the conductor in proportion to the inertia, the inertia which conductors opposed might be fairly termed magnetic inertia. This, for the different metals, varied very much in the same way as their respective specific gravities varied; and the magnetic inertia opposed by a conductor was directly as its specific magnetic inertia multiplied by its mass. The specific magnetic inertia of iron was many hundreds, probably many thousands, of times greater than that of any other conductor; that was to say, if the specific inertia or gravity of iron were expressed in terms of magnetic instead of terrestrial gravity, then iron would be by far the densest of all substances, and it was not too much to say, that were it not that iron possessed magnetic inertia in so large a degree relatively to all other conducting matter, there would be neither dynamos nor transformers. When a primary circuit wrapped on an iron core was surrounded by a closed secondary circuit, as in a working transformer, much less magnetic inertia was encountered than if there was no secondary circuit. The action of the secondary circuit resembled very much that of a brattice which, by dividing an air shaft into two sections, enabled two currents of air to travel through the shaft freely in opposite directions to one another at the same time. The iron bar to be welded was interposed in the secondary circuit of the transformer, but outside of it; and, as there was no separate conducting channel surrounding the iron bar, the inertia of the iron to sudden reversals of the direction of the electric motion tended to produce secondary currents in the iron bar itself; in other words, to set up two currents in an opposite direction to one another. What followed was much the same as that which occurred when the Mr. Varley.

Mr. Varley. brattice of a mining shaft was suddenly destroyed; the energy transmitted through the medium of the transformer being unable to develop in the iron two currents in an opposite direction to one another, it had to overcome the magnetic inertia of the iron, and consequently energy became dissipated locally, by developing heat in the iron in a much larger degree than throughout the secondary circuit generally. Transformers were so far self-regulating that they were capable of accommodating themselves in some degree to the conditions that prevailed, and approximately the voltage of the currents developed in the secondary circuit of the transformer was raised as the inertia resistance of the iron bar increased, the amperes becoming correspondingly reduced. The practical outcome was that the heat developed was confined in a greater degree in the weld itself, which it was desired to heat. He considered this a fair analysis of what occurred when a bar of iron was heated by electric alternations, and which physicists seemed to think sufficiently explained by coining the term hysteresis.

Mr. Walker. Mr. SYDNEY F. WALKER, upon the question of the use of the spark, or the electric arc, in electric welding, as against the use of a dead metallic resistance, observed that electrical engineers knew, to their cost, that when a spark passed between any two points, say when a wire was broken, a switch was making faulty contact, or the brushes of a dynamo were badly set, the heat generated was far in excess of that which would be generated when the spark was not present. In fact, apart from the loss of energy which sparking at the brushes of a dynamo entailed, the great importance of reduced sparking was to keep the machine cool, thereby increasing its possible output, as well as its efficiency. It was also well known that the light given out by an arc lamp was generated at the cost of one-tenth of the energy that would be required to produce the same amount of light from a glow-lamp. Now, seeing the large power required for electric welding—50 indicated HP. for the experiments conducted under the superintendence of the Author of the Paper—the question arose, could not the arc be used for welding in place of the dead metallic resistance, since, if it could be used, a 5-HP. plant could be substituted for the 50-HP. one, and be much more within the means of manufacturers generally? And if the cost could be reduced also, might not electric welding be substituted for soldering and brazing in a number of operations? In the construction of dynamos, for instance, and in electric light mains, wires were getting larger and larger, and still no satisfactory method of

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jointing had been discovered equal to the old-fashioned method of soldering or brazing; while the great difficulty of making a good soldered joint between large masses of metal was a matter of common experience. Apart from this, the soldered joint had a higher resistance than the lengths of the two wires or cables to be connected, and certainly higher than a welded joint. He was aware that the dead metallic resistance was far more manageable, and therefore more convenient than the arc, just as the glow-lamp was better than the arc light wherever it could be used. But he suggested, in view of the saving to be effected in cost and on capital account, that since the apparatus would always be in skilled hands, and the arc would only be required for a few seconds at a time, the problem of using the arc for welding was well worth solving. Again, not more power was required with the alternating than with the continuous current to produce a certain heating effect; but it was a question whether the metal to be welded was affected by the fact that the heat appeared to go from within outwards with one form of current, and from outside inwards with the other. If it was not affected, then the balance of convenience would appear to be with the alternating current. The periodicity of the alternations was, however, an important factor in the case. In the cycle of operations which ruled with alternating currents, the metal would have a certain time to cool between the times when the current was at its greatest strength. If this time was very short, so that practically none was allowed the metal for cooling, then the time required for heating a weld with the alternating current would be the same for the same current strength—the maximum current strength, of course—as with the continuous current. But if the alternations were very slow, a larger current must be employed than with the continuous current, or the welding must take a longer time, owing to the time allowed the metal to cool between the times of maximum current. However, any increase of the number of alternations beyond that required to prevent loss by cooling would give rise to waste of power, as it would increase the dead charges on the dynamo and transformer where one was used.