MISCELLANEOUS.

G. Bell and Sons, Ltd.—Buddhist Psychology, C. A. F. Rhys Davids; Montessori Principles and Practice, Prof. E. P. Culverwell, illustrated. *A. and C. Black.*—A First Book of Experimental Science for Girls, Mrs. Jessie White. *W. Blackwood and Sons.*—A History of European Thought in the Nineteenth Century, J. T. Merz, vol. iv. *Constable and Co., Ltd.*—Letters and Recollections of Alexander Agassiz, edited by G. R. Agassiz. *A. C. Fifield.*—The Discovery of the Future, H. G. Wells, new edition. *Macmillan and Co., Ltd.*—Statistics, by the late Sir R. Giffen, K.C.B., F.R.S., written about the years 1898–1900, edited with an introduction by H. Higgs, C.B., with the assistance of G. U. Yule, Studies in Water Supply, Dr. A. C. Houston, illustrated; Land Surveying, Prof. H. Adams, illustrated. *Methuen and Co., Ltd.*—The Book of the Ball: an Account of what it Does and Why (cricket, football, golf, baseball, tennis, lawn tennis, pelota, polo, fives, pallone, rackets, hockey, lacrosse, croquet, bowls, squash, badminton, billiards), A. E. Crawley, illustrated. *John Murray.*—History of the Royal Society of Arts, Sir H. Trueman Wood, illustrated. *T. Fisher Unwin.*—Surface Waves of Sand and Snow, and the Eddies which Produce them, Dr. Vaughan Cornish, illustrated.

THE BRITISH ASSOCIATION AT BIRMINGHAM.

SECTION G.

ENGINEERING.

OPENING ADDRESS BY PROF. GISBERT KAPP, PRESIDENT OF THE SECTION.

ENGINEERING, the subject with which Section G is concerned, covers so wide a field that it has been found convenient to introduce a rough subdivision into the three branches of civil, mechanical, and electrical engineering. By applying any such term to a particular piece of engineering work we do not necessarily exclude the others; we merely characterise a predominant feature. There is often a considerable amount of overlapping between the three branches, and that is especially the case with mechanical and electrical engineering. Sometimes the boundary-line even becomes indistinct, and then it is difficult to say which branch of our science is the predominant feature. Is the equipment of a works with electric power mechanical or electrical engineering? It is both, but not necessarily to the same degree. The mere replacement of a steam engine by an electric motor to drive the main shafting of a works can scarcely be called a piece of electrical engineering; but if special electric appliances are introduced to perform duties which cannot be done, or not done as well, by purely mechanical machinery, then we have electrical engineering in the true sense of the term.

Electricity has invaded almost every branch of our industrial activity, sometimes as a rival to older methods, but often also as a helpmate, stimulating progress all round. Electricity is a "great source of power in nature," and the "art of directing it for the use and convenience of man" belongs to our generation. Yet, like all new things, it has had to fight its way in the face of strenuous opposition—generally an absolutely honest opposition, not in any way traceable to self-interest, but simply to inability to see things in the right perspective. Let me illustrate my meaning by an example. Shortly after Charles Brown had established the first electric-power transmission between Kriegstetten and Solothurn I happened to visit a well-known mechanical engineer in Zürich, who had in his time been professionally (not financially) interested in so-called teledynamic transmission of power by wire-rope, first introduced into Alsatia by the celebated Prof. Hirn, of thermodynamic fame, about the middle of last century, and then also imported into Switzerland. To my old friend these transmission systems appeared to be the acme of perfection; and on my pointing out that the range was necessarily very limited, he replied that transmission to longer distances would be useless, since there would be no market for the power. My friend was not able to look at the subject in the right perspective; he failed completely in appreciating the fundamental conditions of the problem, and although it is easy for us now, fortified as we are by experience, to appreciate electric transmission of power correctly and feel contempt for the old gentleman's narrow-mindedness, yet we should be careful not to fall into the same error about electrical developments which are new to us, as the transmission of power was new to my Swiss friend.

It is not so very long ago that mechanical engineers thought there was no advantage in electrifying textile mills; and I do not feel quite certain whether a good many and very capable engineers are not still of the same opinion. A commission has been investigating this subject, and its first report was by no means encouraging to the electrical engineer. Yet at the very time when that report was issued hundreds of motors were being installed in Continental mills. The spinners there had found out that by using a motor with very delicate speed regulation they could speed up their frames and increase the output considerably. In the long run a good thing must win through, and the electrification of English textile mills is no exception to this economic law; but in some cases it would almost seem that the way is made longer by the narrowness of the mental horizon of opposing experts. This process of gradually overcoming the opposing expert had to be gone through in all applications of electricity, but the opposition being generally honest, once it is overcome, the very men who opposed become strong friends. There is no question now that electricity can do some things better than could be done formerly. The separation of magnetic from non-magnetic material; the lifting of hot pigs, ingots, plates, and scrap by electromagnets; the production of high-grade steel in the electric furnace; the sinking of shafts by electrically-driven pumps; in mines the use underground of electromotors instead of steam engines, in shipyards the use of magnetically-fixed and electrically-driven tools; the electric driving of rolling mills, and the use of electric traction on tube and other underground railways are familiar examples of the application of electricity in which unanimity as to its advantages has been reached between the electrical engineer and what, without any intention of being disrespectful, we may call the old school of mechanical engineers. There are, however, other applications of electricity where the old and new school of engineers have either not at all, or only partially, reached unanimity of opinion, and it is with one of these applications—namely the electrification of railways—that I propose to deal in this Address.

As regards urban and suburban lines, not only the possibility of electric traction, but its immense superiority over steam traction, is fairly generally admitted. Where we get on debatable ground is when we begin to discuss main-line traffic. Here the process of overcoming opposition, of which I spoke a moment ago in connection with other applications of electricity now generally approved, has only just begun. Will it lead to the same result, or will the electrician have to confess himself beaten by the steam locomotive? The answer each one of us would give to this question must necessarily be biassed by our early training. Most engineers love their profession, and are enthusiasts; being enthusiasts, they are necessarily biassed. This applies as well to the electrical engineer as to the mechanical engineer—perhaps to the electrical engineer most. In many cases he is so biassed that he will not admit any virtue in any other but his own pet scheme of electric traction. A modern steam locomotive is a beautiful and efficient engine, and one can well understand its designer looking at it with the pride of a father whose son has turned out a good man. One can also understand that this engineer will not readily admit the superiority of an electric locomotive. The mental horizon of each of us must necessarily be narrowed by previous training and professional enthusiasm; let us, then, try to forget for a moment that we are engineers, and let us put out of our minds all questions of mechanical or electrical detail, focussing our thoughts merely on what we see going on all around us as regards electrification of railways. We see year by year more lines being electrified. Some are failures; but the very fact that in spite of these failures the process of electrification is going on, shows that the failures are remediable.

In some cases it is easy to understand why a line should be electrified. If fuel is dear, if the trains must be heavy and frequent, if there are steep grades and long tunnels, then obviously steam is at a disadvantage and electricity can beat it easily. But the electrification is not limited to cases where there are such obvious advantages. We see a military State like Prussia electrifying a fairly long line where the traffic is not extremely heavy, where there are very gentle grades, and only few and short tunnels. Moreever, one of the stock arguments against electrification is that in case of war the whole system may be broken down by the enemy cutting the wires; yet this consideration, if it has any weight—a matter on which I cannot pronounce an opinion—does not deter a military State from at least experimenting with electric traction on a large scale. We see suburban lines growing longer and longer, until they might almost be classed as short main lines, and we see the Swiss Government buying up water-powers with the object of utilising these powers in the electrification of its most important main lines. We see in America the electrification of large systems taking place, not only for passenger service, but also for the goods service, comprising trains of 2000 and more tons weight, and of goods yards, to the complete exclusion of steam.

One need not be an engineer to appreciate the significance of such a general development. No Government department, and certainly no board of railway directors, will spend money merely for the sake of an interesting scientific experiment, and, although it is conceivable that in an isolated case such an experiment may be undertaken under a miscalculation as to its possible success, it is not conceivable that such a miscalculation should be the general rule. When we see that in all countries a vast amount of labour is devoted to, and capital is spent on, the electrification of main lines, we cannot but come to the conclusion that this new application of electricity is bound to progress, and that the persons who tell you that electric traction is all right for tramways and urban railways, but will never be able to compete against steam traction on main lines, are very much in the position of my old Swiss friend, whose conception of power transmission was entirely limited to the use of ropes and pulleys.

It is just thirty years since the first electric railway was opened for public use. That was a small line in Ireland, known as the Portrush-Bushmills Railway. In those days only the continuous-current motor was available, and that only at a very moderate pressure and power. These restrictions were from the first felt to be a serious drawback, and inventors tried to overcome them in various ways. Of these, two may be here noted, in passing. Ward Leonard in 1891 made the suggestion of carrying on the train a converting station. He argued, quite correctly, that for the transmission of power to long distances the alternating current was eminently suitable, and that, consequently, the power should be sent to the train in the shape of high-pressure alternating current. On the other hand, such a current was, in those days, quite unsuitable for motors; hence the necessity of its conversion into continuous current, with which the then available motors could alone deal. Ward Leonard suggested to put on the first vehicle of the train a synchronous motor, which drives an exciter and continuous-current generator. The current obtained from this generator was to be used to drive the train-motors, which might be distributed in a number of motor coaches. The regulation of speed and tractive force was to be effected entirely by suitable adjustment of excitation, and therefore without rheostatic loss. It will be admitted that this proposal has some attractive features. It is essentially a long-distance system, and at the same time it offers the possibility of great and uniform acceleration, a matter of great importance in urban traffic, so that it is equally suitable for both kinds of service. Moreover, the current can be taken with unity-power factor. Unfortunately the extra weight which has to be carried in the shape of converting machinery is a serious drawback; and for this reason the Ward Leonard system (excellent as it has proved in other applications of electric power) has in the domain of traction never got beyond the experimental stage.

The experiment has been made on a fairly large scale, but with this difference, that the traction-motors were placed not only into motor coaches, but on the first vehicle itself, which thus became an electromotive; also, in order to save the weight and cost of starting and synchronising gear, the asynchronous type of single-phase motor was adopted, thus sacrificing the advantage of unity-power factor. The electromotive developed at the hour-rating 200 horse-power, and weighed 46 tons. This is not a very brilliant achievement, and it was beaten by a sister engine of the same power, but using alternating-current motors. This electromotive weighed only 40 tons.

It is probable that a better weight efficiency could be obtained nowadays with this system if carried out on a larger scale, and if the motor-generator were replaced by a converter, in which case the step-down transformer would have tappings on its secondary side for starting and regulation. It is, however, doubtful whether even then it could compete with electromotives using the alternating current in the motors directly. Motors of this type have recently been so much improved that the margin of weight that could be saved by the use of continuous-current motors is probably less than the excess weight of the converting machine.

The other attempt to combine high trolley-voltage with low motor-voltage has shared the same fate. This consisted in the application of the three-wire principle of continuous-current supply to electric traction. It is in successful operation at a moderate voltage on a London tube railway, but as far as main-line working is concerned it has not got beyond an application on two small lines in Bohemia. The principle adopted is to make the trolley wire of the up-line the positive and that of the down-line the negative side of the system, whilst the rails take the place of the zero wire. Each electromotive is fitted with four motors, of which at least two are in series, taking 1500 volts. Thus, whilst the voltage of one motor is kept within the customary limit of 750 volts, the pressure of the whole system is 3000 volts. The objection to this arrangement is that its fundamental supposition of a fairly close balance between the two halves of the three-wire system must in actual railway working be rather the exception than the rule, and that the obvious remedy of combining both halves of the system in one and the same train would involve the use of two overhead trolley wires, and thus introduce the very feature which the advocates of the continuous-current system find so objectionable in three-phase traction. Moreover, the recent improvements made in continuous-current motors has reduced the importance of the three-wire principle. Continental makers are prepared to build motors for 1200 volts, and one English maker is actually building motors for 1750 volts, so that with two motors in series a trolley-pressure of 2400 and 3500 volts respectively can be used.

The present tendency in electric traction is in the direction of simplicity, in the sense that mixing up of different types of current and dependence of one train on another is avoided. Only three tvpes of current are used—namely continuous, three-phase, and single-phase. The two first-named are used direct; the last through the intervention of a transformer. In a large measure the different systems have already become standardised. As regards the C.C. system, up to 750 volts the process of standardisation has been completed long ago. It is almost generally adopted for urban and suburban lines of moderate length, unless there are local difficulties as regards the third rail, or it is desired to work the suburban and the main-line service on the same system. The three-phase system has also been fairly well standardised, but the single-phase system is still in a process of development—a development which, however, takes place on a fairly large scale. In France the Compagnie du Midi is electrifying on the single-phase system nearly 400 miles of track; the German Government have already electrified the Dessau-Bitterfeld of the Leipzig-Magdeburg line, and are electrifying the line Lauban-Koenigszelt in Silesia, to say nothing of some smaller private lines in the south of Germany, which have been in operation for some years. In Switzerland the Berne-Loetschberg-Simplon Railway, already in operation, and the Rhætian Alp Railway, nearing completion, also employ single-phase electromotives. Both in France and Germany the type of electromotive to be finally adopted has not yet been settled, but half a dozen different types, supplied by as many different makers, are being tried, and it is in this respect that one may look on single-phase traction as still in the process of development. As regards the Loetschberg the period of trial is over. Three years ago the railway company ordered a 2000 horse-power electromotive, and have had it at work ever since with such satisfactory results that they have decided to adopt this type definitely, and have ordered thirteen more engines, but of the slightly larger power of 2500 horse-power on the 1½-hour rating. Of these I shall have to say something more presently; but before entering into the details of single-phase traction it is expedient to glance briefly at the present position of the rival system of three-phase traction.

The first application of this method of working dates back to the end of last century, and took place on a small Swiss line; then followed the well-known Valtellin line, and, later still, when the Italian Government took over the railways, the Government engineers decided to extend the application of three-phase traction to some other lines—a decision which practical experience has shown to have been perfectly justified. The total power represented by three-phase electromotives either at work or on order in Italy to-day exceeds 200,000 horse-power (95,000 horse-power in service, and 120,000 horse-power building). Ten years ago the three-phase system was the only possible one for main-line working, but later on there came on the scene the single-phase, and, later still, the high-pressure continuous-current systems, and I need scarcely mention that between the advocates of the three systems there has been waged a fierce battle, each claiming that his is the best and the others very inferior. I am afraid that battle is still raging; but it is a futile war, for there is no such thing as a best system generally. One system is the best for one set of conditions and another for another set. Thus the German railway engineers found that the single-phase system would serve them best, and they adopted it. There is in this matter no question of personal feeling or national prejudice. I have no intention to enter the lists as an advocate for any one of the three possible systems for main-line traction; each has its special features and special merits, and all I can do is to place before you some of these. As the three-phase system is the oldest, it will be convenient to take it first.

It is curious to note that the three most obvious objections which have been raised against three-phase electromotives by theorists have been found to have but little weight in practical work. These objections were: the complication of a double overhead wire, the danger that the motors would not share the load fairly, and the inability to run without rheostatic waste at intermediate speeds, or to run at a higher than synchronous speed to make up for lost time.

That an overhead wire is inconvenient must be readily admitted, but the inconvenience applies to all methods of main-line working, for the so-called third rail is not applicable to high pressure, and even if it were, the consideration of the safety of the platelayer would preclude its use. The question then is: are two wires twice as objectionable as one? Possibly, but the most objectionable feature is not the wire itself, but the posts or gantries on which it is carried, and the number of posts is the same, whether we use three-phase, single-phase, or continuous current. There is a little more complication at the cross-over points and at the switches; but this is not a serious matter, if one may judge from the perfectly smooth working of so extended a yard as that at Busalla, where there are five miles of track, connected by thirty-seven switches and crossings. The other objection—as to the motors not sharing the load equally—is theoretically sound. The torque developed by the motor is proportional to the slip, and in order that the two motors on an electromotive shall share the load equally their slips, and consequently also their speeds, must be the same. Now, it is conceivable that, owing to a slight difference in the size of the drivers, that motor which is geared to the larger drivers will, by reason of its lower speed and consequently greater slip, take more than its fair share of the load. In practice this difficulty does, however, not arise. With reasonably good workmanship there should be no sensible difference in the size of the wheels; but even if we admit the possibility of there being a difference of ½ per cent. in the diameter of the wheels, this would, with the usual slip of 3 per cent., only mean that the motor geared to the larger wheels develops 8 per cent. more, and the other 8 per cent. less, than its normal power. The larger wheels will develop 16 per cent. more tractive effort than the smaller wheels, and having thus a greater wear, the difference originally existing will diminish in service. For the same reason, any tendency to wear unequally, say, in consequence of unequal material, is counteracted by the slip-adjustment of the motors. This point has been tested practically by the makers of the Simplon three-phase electromotives. It was found that if originally a slight difference in diameter of the drivers had been permitted to exist, after a short time this had vanished. That is as regards the condition on one electromotive; but if we come to the case of a train being hauled by two engines, then a sensible difference in the size of their wheels may exist. In this case it is necessary artificially to adjust the slip so as to make each motor take half the load.

This problem has been solved by Mr. v. Kando in the electromotives which he designed for the Italian State railways. In these engines only liquid resistances are used in the rotor circuit for starting and speed regulation. The liquid is raised or lowered in the rheostat chambers so as to cover more or less of the contact plates, and the level of the liquid is controlled by a solenoid under the influence of the working current. The working current, and therefore also the tractive effort exerted by each motor, is thereby automatically kept constant, notwithstanding any difference that may exist in the size of the drivers on the two electromotives. Incidentally, it may be mentioned that this method of liquid rheostat control has also the advantage of a perfectly constant acceleration during the starting period—a point which makes for comfort of travel in a three-phase train.

The third objection advanced by theorists against three-phase traction is against the waste of energy consequent on rheostatic speed control and the inability to run at more than synchronous speed so as to make up for lost time. The obvious remedy for the last-named difficulty is to fix the time-table so that the synchronous speed should be high enough for making up lost time and to employ motors which can run economically at less than synchronous speed. As a matter of practical experience, three-phase trains are not more unpunctual than any other kind, steam not excluded. A train pulled by a series motor (C.C. or A.C.) runs slower on an up-grade or if abnormally heavy; this is one of the characteristics of the series motor, and it is valuable, because it limits the excess load thrown on to the source of power; but it is clearly not a condition making for good time-keeping. With a series motor time lost cannot be recovered on an up-grade, whilst with a three-phase motor the speed on an up-grade may be kept practically the same as on the level or on down-grades, so that the process of gaining time is not restricted to the easy parts of the line.

The problem of speed control without rheostatic waste has been solved in various ways. One of the simplest and generally adopted solutions is that of cascade and single working. If the two motors are put into cascade connection the speed is halved. The cascade is used in starting and on heavy grades (unless time has to be made up), and on the easy grades or on down-grades the motors work singly—that is to say, in simple parallel connections. Intermediate speeds may be obtained by some pole-changing device. Ordinarily, such devices have to be applied to stator and rotor, but in some of the Simplon electromotives only the stator is arranged for pole-changing, the rotor being a squirrel cage. In this arrangement the advantage of cascade-working has to be given up, but the system has the merit of great simplicity. The number of poles may be changed from twelve at starting to eight, six, and four at top speed. Thus, four different speeds, all without rheostatic waste, are possible. The single bars in the squirrel cage rotor are connected at their ends by resistance-connectors made of an alloy having a high temperature coefficient. At starting the rotor current is large and heats up these strips, thus automatically providing what is technically termed a starting-resistance. When the motor is running the current is less, and by reason of the fanning action of the connecting-strips these get cooled so as to bring their resistance down to a permissible amount. Thus the efficiency of the motor when running under load is only a few per cent. less than that of a motor with a wound rotor.

A valuable feature of the three-phase system is the automatic recuperation of current whenever the speed exceeds synchronous speed by a few per cent.: and, connected with this property is the further advantage that it is impossible for a train to race on a down-grade. Obviously recuperation can only take place if power is given to the motor. This is provided partly by the electromotive itself and partly by the train pushing it on a down-grade. This means that the train is braked in front only, and railway engineers have raised the objections that such a method is contrary to the accepted rules for safe working, which require that even on a down-grade all the couplings should remain in tension, which means that each coach must be independently braked. Here we have again a case where the theorists' objections have been proved to be without foundation in actual practice. It is no doubt objectionable to brake a train in front only, if the braking action is jerky; but with the automatically controlled liquid rheostat the braking comes in quite gradually, and is throughout so even that it has been found possible to permit a higher down-grade speed with recuperation than with ordinary braking. On the Italian State railways the regulation permits on heavy down-grades a speed of thirty kilometres per hour for steam trains, but the electric goods trains on the Giovi line are permitted to run at forty-five kilometres per hour. This concession is not extended to passenger trains. Nevertheless the economic effect is considerable. Recuperation saves 17 per cent. on the coal bill, and this amount is sufficient to provide for interest and sinking fund on the electrical plant at the generating station.

One advantage of three-phase traction over steam traction is the lessened weight of the locomotive in comparison with its tractive force and power. As an example, we may take the Giovi line in Italy where steam trains, consisting of 310 tons of rolling-stock and 202 tons of locomotive (one in front and the other at the back), have been replaced by three-phase trains, consisting of 380 tons of rolling-stock and two electromotives, each weighing 60 tons (also placed front and rear). Thus there has been a saving in total weight of 12 tons, and at the same time an increase in useful weight hauled of 70 tons. The average grade of this line, over which passes the whole traffic between the Port of Genoa and the Plain of Lombardy, is 27 per mille, and the maximum is 35 per mille This traffic is now worked with forty electromotives, each of 60 tons weight. These engines have five driving-wheels connected to two eight-pole motors by gear-wheels and rods. The pressure on each driving-axle is 12 tons. Each electromotive develops 2000 horse-power at the hour-rating; thus 1 horse-power is obtained for each 30 kilogramme weight of engine.

The number of patented designs for single-phase traction motors is very large; but, notwithstanding considerable difference in matters of detail, all motors which have been successfully applied in practice may be ranged under three great groups—namely, the so-called repulsion type, the repulsion type with additional excitation of the rotor, and the straightforward series motor. The present tendency is rather in favour of the series motor, and the practical results obtained with it are certainly very promising. The latest design made by Dr. Behn-Eschenburg shows a remarkable weight efficiency. His 2500 horse-power electromotives (the power being at a one and a half-hour rating) weigh only 108 tons, so that at this rating 1 horse-power is obtained with a total weight of 43 kilogrammes. This compares favourably with the high-pressure C.C. system, where 50 to 70 kilogrammes per horse-power may be taken as normal values.

The so-called "repulsion motor" invented by Prof. Elihu Thomson has been applied to railway work in the slightly modified form due to Mr. Deri, where, instead of there being only two brushes per pair of poles, double the number is provided, and the adjustment for speed and torque is made more accurate, whilst at the same time the commutation, being split up into two steps, becomes easier. In the matter of simplicity, an electromotive fitted with Deri motors cannot be surpassed by any other arrangement. There are no rheostats, contactors, control switches, or other gear; all the regulation is effected by mechanical transmission of the movement of a hand-wheel placed in the driver's cab to the brushes of the motors. At one time it was hoped that this system would win its way to a general application; but, unfortunately, the motor must run somewhere near synchronous speed, and becomes therefore rather heavy with the low frequencies alone possible in traction. Moreover, as the power-factor obtainable is only about 0·80, that is, considerably below the value obtainable with other motors, there does not seem to be any great future for this system for heavy work, although its great simplicity may still turn the balance in its favour on lines with a light traffic. For heavy lines the choice at present lies between the induction motor, with direct rotor excitation, and the straightforward conduction-motor, where rotor and stator are traversed in series by the same current. The former type of motor—also called the Latour-Winter-Eichberg motor—depends for its working current in the rotor on electromagnetic induction, which produces the working current in the rotor much in the same way as the current in the secondary circuit of a transformer is produced by induction. Since the motor has in part the character of a transformer its weight would, as is the case with any transformer, be unduly augmented by too great a reduction in the frequency. Experience has shown that a frequency of twenty-five periods per second is high enough to render the transformer action effective, and at the same time not so high as to introduce serious difficulties as regards e.m.f. of self-induction and commutation. This frequency has been adopted in most cases where electrification of main lines has been carried out by motors of this class.

One valuable feature of this motor is that at a speed slightly exceeding synchronism the power-factor may be brought up to unity. At this speed the commutation takes place under conditions which may be described as theoretically perfect. A fair number of Continental lines have been electrified by using these motors, and they have also been adopted, with very satisfactory results, in the electrification of the London, Brighton and South Coast lines between Victoria and London Bridge and to some distance south of London. On this line no locomotives are used, but only motor coaches. It is therefore not possible to make a direct comparison as to weight efficiency with a locomotive. The latter has only to carry the propelling machinery, whilst the former has to provide accommodation for passengers as well. The 600 horse-power motor coaches on the Brighton line weigh 50 tons, or at the rate of 83 kilogrammes per horse-power. A 1000 horse-power C.C. electromotive taking current at 1200 volts weighs 74 tons.[1] By making a suitable reduction for the extra weight of the passenger accommodation in the A.C. coach, its weight per horse-power comes out at something like 60 kilogrammes, against 62 kilogrammes in the C.C. engine.

Series motors are employed on the electrified lines of the Midland Company between Heysham, Morecambe, and Lancaster. Also in this case motor coaches, and not electromotives, are used. At the hour-rating a motor coach develops 420 horse-power, and as its total weight is about 35 tons, we have here the same weight-efficiency as on the Brighton lines—namely, 83 kilogrammes per horse-power for the whole coach.

Of high-pressure continuous-current lines there are many examples, both in Europe and America. The term high-pressure does, of course, not imply the same order of magnitude as in single-phase A.C. lines. There high-pressure may mean anything up to 15,000 volts, the pressure which is likely to become a standard in future electrifications; but in C.C. work one must class anything over 1000 volts or 1500 volts as high-pressure. The general rule is to employ motor coaches, and not electromotives; but there is a private line belonging to a steel-works in Lorraine, where two electromotives, each of 600 horse-power (four C.C. motors of 150 horse-power) are working the mineral trains under a pressure of 2000 volts. The Southern Pacific Railway also employs C.C. electromotives of 1000 horse-power each. Each engine weighs 74 tons, and hauls a train of 270 tons on grades of 40 per mille. This is a remarkable performance, rendered possible by the fact that with the even torque exerted by the electric motor a much large co-efficient of friction than is possible in steam traction may safely be permitted. Electrical engineers generally base their calculation of the possible tractive effort on a co-efficient of 0·17, without sand, and as high as 0·25, or even 0·28, if sand is used. The voltage in the case of the Southern Pacific engines is only 1200 volts, taken by two motors in series, and there is provision made to change over from the overhead wire to third rail, with 600 volts, when the motors are all in parallel.

On European C.C. lines the voltage is higher—generally 2000 volts, as on the Chur-Arosa and some other Swiss lines—and the tendency is still in the direction of higher pressures. Continental makers are now prepared to go as far as 1200 volts per motor, so that with the usual system of series-parallel control a line-pressure of 2400 volts becomes possible The greatest step in advance in this direction has, however, been made in England, where Messrs. Dick Kerr, Ltd., have adopted a line-pressure of 3500 volts as their standard, involving the use of motors constructed for 1750 volts. After having experimented with this high-pressure system for two years, they have undertaken the electrification of a short section of the Lancashire and Yorkshire Railway with continuous current at 3500 volts. I am indebted to the firm for the following particulars: The current is collected by pantograph from an overhead wire with catenary suspension. The train consists of a motor coach and two trailers. The motor coach is equipped with four 300 horse-power motors, and weighs 62 tons; the trailers weigh each 26 tons. From these figures it will be seen that the weight of the motor coach per horse-power is only 52 kilogrammes, and thus considerable below what the weight of an equivalent single-phase motor coach would be. It is especially the saving in weight and the avoidance of any telephonic disturbances which renders the C.C. system so attractive that, in spite of

1 See Gratzemueller's paper read at the Paris meeting of the I. E. E. and S. Intern. des Electr. (Paris, May, 1913).

a natural reluctance against the use of high-pressure on a commutator, designers are giving increased attention to the use of continuous current for electric traction. The difficulties which some engineers anticipate with commutator and brushes seem, however, rather imaginary than real, if we may judge from the experience with the 3500-volt motor coach. The makers inform me that they estimate the mileage for a set of carbon brushes at 50,000 miles. The motors drive the car-axles by single reduction gear, and are controlled by contactors operated from a master controller. The current for operating the contactors, driving the air-pump motor, and for the general service of lighting and heating is obtained from a small motor-generator, fed on the primary side at 3500 volts, and delivering C.C. at 210 volts. All motors have commutating poles—a practice which has become universal in C.C. traction work.

From the figures quoted above it will be seen that where motor coaches are employed the C.C. system has an advantage in point of weight over the single-phase A.C. system. But main-line traction, including goods trains, is not going to be done by motor coaches, and if we come to large electromotives of some 2000 to 3000 horse-power, then this advantage is likely to vanish. No high-pressure C.C. electromotive has as yet been built for so large a power, and it is therefore not possible to make a direct comparison; but, if we may judge from the largest engines yet built for moderate-pressure C.C. there is little probability that the C.C. system for high-pressure can beat the single-phase system, and none whatever that it can beat the three-phase system.

In the early days of single-phase traction some trouble has been experienced in the matter of telephonic disturbance. A systematic investigation carried on for over a year on the Seebach-Wettingen line, chiefly by means of the oscillograph, showed that this trouble was due, not as had originally been suspected, to the commutator, but to the employment of open slots in the rotor, and the trouble nearly ceased when new rotors with semi-closed and spiralled slots were used. To improve the telephonic service further the usual remedy of metallic return and drilling the telephone lines was employed. Although by these means it is possible to render telephonic speech over a line alongside a single-phase railway nearly, and perhaps quite, as clear as it is along a C.C. railway, there still remains the danger that the telephone lines may, by electrostatic induction, acquire a very high potential. The remedy against this danger, first applied on some Swedish experimental lines, is to short-circuit the two wires of each circuit by a choking coil of very high inductance, the centre of which is earthed. The static charge is thus carried off to earth, whilst the telephonic currents are only inappreciably weakened.

One of the advantages possessed by the alternating over the continuous current is the simplicity of regulation. There are no contactors and no rheostats used, the power and speed of the motors being adjusted by the use of tappings on the secondary side of the transformers. As transformers are necessary in any case in order to work with a high voltage on the trolley, the introduction of tappings does not materially increase the weight, whilst at the same time it effects a great reduction in the primary starting current. The only difficulty that still remains is that of sparkless commutation, and inventors have evolved many, and sometimes very complicated, arrangements for overcoming it. As so often happens with engineering problems, the most simple solution is, after all, found to be the best in practice; and of all the ingenious inventions patented during the last ten years very little use is made by the designer of traction motors.

Broadly speaking, only two methods are in use; the one is the method first made known by Messrs. Winter and Eichberg, where the working field is produced by direct excitation of the rotor and the transformer e.m.f. in the coils short-circuited by the main brushes is balanced by an e.m.f. of rotation due to a transverse field; and the other method applicable to the straightforward series motor, where a non-inductive shunt is connected to the terminals of the compensating or commutating winding. The effect of a non-inductive shunt is to make the armature field slightly leading over the field produced by the compensating winding. The resultant of these two fields is in position coincident with the brush axis, but has in point of time a phase difference of a quarter period over the working current, thus balancing the e.m.f. of self-induction, which lags by a quarter period. Obviously this balancing effect can only take place when the motor is running, since it depends on the balance between an e.m.f. of self-induction which is independent of speed and an e.m.f. of rotation which is proportional to speed. At starting, when there is no speed, there is no compensation. Thus there would appear to be a new difficulty in the way of the use of single-phase current; but also this has been overcome in quite a simple manner. Experience has shown that a potential difference of 7 volts between heel and toe of brush, and a current density of 15 A. per sq. cm. is permissible.

If, then, we use narrow brushes, covering at any time not more than three segments, use coils of only one turn to each segment, and work at a reasonably low frequency, and not too high a total flux, it is possible to keep the transformer voltage and current density well within the above limits. This is not a severe limitation, for it enables the designer to use a flux out of one pole of 2·4 megalines if the frequency is 25, and 3·6 megalines if it is 15. The number of poles has then to be selected in accordance with the power desired. Obviously the lower periodicity is to be preferred, because the motor may be built with a lesser number of poles, and will then occupy less room—a matter of considerable importance considering the limited space which is available in an electromotive. The frequency of 15 has also some other advantages over that of 25. The e.m.f. of self-induction is proportionately less, and, in consequence, the power-factor is about 5 per cent. better. The skin effect in the rails is much reduced, and also disturbances on neighbouring circuits which may be due to inductive or capacity effects. On the other hand, the generators become a little more expensive and the transformers on the electromotives a little heavier. But, notwithstanding these drawbacks, the balance of advantage is with the lower frequency, and that is the reason why the Commission of Experts called together in 1904 by the Swiss Government to establish standards for the electrification of the Swiss railways has decided that 15 shall be the standard frequency, with a tolerance down to 14, and up to 16⅔. Since then other States have fallen into line, so that 15 is now the standard frequency nearly all over the continent of Europe. The standard pressure is likely to be 15,000 volts. For three-phase tractions the standard pressure is 3000 to 3300 volts.

The subject of electric main-line traction is so vast that in the limited time at my disposal I have only been able to mention a few of the important features of this interesting problem. A detailed account of all that has been done in electrification would take far more time than we can spare; but, by way of example, I give below two tables referring to the Italian State Railways. I am indebted for the information to Mr. v. Kando, who may justly be described as the father of three-phase traction.

Italian State Railways Electrified on the Three-phase System.

Location of line	In service			In construction		
	Lecco Colico Sondrio Chiavenna	Campasso Pontederimo Busalla	Bussoleno Bardonecchia Modone	Savona S. Giuseppe Ceva	Lecco Monza	Genova Sampierdarena Ronco
Length, in kilometres	107	19	58	45	38	28
Heaviest grade per mille	22	35	30	25	12	17
Numbering of transforming stations ...	10	4	7	4	4	2
Transmission voltage	20,000	13,000	59,000	62,000	25,000	57,000
Trolley voltage ...	3,000	3,000	3,300	3,300	3,300	3,000
Frequency (cycles per second)	15	15	$16\frac{2}{3}$	$16\frac{2}{3}$	$16\frac{2}{3}$	15
Source of power ...	Water	Steam	Water	Water (steam reserve)	Water (steam reserve)	Water (steam reserve)
Number of electromotives	14	20	15	61 for the three lines		
Number of motor coaches	10	—	—	—	—	—
Weight of trains, minimum	150	190	—	not given		
Weight of trains, maximum	370	380	220			

Three-phase Electromotives on the Italian State Railways.

Type	034	036	038	050	030
Maker	Ganz	Ganz	Ganz	Westinghouse	Westinghouse
Number in service ...	2	3	4	40	—
Number building ...	—	—	—	45	16
Total weight, tons ...	45	62	62	60	66
Weight on drivers ...	45	43·5	43·5	60	48
Number of driving axles...	4	3	3	5	3
Total number of axles	4	5	5	5	5
Weight on drivers, tons	11·3	14·5	14·5	12	16
Diam. of drivers, m.m.	1,396	1,600	1,600	1,370	1,630
Frequency (cycles per second)	15	15	15	15	$16\frac{2}{3}$
Method of transmitting torque of motor to driving axles	Quill and flexible coupling	Cranks and connecting rods			
Speed, in kilometres per hour	30	32—64	22—45—63	22·5—45	37·5—50—75—100
Method of speed regulation	—	Cascade	Cascade	Cascade	Cascade and pole-changing

The most recent example of single-phase electrification is that of the Loetschberg line establishing direct communication between Berne and the Simplon line. I am indebted to Dr. Behn-Eschenburg, the designer of the electromotives, for the following information. The power at the one-and-a-half-hour rating is 2500 horse-power, and the total weight of the engine is 108 tons, of which 85 tons is taken by the five driving axles. At the normal speed of 50 kilometres per hour the tractive effort is 10 tons. This can be increased at starting to 18 tons. On the heaviest grade (27 per mille) the tractive effort is 13·5 tons, which suffices for a train of 310 tons. The maximum speed is 75 kilometres per hour. There are two 1250 horse-power motors on each engine. Each has its own transformer and controller, the principle of duplication being carried out in all the details, so that in the event of a defect to any one part the other remains serviceable. The potential difference between tappings is 45 volts, and the last step gives with 15,000 volts on the trolley 520 volts. This is in excess of what is required by the motor, and thus provides for the event that the trolley-voltage should for some reason fall below the standard pressure. The normal voltage of the motors is 420, and the full-load current 2700 A. At starting on the level the line-current is about one-third of the full load-current, and the power 10 per cent. of the full power. When starting on an up-grade of 27 per mille with a train of 310 tons, the current taken from the trolley is 40 per cent. of the normal full-power value, and the acceleration 0·05 metres per second per second. The current is taken from the overhead trolley by two pantographs, the pressure being 15,000 volts, and the frequency 15. The controller drums are each worked by an electromotor and rocking pawls under the electric control of a master controller, so that the driver is relieved of any physical exertion in attending to the regulation of the motors. These have 16 poles, a compensating winding to increase the power-factor, and commutating poles shunted by a non-inductive resistance to insure sparkless collection. The power-factor is about 0·95 over a wide range of load. The motor is geared by double helical wheels (ratio 1 : 2·23) to a blind axle, from which the turning moment is transmitted to the drivers by cranks and connecting-rods. The weights are as follows: Motor, 11·8 tons; gear, 2 tons; transformer, 7·5 tons; and controller, 1 ton; total, 22·3 tons; or at the rate of 17·8 kilogrammes per horse-power on the one-and-a-half-hour rating. The total weight of the electromotive is at the rate of 43 kilogrammes at the same rating. This is a remarkably high weight-efficiency, which has up to the present not been reached by any continuous-current electromotive, and has only been surpassed by the three-phase 2000 horse-power electromotives (taken at the one-hour rating) of the Italian State railways, which works out at 30 kilogrammes per horse-power.

In conclusion, let us briefly glance at what is being done in the electrification of the Gothard line, that main link of commerce between Germany and Italy. I am indebted for the following notes on the subject to Mr. Huber-Stocker, the scientific adviser to the Swiss Government in the matter of railway electrification: The part to be electrified first is that between Erstfeld and Bellinzona, a total length of 110 kilometres, of which about 29 per cent. is in tunnel. This part also contains the longest and heaviest grades, so that the limitations of steam as compared with electric traction are here most prominent and a relief most urgent. On this section the average daily train movement, taking both directions together, was, in 1911, not less than 1,680,000 kilometre-tons, and the maximum on any day 2,282,000 kilometre-tons. It is estimated that in 1918 the average train movement will have increased by 35 per cent. over 1911, and in 1928 by a further 30 per cent. In the 45 kilometres on the north side of the tunnel the train climbs 569 metres, and in the 65 kilometres on the south it descends to Bellinzona 900 metres, with a steepest grade of 27 per mille. The section Erstfeld-Airolo is to be opened for electric traction in four years from now, and the southern section one year later. The present arrangements are made with the intention of extending the electric service on the north to Lucerne (60 kilometres), and on the south to Chiasso (55 kilometres) at some future date not yet fixed. There will be two large power-stations, one at Amsteg, where at first 32,000 horse-power will be available on the turbine shafts, and 56,000 to 60,000 when the station is completed; and the other at Piotta, where at first 40,000, and finally 50,000 horse-power will be available. The head of water in the northern power-house is 267 metres down to the Reuss, and an accumulation of one million cubic metres is provided for to compensate for diurnal variations. In the southern power-house the head of water is 900 metres, and there the Ritom Lake offers a natural reservoir, with 19 million cubic metres, to compensate for annual variation in the water-supply. The power-current will be sent along the line by two independent cables, each capable of carrying the full power at twice 30,000 volts, with earthed neutral. The current will be transformed down to 7500 volts at first, and 15,000 volts later on, if the experience gained with the lower pressure should warrant the increase to double pressure. This will not involve any additional plant, since the secondary winding of transformers both along the line and on the locomotives can from the first be arranged with this alteration in view. It is also contemplated to establish sub-stations in Biasca, Goeschenen, Lavorgo, and Bellinzona The trolley wires will be suspended from gantries, each wire independently insulated. The section varies according to the gradient from 100 to 160 square millimetres. The feeders are separate for the up and down line, and are 100 square millimetres in section. At all railway stations there are change-over switches for trolley wire and feeders. In the tunnels the wires are carried by brackets fastened to the crown of the tunnel. The rails will be bonded, and, in addition, there will be a bare return conductor either laid in the ground or placed between the trolley wires. A variation in the supply of voltage of from plus 10 to minus 15 per cent. is allowed for. There will be no motor coaches used, only electromotives. It is intended to haul express trains weighing 420 tons with a speed of 50 kilometres per hour on grades of 26 per mille, for which service the electromotive will have to develop 3000 horse-power on the rails. Goods trains weighing up to 670 tons will run with a speed of from 27 to 28 kilometres per hour, and have two electromotives, one in front and one in the rear, each rated at 2800 horse-power. Passenger trains will be heated by steam, the boiler being carried in a special heating coach. Except for the stipulation that the traction must be single-phase at 15 frequency and a voltage of 7500, which may eventually be raised to 15,000, no definite type of electromotive has as yet been selected, but there can be no doubt that several of the already existing types of mono-phase electromotive can be adapted to the special requirements of the Gothard line.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

BIRMINGHAM.—Prof. P. F. Frankland, F.R.S., has been elected dean of the faculty of science in succession to Prof. S. M. Dixon.

Dr. F. C. Lee has been nominated to the chair of civil engineering vacated by Prof. S. M. Dixon.

CAMBRIDGE.—The director of the psychological laboratory has appointed Mr. Cyril Burt, psychologist to the London County Council, to be assistant in experimental psychology.

The professor of zoology and comparative anatomy has appointed Mr. T. J. Saunders to be demonstrator of comparative anatomy.

At Emmanuel College, Mr. J. B. Peace, bursar of the college, resigned the tutorship in mathematics at Michaelmas, and Mr. P. Worsley Wood has been appointed his successor. The exhibition of 50*l.* offered to a research student commencing residence this October has been awarded to Mr. J. Conway Davies for research in history. An additional exhibition of 30*l.* has been awarded to Mr. H. Ogden for research in physics.

The next combined examination for fifty-six entrance scholarships and a large number of exhibitions, at Pembroke, Gonville and Caius, Jesus, Christ's, St. John's, and Emmanuel Colleges, will be held on Tuesday, December 2, and following days. Mathematics, classics, natural sciences, and history will be the subjects of examination at all the above-mentioned colleges. Most of the colleges allow candidates who intend to study mechanical sciences to compete for scholarships and exhibitions by taking the papers set in mathematics or natural sciences. A candidate for a scholarship or exhibition at any of the six colleges must not be more than nineteen years of age on October 1. Forms of application for admission to the examination at the respective colleges may be obtained from the masters of the several colleges, from any of whom further information respecting the scholarships and exhibitions and other matters connected with the colleges may be obtained.

GLASGOW.—Prof. Archibald Barr has resigned the Regius chair of civil engineering and mechanics, which he has held since 1889. The magnificent James Watt engineering laboratories, in which the department is accommodated, were erected and equipped under his direction. The Crown has appointed Prof. J. D. Cormack, dean of the faculty of engineering in University College, London, and a governor of the Imperial College of Science and Technology, to the vacant chair. Prof. Cormack is a graduate of Glasgow, and was formerly a lecturer in the engineering department.

MR. C. R. BURY has been appointed assistant lecturer and demonstrator in chemistry at the University College of Wales, Aberystwyth.

A GIFT of ten lakhs of rupees for the promotion of scientific technical knowledge has been made by Dr. Rash Bahari Ghosh to the University of Calcutta.

THE McCosh professorship of philosophy at Princeton University has been resigned by Prof. A. T. Ormond, who has accepted the presidency of Grove City College.

WE learn from *Science* that by the will of Miss Katherine Allen, of Worcester, the Worcester Polytechnic Institute has received a bequest amounting to about 20,000*l.*

MR. L. C. PLANT has resigned his position as head of the department of mathematics in the University of Montana on accepting a similar post in the Michigan Agricultural College. He is succeeded by Dr. N. J. Lennes, of Columbia University.

BY a trust settlement of Dr. Gavin P. Tennent, of Bath Street, Glasgow, the sum of 25,000*l.* is bequeathed to the governing body of the University of Glasgow, to be applied for such objects or object in connection with the faculty of medicine as the trustees may determine.

THE Gresham lecturer on astronomy, Mr. Arthur R. Hinks, F.R.S., will deliver a course of four lectures on astronomy in daily use on October 14, 15, 16, and 17, at 6 p.m., at the City of London School, Victoria Embankment. The subjects of the four lectures are respectively:—The determination of time; the distribution of time; the determination of position; and measurement of the size and shape of the earth. The lectures are free to the public.

A STRONG committee, mainly consisting of old students of the Royal Agricultural College, Cirencester, is about to issue a special appeal with the view, in the first place, of collecting the balance of 1685*l.* still required to complete the 5000*l.* necessary to secure the advance of a similar sum from the Development Fund for erection of King Edward's wing of the college. When this sum has been subscribed, the appeal will still be continued so as to provide for further much needed extensions The honorary secre-