

experiments because he had a generator plant of relatively infinite capacity to work on, and therefore his terminal E.M.F. wave-form would be independent of anything that took place in his transformers. I envy him. The applied voltages in my testers were, however, of the order of 100 volts per phase, not 20 volts. The size of the testers would not affect the results. Mr. Taylor in his experiments was striving to obtain a practical frequency changer with a good voltage regulation, and he has apparently succeeded, but I do not understand how his arrangement of choking coils in mesh connection and separate working transformer tends to accentuate the triple-harmonic component of the flux in the core of each choking coil. So far as the triple harmonic of the induced electromotive force is concerned, there is a circuit of considerable inductance, and therefore the triple-harmonic current will lag and will tend to wipe out the flux harmonic producing it. I do not believe Mr. Taylor will be very successful in the determination of the core losses by the calorimetric method suggested. The possibilities of error are too great. A wattmeter method is preferable. The voltage drop with I_3 equal to one-third of its short-circuit value (Fig. 4) was 9 per cent, but that figure will be of little value to anyone since the primary line electromotive force could not be maintained a sine wave during the tests. With reference to Mr. Taylor's remarks on Figs. 5A and 5B, it is apparently not clear that Fig. 5A also refers to tests with mesh short-circuited. The triple harmonics of the induced electromotive forces in the windings D are always simultaneous and in phase with each other; each phase induces an electromotive force, e_3 , of triple frequency, and the open-circuited mesh voltage is $3e_3$. The mistake which Mr. Taylor seems to have made* was to assume that the electromotive force (secondary) due to each of the currents in the three phases of his choking coils consisted of a triple harmonic with each third half-

* *Journal I.E.E.*, vol. 52, p. 703, Fig. 6, 1914.

wave missing. In reality the electromotive force consists of a component of fundamental frequency together with a large triple-harmonic component. All three choking coils are equally active at any instant.

Professor Robertson refers to a possible error in the correction for the air flux enclosed by the search coil; a correction was made only for the air flux of fundamental frequency, and therefore the values of the magnetizing currents were taken from the curve marked I_1 in Fig. 13. That may account for the difference between Professor Robertson's figures and mine. In this correction for the air flux it is interesting to note that the air fluxes due to the higher harmonics, i_5, i_7 , etc., lag approximately one-half period behind the corresponding fluxes in the Stalloy core, and hence the higher harmonics, e_5, e_7 , etc., in the induced electromotive force are somewhat less than they would be if the air flux were absent.

Dr. Smith's reference to the reaction of the distorted current wave of an over-excited choke coil on the field of the alternator is very interesting, and shows that the shape of the pressure wave of an alternator should never be taken for granted until the nature of the load is known. The slight difference between the two sides of the current curve is due to the hysteresis loop, and is affected by supplying the triple harmonic from an external source. If the tester has to supply its own current, i_3 , it will also be forced to supply the i^2r losses due to this current, and these losses would affect the shape of the B-H loop. With the apparatus at hand it would not be possible to carry out experiments at 50 cycles per second.

Mr. Haigh emphasizes the difficulties experienced in separating the eddy-current from the hysteresis losses. It is also of interest to note that he takes the view that beyond a certain critical value the hysteresis loss might be expected to increase. As already mentioned, the experimental results seem to bear out this contention.

BIRMINGHAM LOCAL SECTION : CHAIRMAN'S ADDRESS.

By A. H. RAILING, D.Eng., Member.

(Address delivered 18 November, 1914.)

I have chosen as the subject of this address the position of electrical engineering in the world's social organization. I propose to show how and why in the chain of occupations and professions the advent of the electrical engineer has of necessity been a late one, and how he, like most late developments, therefore represents one of the highest developed, shall we call it, organisms and must realize his position as such. Out of this recognition there arises the duty to use the accumulated experience of the intermediate formations for the purpose of achieving further progress, the duty to advance the age and the professions which have produced him, until he in turn has led to new and higher developments, to an increase in efficiency of matters humane and in nature, and to an increased knowledge of matter by man.

In our age of specialization on the one hand, and of

increased and highly developed tools, mechanical and spiritual, on the other, the mental worker himself often succumbs to routine. In such a state—as too often the manual worker—he becomes, knowingly or unknowingly, a unit that in its daily routine work has forgotten the logical place which he and his work take in the “continuity scheme of Nature.”

Nature herself shows that as she passes from the lower to the higher species she separates the functions which originally were fulfilled promiscuously by organisms of a general character, and develops more efficient organisms with special functions for the various purposes of human life, such as movement, feeding, reproduction, etc. Human development unconsciously in the course of its progress, and human society in its progress from a rudimentary to a complicated organism, have followed this same law.

In order to obtain the best overall efficiency, definite organisms have been created, specially devoted to and developed for specialized work. This overall efficiency in human society, however, will only be obtained when the specialized organism is aware of the bond connecting it to the common body, the reason for its specialization, the work that it has been created for, that part of the task which its predecessors have accomplished, and the tasks that are before it. Otherwise, instead of giving rise to increased efficiency, specialization is bound to lead to dissolution. Only the man who understands his work in this sense is worthy of the name "electrical engineer."

In order clearly to conceive our position, I propose to consider whether, as a body, we have a claim to be mentioned amongst the groups of workers whose names are identified in history with distinct and definite progress of humanity.

Man's original occupation was that of a hunter; he had to find food, and he had to defend himself. All classes since that day owe their existence to Nature's law of the survival of the fittest, *i.e.* the most efficient being. The most urgent immediate requirements of humanity were improvements in the methods of defence and of obtaining food in a more regular, secure, and easy way. The rearing of cattle and the tilling of the soil served this purpose.

Efficiency demanded that special knowledge, whether in regard to good or bad land, or to movement of sun and stars, or healing, should be centred in certain individuals, and handed on by them from one generation to another. Priest castes filled this gap, and from them separated in the course of time the physician, the teacher, the lawyer, and the philosopher.

As civilization progressed, humanity learned the use of materials. It learned the exchange of materials—the importance of the trader, who contributed to efficiency by removing the restriction in the use of certain commodities to certain localities and times.

The justification for all these classes of workers, therefore, was that they represented tools specialized for doing away with waste, either by producing more efficiently necessities of life, or by preventing undue waste of life, or by co-ordinating the actions of men so as to remove friction and waste, or by developing brain and morale, thus producing a more far-sighted, more efficient being, or finally by creating efficient communication between communities, thereby tending to equalize abundance and need.

All these vocations have already been in existence for thousands of years. Why has engineering, and especially electrical engineering, come so late, and what is its mission?

As humanity progressed, it dealt with men and matter as it found them, and it used the kinetic energy of men and animals, and perhaps of wind and water, as well as certain substances and some of their physical properties. Although attempts were made from time to time to probe deeper, practically nothing was known of the structure of matter, or of energy in its manifold variations. The problems of dynamics, if we leave out Aristotle, were dead until the time of Galilei and Newton; the problems of matter until Priestley and Berzelius. Engineering science meant, as in Galilei's law, going away from this earth, or, as in the atomic theory, going into the infinitesimal.

Electrical engineering started when humanity was pre-

pared for an advance in this direction. In its narrower sense it means the application of the knowledge of what we call electricity. In its broader sense it is the knowledge of matter and its attribute "energy"—or, vice versa, energy which manifests itself in the form of matter—and their applications.

If we consider history as the progress of the knowledge of matter, the sequence is a logical one from physical properties to the properties of the molecule, from the problem of the molecule to that of the atom, and from the problems of atoms to those of the corpuscle, proceeding step by step to smaller and smaller units of matter.

If, on the other hand, we consider history as the progress of the knowledge of movements, we find exactly the same development from Galilei's and Kepler's law of the planets to the knowledge of the potential and kinetic energies of moving bodies, to heat and cohesion, to chemical energy, and from there to electricity and light, the energy of corpuscles, as the basis of all.

The knowledge of all these problems and the application of such knowledge went hand in hand, sometimes the application leading and the explanation following, sometimes theory first and application afterwards, and it is self-evident that the sequence depended partly on the greater pressure for practical application, the pressure to achieve something, to prevent something, or the greater need to understand certain facts, certain problems, and by understanding them to govern them.

I have tried here to show how and why engineering, and especially electrical engineering, came as the latest development proceeding from visible matter and the energy of visible matter, further and further into the region of the invisible and infinitesimal.

Having realized what led to our profession, I now come to the second point, which I set out to consider: In how far has electrical engineering already contributed to human development, by, shall I say, improving human progress and efficiency.

This problem has been dealt with in innumerable ways. I am not going to speak about the "thousands of miles of telephone wires, and the millions invested in electrical undertakings," which have become almost proverbial; nor shall I give statistics. I hope, however, to be able to show, shall I say from a philosophical point of view—which translated into modern language means a natural science point of view, or from the point of view of the laws of energy—that we have established our claim and have achieved greater efficiency in the universe.

What is the problem? Humanity, that is a number of human beings endowed with mental and physical energies (which may or may not be of the same nature), inhabits for a certain time a certain space. They have at their disposal a definite sum of matter in innumerable varieties and combinations, and a definite sum of energy, part of which is free energy in all its known forms, and perhaps in some that we do not know yet.

Electrical engineering is a power for civilization if it increases mankind's efficiency in dealing with these factors:—

- (1) If it enables us to make better use of matter either by increasing the number of varieties in existence or by producing them more cheaply, or by making better use of their properties.

- (2) If it enables us to make better use of the available forms of energy.
- (3) If it increases the space that can be inhabited and made use of by men.
- (4) If it increases the physical or mental power and efficiency of each individual.
- (5) If apart from increasing the efficiency of the individual, it increases the efficiency of the composite body—human society—either by increasing the average efficiency or by increasing the total efficiency.

I propose here only to touch on the influence of electrical engineering—which for the purpose of this discussion, includes science and application—on these various matters, since it is obvious that books could be written on each of these subjects.

The influences of electrical engineering on mastering energy and matter must to a certain extent be considered jointly. The mastering of the subject depended on the knowledge of their nature and on the application of such knowledge.

As to the influence of our knowledge, the study of electrical phenomena has explained much that was not clear in connection with the great variety of matter and movement around us. Formerly we had recognized that all substances are composed of molecules, and all molecules of atoms of a variety of elements. We now recognize that all elements are either interwoven with or composed of a variety of corpuscles.

We have in successive steps reached the point where all energies are restricted to and based on one, and one only, viz. corpuscular energy—electricity. All other energies are variations. Radiation; the energy of accelerated corpuscles—chemical energy; the energy of groups of corpuscles called atoms—heat; the energy of groups of atoms called molecules—mechanical energy; the energy of molecules grouped in measurable volumes. These theories may not be absolutely proved; it may be doubtful whether the theory of energy which denies the existence of mass will be victorious, or the pure, shall I say corpuscular theory, which simply accepts substance with its energy as one of its attributes inherent to it, inseparable from it. I personally accept the latter. For the present purpose, however, it is immaterial.

It would lead me too far to show the successive stages and the varying theories which electrical scientists and physicists in general had travelled before this definite qualitative knowledge resulted. Three different important discoveries had been made previously, more of a quantitative than a qualitative character.

- (1) The law of conservation of mass, or rather of substance (since the conception of mass may have to be changed in the light of Sir J. J. Thomson's explanations).
- (2) The law of conservation of energy.
- (3) The law of dissipation of free energy.

Whilst these three laws had given great impetus to applications, it required a qualitative explanation, such as the one put forward so far in its clearest form by Sir J. J. Thomson, to understand fully and connect the facts which are expressed by these laws. In the light of these explanations, the world is the field of the electrical engineer.

Electricity, its corpuscles* and their movements, the youngest child of natural science as we know it, must be recognized as the mother of all others: optics, dynamics, chemistry, perhaps of psychology, biology. The increased efficiency that this means to all these branches of studies, if they can work in parallel paths, with the same foundation, and with the help of constant analogies, is obvious, and the future even more than the past will show this advantage; but the achievement of a common basis, together with the laws mentioned above, and other quantitative results such as those obtained by Faraday, Ampère, Ohm, Kirchhoff, and Kelvin, not only give us the advantage of parallel working and of analogy in all these schools, but also the connecting link, the actual possibility of transformation, its mechanism, and its laws.

They enable us, first, to transform all forms of energy into one another; secondly, to transform combinations of elements, and permit us to hope that one day we may even (if we have not already done so) transform the so-called elements; and thirdly, to make use of the available free energy in whatever form we like.

If we turn to applications, this means that we possess in certain places, bound to certain materials, forms of energy which on account of our recognition that all energy is of an electrical nature, we should be able to make use of, as, when, and in whatever form we require.

Now it happens that for this particular purpose electrical energy in its narrower sense is more suitable than any other known form of energy. Let us see why. We have certain energies in the world, in certain localities, running to waste, i.e. being transformed into bound energy. Most of these energies originally go back to the radiation energy of the sun. Radiation energy evaporates water and carries it to certain altitudes, transforms it into the kinetic energy of our rivers, and is stored and transformed into the chemical energy of coal, of oil, and of organic substances. The supply of these energies, and of wind, tides, etc., is available in definite districts. Human habitations and the stores of other materials where energy may be required are in different places, since they have been laid down or accumulated without consideration to "available free energy."

Human society to-day requires these energies in order to apply them as light, heat, chemical energy, mechanical energy. Therefore it has either to transplant itself to these sources, or to transport the available free energy.

Corpuscular energy is most suitable for this purpose.

- (1) Because the available source can be conveniently transformed and electrical energy generated.
- (2) Because electrons are the lightest carriers of electrical energy known, and therefore the easiest to transport; or, differently expressed, they carry a maximum amount of energy per volume of weight, and are therefore the most convenient form of energy carriers.
- (3) Electrical energy can be re-transformed in a most convenient way into all the various forms of energy used by mankind.
- (4) Electrical energy, as an intermediary to the other forms, allows us to store energy in a more convenient and more efficient way than would otherwise be possible.

If therefore, on account of these facts, it is possible to use the limited amount of free energy which is running to waste in our solar system, independent of its position (by transmitting it) and time (by storing it) we have one of the most valuable results and achievements for mankind.

The four advantages shown lead us to the most important fields of electrical engineering, in its narrower sense, to electrical generation, electrical transmission, electrical re-transformation, or application to motive power, heat, lighting, and chemical processes, and finally to electrical storage.

(1) GENERATION.

We have shown that the solar energy is available for use either in the form of kinetic energy in our rivers or in the form of chemical energy in plants and other organic substances, the one running to waste all the time (*i.e.* being transformed into bound energy), the other one stored. Where kinetic energy is available, as in water and wind, the transformation into electric energy is ideal. The efficiency of the process of transformation is fairly high, and the capital outlay, especially where high velocity can be obtained, comparatively low (with the exception of tidal works where large masses have to be employed, since the potential energy per volume is small). Efficiencies of say 90 per cent can be commercially obtained.

Where chemical energy has to be transformed, the efficiency of transformation is still low, and it is to be hoped that in time either some more efficient mechanism of transformation may be found, or that it may be possible to transform the energy of radiation direct into electrical energy, without the intermediate steps of heat and mechanical energy, each one of which is of course a source of loss. The direct transformation of chemical into electrical energy through primary cells, and of heat into electrical energy by thermo batteries, whilst useful for specialized purposes, is, on account of the relatively small energies which come into play, of secondary importance.

(2) TRANSMISSION.

The transmission of electrical energy can be accomplished with a higher efficiency than that of any other form of energy (except electromagnetic radiation). We can construct transmission lines 50 or 100 miles long having 85 to 90 per cent efficiency, and we could transmit electrical energy over still greater distances if free energy became so scarce that a higher capital outlay for the transmission line would be advisable. The only alternative, transmission by radiation, whilst practicable and carried out for small amounts of energy, is yet impracticable for large quantities, for the same reason that light cannot be transformed conveniently into electrical energy, *i.e.* because an efficient mechanism of transformation has not yet been discovered. An excellent potential field for research is here open.

(3) APPLICATION.

The re-transformation of electrical energy into other forms of energy is to-day so well known that energy can be obtained in all the forms in which we can apply it.

Light.—This is produced relatively with efficiency, since we can conveniently obtain high temperatures at which the ratio of light rays to heat rays is great, *i.e.* the transformation losses are low. We produce it cheaply because of the low losses in transmission and transformation; furthermore,

because the method of starting and stopping is simple, can be carried out at a minimum cost, and can be effected by remote control. We produce light without the bad influence on human organisms exercised by all other methods which rely on the oxidization process. It is clear that these facts make us work more efficiently, independent of movement of the sun, *i.e.* of day and night; they also obviate to a certain extent the differences between the seasons in countries of high latitude, increase our efficiency for work indoors and underground, and prolong in general the time of work and of life under suitable sanitary conditions.

Heat.—As in the case of light, heat is produced without creating fumes, without a long period for starting and stopping, with the possibility of remote control and of easy, simple, and efficient regulation. For domestic purposes of heating and cooking we are only at the beginning of the development. For industrial purposes, it need only be stated that electrical energy, beside the advantages already mentioned, allows us to produce higher temperatures than by any other known means, and that it allows us to concentrate heat on limited areas better than in any other known manner. Electrode furnaces and induction furnaces were developed to apply heat in this way. This knowledge has given us a new metal in aluminium, and has enabled us to produce high-class steel electrically, to melt quartz, to manufacture calcium carbide, carborundum, and graphite, and to fuse and weld metal. It has presented us with all the advantages connected with the application of these materials in their new or cheapened form, and has therefore resulted in their more general use.

Chemical energy.—By passing the current into solutions containing copper, silver, and gold, these metals are refined. We are able to reduce them from low-grade ores, by electrolytic methods, such as gold by the cyanide process. The great increases in the industrial consumption of such metals, for instance of copper (42,000 tons in 1870 to 700,000 tons in 1907, with a price reduction from £105 in 1870 to £65 per ton in 1907), have only been rendered possible because electro-chemistry allowed us to work up lower-grade deposits of copper by economic methods. Zinc and lead are produced in a similar way.

Gold, silver, and copper can be deposited by means of the electric current: the origin of the plating industry. We produce oxygen and hydrogen for oxidizing or reducing processes in connection with numerous industrial applications, like the bleaching of cotton and paper, and for sterilization purposes. By electrolytic processes we produce caustic soda. We separate the nitrogen out of the air and make nitrates to fertilize the soil. We produce chemical energy for the growth of those plants which we can assimilate in our human organism, so as to replace the free energy which we spend—a long row of energy transformations this last series—from the corpuscle energy which in the electric arc combines nitrogen and oxygen from the air, until it becomes mental or muscular energy in our body.

Only when we look closely into transformations of energy such as that just mentioned, does it become clear to us that such a series of immensely complicated transformations can only be performed by extremely fine transmission apparatus, with energies highly concentrated in small masses, and that the dynamic energy of larger

masses could hardly undergo such transformations without great loss and consequent inefficiency.

Mechanical power.—The transformation of electric energy into mechanical energy leads us into practically every sphere of human activity. This field is so well known that there is hardly any need to go into details.

Electrical energy allows us to concentrate on practically any point larger amounts of mechanical energy than would otherwise be possible. It makes us independent of position. We can apply it underground, under water, or in an inert atmosphere. On the other hand it gives us the immense advantage of sub-dividing power into small units and applying it at the exact spot where the energy is required, without necessitating great expense and without inefficient mechanical transmission apparatus. In addition to the possibility of concentration of power and of decentralization, are the advantages of instantaneous starting and stopping and very easy regulation, which mean increased efficiency.

The effects of these advantages cannot be adequately dealt with here. They have resulted in a very great increase of output from coal-bearing areas, and a huge extension in the areas worked, at the same time in a cheapening of the coal produced. They have led to an enormous increase in the production of iron and steel and in a cheapening of production, and have also resulted in a large increase of production in the cotton industry, in improvement of the uniformity of the product, and in the cheapening of it.

The broad effect, however, is that they have produced an immense cheapening of raw material and of finished products, such as necessities like food, clothing, and tools, and also of luxuries.

The next result of the cheapening of these commodities consisted in increasing the individual and average comfort of living in producing centres.

A third result is following from the application of electrical energy for transport purposes. Electrical energy has the advantage over other forms of energy for use on cranes, as well as on tramways and railways, that the carrying of energy does not mean the carrying of large weights of material, that it allows the use of higher speeds and the possibility of regeneration.

The two advantages already mentioned, namely, decreased cost of necessities and luxuries, and consequently increased individual and average comfort of living in producing centres, were thus extended to a wider and wider area, rendering possible the growth of our cities and equalizing living conditions in town and country, in countries of different climatic conditions, in countries of old civilization, and in uncivilized territories.

This consideration concludes the series of advantages which electrical engineering gives us, by enabling us to make better use of the material and the energies available in the universe.

It leads us to the next civilizing influence which was mentioned before, namely, that electrical engineering fulfils its mission if it can be shown that it increases the space which can be inhabited and made use of by mankind. Given a definite number of human beings, the increased rapidity of locomotion to which I have referred has the effect of decreasing distances, thus increasing the radius of action of every human being. But electricity does more.

Since it allows us conveniently to transform available energy, it is a great equalizer. It allows us to produce lower temperatures in hot climates and heat in cold areas, it enables us to irrigate dry territories and thereby bring them under cultivation, and it allows us to build canals and recover swamps. Activity of this kind is going on all over the world—for example, in India, and on the Panama Canal—resulting everywhere in better living conditions and in increasing the area which can be inhabited by man.

Electrical engineering is a factor in civilization. I come to the last point but one on page 265—if it increases the physical or mental power and the efficiency of the senses of the individual. Each school of science fulfils this object, and electrical engineering, as we know it, must do so in a, I should say, greater, but certainly not in a less degree than the others.

Without knowledge of matter and energy, *i.e.* without the knowledge of their application, in which is bound up practically the whole of the activity and the organization of modern society, an efficient grasp of the problems of the world, of life, and of society seems impossible. This shows us that in our profession we have arrived at a stage where it is impossible to keep our knowledge as that of a caste, where it is essential that its fundamentals should and must become matters of general knowledge—as in previous periods the knowledge of carrying arms, of handicraft, of ethics, and of reading and writing, all originally known to a few, had to be distributed broadcast when it became evident that they mattered more than anything else for life and progress.

Having shown that the knowledge of electrical matters to-day has become essential in order to understand matter, energy, and their manifestations, and that knowledge of these matters necessarily increases the general efficiency of the individual, I must add one other reason why electrical engineering and knowledge of it increases the individual mental and physical power and efficiency.

I come to the influence of electricity on living organisms. This field is still rather undeveloped, in regard both to theory and to application of theory. Biology and psychology are relatively young branches of science. It is only recently that, as Sir Oliver Lodge says, "we had to grasp that for all terrestrial manifestations of life, the ordinary physical and chemical processes have to serve. There are not new laws for living matter and old ones for dead organisms. The conservation of energy, the laws of chemical combination, and the laws of electric current and of radiation may be applied without hesitation in the organic domain."

It is clear that if the theory of corpuscles helps us to understand what we call dead organisms, it will help us to understand the living ones in all their manifestations.

It may be further assumed that if we have learnt better to understand living organisms, which include our own, such knowledge will help to make us more efficient, either by revealing to us how we are constituted, by showing us how we can remove obstacles and harmful resistances from our own development, or by indicating how positive results can be achieved by us. I do not propose to enter into the controversy that rages round vitalism. It is certain that a number of the theories which have been propounded are not yet definitely proved, but it is equally certain that the

knowledge of electrical matters and especially the theory of ether, or, as we know it now, of the corpuscle, has enabled us partly to prove existing laws in organic matter, and partly to form pictures, working hypotheses for chains of facts, which otherwise could hardly be understood.

Amongst a few, the mechanism by means of which our senses receive and transmit an external stimulus to the central organ of the brain, and how they respond to an internal stimulus, has been explained. It has been found that the tissues of vegetable and animal matter respond to any external stimulus of heat, radiation, or other electrical or mechanical energy in a definite way, which, if not constituted, is at any rate accompanied by a movement of corpuscles, a movement that can be galvanometrically measured. The influence of strength of stimulus as producing a definite strength of sensation, positive or negative, its change with the dying of the tissue, its alteration when conductivity is altered by anaesthetics, and its strength when produced by internal energy of the human body as against an external one, have been ascertained, and in this way we have definitely established some laws, showing that in the human body the receiving and transmitting mechanisms are of partly electrical nature. There are scientists who go so far as to say that they consider all processes of living matter are produced by corpuscles, such as growth, contraction of muscles, genesis, etc., or, as Arrhenius says, "It is the ions which work, they produce contraction in heart and muscle." Biologists and psychologists have actually explained memory, inheritance, and telepathy, by means of the vibration of electrical corpuscles, and if these explanations are far from conclusive, it must be confessed that they give a better picture of the facts than any other yet in existence. If through this better understanding, only some of the factors that influence these phenomena can be definitely ascertained in regard to quantity or quality, and be thereby made amenable to our influence, an immense vista of new tasks would be in front of electrical engineering.

Electrical engineering in mastering matter is trying to probe into the mechanism of living organism and into problems which concern the human body and mind. In every result which they have achieved, and in every further one that they may unravel, these endeavours mean an increase in the efficiency of the individual.

I have thus already started on the last proof that I have to give for the mission of electrical engineering, namely, its influence on improving the collective efficiency of mankind. It is clear that the last-mentioned problems are of as much importance for human society and its efficiency as for the individual.

I have shown that electrical engineering has acted as a great, perhaps the greatest, democratizing agent. It has taught us to make full use of the materials and energies available, and thus, on the one hand by cheap production, and on the other by cheap transportation, has made commodities and tools, which were the properties of the few, the tools and properties of the masses of mankind.

Its second influence consisted in replacing an ever-increasing extent manual labour by other available energies, thus conferring a further boon on mankind by allowing us to spend our energy more and more in a form which we are allowed to call a higher one—mental energy. The very great progress in science during the last century is largely due to this fact. Science and knowledge, through

this emancipation of mental energy, have become, from the labour of the few, the labour of many.

In conclusion, I wish to refer to a third factor contributing to the efficiency of the human race. This efficiency, as has been already pointed out, greatly depends on the universal spreading of knowledge or experience that has been gained by individuals either in theory or application. Such knowledge originally adhered to the individual until language enabled him to communicate with his fellow-men, until the written, and later on the printed sign allowed him to hand it over to a greater and greater number. To-day, the knowledge of one individual can be within an hour the knowledge of mankind in all distant parts of the globe. The transmission of messages by electric currents in a cable or by radiation in wireless telegraphy has removed the time factor and the factor of distance in the spreading of knowledge throughout the universe.

Though the picture is not complete, I think I have shown that electrical engineering has led to a better understanding, a more extended and a more efficient use of nearly all existing matter and energy. It has led to a better understanding of animal and human organisms and problems. It has bridged space and time and minimized their influence where they become resistance factors against energies mental and physical, it has increased the efficiency of individuals and of society, and it has therefore established its claim to be one of the most valuable factors in the progress of mankind.

For the electrical engineer, however small and however unimportant his specialized work may often appear to him to be, this knowledge should be a profound source of satisfaction and happiness and a spur to increased activity. Happiness, if we look at it purely from the energy point of view, should of necessity be such a spur. It acts as a tonic, that is, either in the form of better conductivity between the brain centres or in our receiving apparatus of nerves, or in our electromechanical transformer of muscles, or in general as a better efficiency of all the energies which we accumulate in our system and which we spend mentally and physically.

Happiness has been defined as the product of human energy spent and progress (positive or negative) achieved by an individual or a class.

The knowledge of what as a class we have accomplished should therefore act as a stimulant to further work. Whilst we have as a definite achievement a picture which describes the world—matter in all its variations—much remains to be cleared up, from the structure of the atom, the mechanism of the corpuscle, and the problem of continuity which Sir Oliver Lodge has put before us, to the knowledge of the mechanism of the transforming apparatus for the various energies and the actual construction of such apparatus. Much also remains to be done from the design of machinery for the increased concentration of energy in all its forms to the design of machinery for the thousand-and-one forms, applications for which we have to specialize so as to embrace an ever-increasing knowledge, and to study an ever-increasing variety of applications of that all-pervading substance which we call electricity, ether, corpuscle, and which forms and means the universe.

In this sense the profession of electrical engineering, the history which led up to it, the tasks which it has accomplished, and the problems which it still has to conquer, should be understood.