POWER DEVELOPMENT.

Marvellous Progress Outlined.

Industrial and Social Possibilities.

Masterly Review by Sir John Monash.

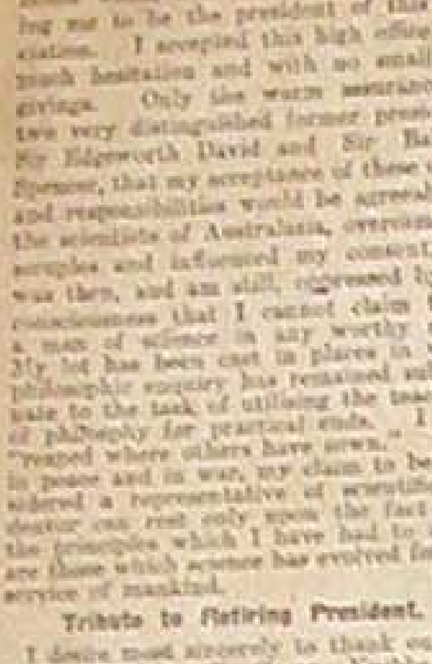
Like a fairy tale in interest and romance was the story of the advance in power development and its future possibilities as unfolded by Sir John Monash in his presidential address last night to the Adelaide meeting of the Australasian Association for the Advancement of Science.

After having been declared president by the retiring president (Sir George Knibbs), Sir John Monash said:—

My first duty is to try to convey to you my deep appreciation of the coveted honor which has been done me in electing me to be the president of this association. I accepted this high office with much hesitation and with no small misgivings. Only the warm assurances of two very distinguished former presidents, Sir Edgeworth David and Sir Baldwin Spencer, that my acceptance of these duties and responsibilities would be agreeable to the scientists of Australasia, overcame my scruples and influenced my consent. I was then, and am still, oppressed by the consciousness that I cannot claim to be a man of science in any worthy sense. My lot has been cast in places in which philosophic enquiry has remained subordinate to the task of utilising the teachings of philosophy for practical ends. I have "reaped where others have sown." Both in peace and in war, my claim to be considered a representative of scientific endeavor can rest only upon the fact that the principles which I have had to apply are those which science has evolved for the service of mankind.

Tribute to Retiring President.

I desire most sincerely to thank our retiring president, Sir George Knibbs, for the generous terms in which he has this evening so graciously introduced me. It shall be my very earnest endeavor to discharge worthily the duties of the office which he has just vacated, and to emulate the example of so illustrious a predecessor.



Sir John Monash.

There is no man who has rendered such great and continuous services to this association. He has been a member from its birth 30 years ago. He has been its vice-president for fourteen successive years and he has, for the term of his occupancy, adorned and rendered notable the presidential office.

Sir George Knibbs stands in the esteem of the world of science and learning in an unchallengeable position. His profound erudition, his graceful culture, his eloquent discourse, and his wide and valuable scientific labors make up that charming personality which has commanded the admiration, the respect, and the affection of his generation. It would, indeed, be difficult, as it is entirely unnecessary, to recite in adequate terms the tale of his life of service to the nation and to science, of the innumerable scientific bodies which claim the privilege of his membership, and of the products of his fertile mind and fruitful pen.

The Commonwealth Institute of Science and Industry, of which he is the director, was launched with a high promise of fulfilment, an expectation confirmed by the acceptance by Sir George Knibbs of its leadership. But the short-sighted neglect of successive Governments to make financial provision even for the bare statutory functions of the institute have falsified the hope that under such able guidance it would become a source of varied and useful output of scientific knowledge and an inspiration to our scientific workers. Sir George Knibbs has himself, with no uncertain voice, made clear the opportunities thus lost to Australia. We can but hope that, in course of time, a more educated public opinion will bear fruit in an adequate endowment by the State, in this and in other fields, of that pursuit of science, which is, beyond dispute, the greatest social force in modern civilisation. Although we cannot hope to overtake the lead given by the wealthy and populous nations of the Northern Hemisphere, yet, surely the people of these southern Dominions, when they realise the importance of science to their progress, will be unwilling that they should lag this far behind their notable performance in so many other fields. (Applause.)

The Search For Truth.

I take this opportunity also, on behalf of the association, to express to the people of Adelaide, and of this State, our warmest thanks for the ready and considerate hospitality, in so many quarters, which has already assured the success of this meeting and the comfort and pleasure of all the visiting members. It is seventeen years since the association held its meeting in this city. The world has, in the interval, passed through a fiery ordeal, and the free interchange of thought between men of science among the nations has been, for some years, rudely interrupted. But science is cosmopolitan; the search for truth knows no international boundaries. And so we may hope that, as the echoes of the Great War die away, the people of the earth will again, as in the old days, reap the benefit of a world-wide community of thought and purpose in the task of wresting the secrets from Nature.

I desire, in this place, to express the acknowledgments of this association to Professor A. Liversidge, now of Kingston Hill, in Surrey, and to Professor Sir William Bragg, formerly of Adelaide, and now of the University of London, for their ready response to our request that they should represent this body at the meeting of the British Association for the Advancement of Science, which was held in Liverpool last year. Both gentlemen have been presidents of this association; and both have rendered to it distinguished services throughout many years. We are glad to know that, in the recent gathering of our parent body, we, of the Antipodes, were actively represented by these distinguished men.

Recognition is also due to the American Association for the Advancement of Science for its kind and helpful action in making available to us a complete copy of its literature, which includes its periodical named "Science."

Since the last meeting of this association, at Wellington, the outstanding science happening in Australia has been the Pan-Pacific Congress in Melbourne and Sydney last year, the great success of which was undoubtedly due to the preparatory work done at Wellington.

The Great Barrier Reef.

Although it is not a subject to enter upon in detail, I should like, nevertheless, briefly to direct the attention, and enlist the sympathies of, the members of this association, and the Australasian public generally, to a highly important and essentially Australian field of science research which has been opened up in something more than a theoretical manner since our last meeting. I refer to the formation of the Great Barrier Reef Committee, at the head of which His Excellency Sir Matthew Nathan has been placed in anything but a nominal capacity.

The Great Barrier Reef is unique; and it is of such surpassing interest and value that it should be studied exhaustively. It is a great coral mass possessing many products of high commercial value, such as pearl, tortoise and other shell; beche-de-mer, sponges, and the like, as well as, very probably, fish food on a vast scale. The causation and the adaptation of these resources to serve human needs are worthy subjects of study, and present many problems to the geologist, the zoologist, and physiographer. The coral reef, the coral islands, the adjacent continental coast line, and the intervening lagoons, and their fauna, are awaiting scientific exploration on a substantial scale.

POWER DEVELOPMENT.

At our last meeting, in New Zealand, our retiring president, Sir George Knibbs, delighted us, in his presidential address, entitled "Science and its Service to Man," with a learned and masterly survey of the recent progress of scientific investigation and development in very many fields. That was barely eighteen months ago. To follow so able an exponent on similar lines—even were I qualified to do so—would add little that is new to that very brilliant contribution. Remembering, however, that one of the purposes of this association is to familiarise the general public with the achievement of science, and to create a widespread interest in scientific progress and in the patient investigations from which it springs, it has seemed to me that it would not be inappropriate to attempt, upon this occasion, an exposition of the practical application of scientific discoveries, in a particular field of human endeavor which has become of paramount importance to the progress of civilisation. I refer to "Power Development." And I undertake this task with the greater temerity because, as you have been told, it has been my fortunate task, in post-war days, to assume the direction of a great undertaking of this nature, in my native State of Victoria, and to labor in a field of applied science, of which a phenomenally rapid progress has been the chief attribute.

Electricity is a branch of physics: but many other sciences are its hand-maidens. It would indeed be difficult to instance any other department of science in which abstract research and experimental investigation have led so repeatedly, and with such convincing directness, to practical advancement.

THE SERVITOR OF HUMANITY.

Electric energy has become the servitor of humanity. Its utility is assuredly destined to expand until it may even dominate future civilisation. In the course of a single generation we have witnessed the almost complete obliteration of a social and economic condition which was thought to have been the acme of progress. Factories, industrial plants and workshops, belching forth pollution through forests of chimney stacks, are almost a thing of the past. Those which still survive are rightly deemed an anachronism. The horse-drawn tram, only very recently thought to be an indispensable public utility, has become a relic of the past. The days of the steam-railway-locomotive are numbered. Electro-chemical and electro-metallurgical processes, entirely unheard of a bare decade or two ago, have superseded methods then looked upon as fully perfected. Motive power in almost every form has become the offspring of electricity. Even our homes have been invaded, and the conditions of domestic life have been wholly transformed. The civilised world is becoming, by a process of gradual penetration, steadily, but none the less surely, electrified. (Applause.) And, moreover, these master strokes of progress have been delivered silently, insidiously and relentlessly. All the physical sciences have at every stage made their contribution to each successive advance. Each advance has stimulated fresh enquiry, and has become the "jumping-off line" for another forward bound.

IMAGINATION BAFFLED.

In the light of the transformation which has taken place within the short period of a quarter of a century, the imagination is completely baffled in any attempt to foresee—with convincing sureness—the influence which the development of electric power may have upon society in the next decade or two. The speculations which were announced during the closing years of last century, as to the approaching broadcast use of this new form of energy—arrestingly fertile as they were—have been completely falsified. Nor could it have been foreseen how the whole social fabric and every phase of human activity would have become transformed. The history of past experience and the future possibilities of electric power development, present, in short, a fascinating and an inspiring example of the intense application in the industrial field, of the knowledge won in many departments of pure science, by many great thinkers and by an army of patient investigators.

A brief reference to the outstanding events in this short, but eventful story will, perhaps, afford the best introduction to a more detailed examination of the position which we have reached in power development, and of the technical and economic considerations upon which it rests.

GROWTH OF CONSUMPTION.

Sir John here dealt with definitions and referring to the growth of the consumption of electricity continued:—

The application of electricity to the service of man began, on a modest scale, and with a very restricted scope, in Europe and America, 40 years ago. There are many still living who can remember the first serious entrance of electricity into our social structure. Scientific research had not then progressed beyond the point where it had been found to be possible to generate a direct current by the use of electro-magnetic machines known as "dynamos," and to transmit same, by the aid of metallic conductors, for limited distances, and with indifferent efficiency. The requisite motive power was provided by small steam engines of the reciprocating type, and was at first applied in a primitive manner by belt drive. The use of the current so produced was confined, for some years, to lighting purposes in restricted city areas, in isolated buildings, and in groups of shops. The forms of electric lamps then employed have long ago been superseded as woefully inefficient.

BEYOND EXPECTATIONS.

We are justified in saying that these numerous and diverse applications of electricity have already reached proportions far beyond the expectations of the most sanguine thinkers of 20 years ago. This will be the more readily accepted when I make, later, a brief commentary upon the latest available statistics of the consumption of electrical energy throughout the civilised world. It is, nevertheless, justifiable to assume that, apart from the increase to be expected from the growth of population, the "saturation point," or limit of electrical application (measured by the consumption of electrical energy per capita per annum) is yet far off, and has not been even remotely approached in any single country. If such an assumption is justified, it is plain that a vast preparation must be made for the future. (Applause.)

It is not difficult, in the light of available data and experience, to speculate upon a figure of consumption likely to be reached by a civilised community of the first rank, when the present rapid expansion of the use of electricity has reached a larger measure of development of service for the then existing population. The following are estimates of annual consumption which, it appears to me, will quite probably be reached, at any rate in capital cities, and in industrialised areas, in the not distant future:—

Domestic uses (light, warmth, power, cooking), 443 units.

Public lighting, 10 units.

Commercial (light, warmth, elevators), 40 units.

Industrial (mechanical power), 400 units.

Transportation (railways and tramways), 150 units.

Total, 1,043 units, or, say roundly, 1,000 units per head of population per annum. In this estimate I have taken no account of such great users of electric energy which are coming into this field, as the electro-chemical industries, such as those which deal with the fixation of nitrogen from the atmosphere, or those which produce carborundum, carbide, aluminium, chlorine, electrolytic copper, electrolytic zinc, and the like—some of which have already found a home in Australia. Nor have I made any special reference to the use of electricity for farm power. But it requires no great imagination to visualise the possibility of the application of electric energy to almost every form of agricultural procedure, and such developed uses may readily, in course of time, lead to a rural consumption, at least as intense, when measured at per head of population, as that envisaged for the dwellers in the larger communities.

DEMAND IN AUSTRALIA.

Let us see whither these considerations will lead us. If we assume the population of Australia at roundly six millions, and further assume, what is true for all practical purposes, that population to be so distributed that the great majority will exist within the sphere of influence of an electric supply system, it will be seen that the visible prospective consumption of electrical energy, by the present population of the Commonwealth, amounts to close upon 6,000 million "units" per annum. If we further assume that this consumption represents the use of the maximum load during as much as 12 hours in each day (which is a very conservative assumption), the "maximum demand" upon the whole of the electric supply systems of Australia will then have reached over one and one quarter million kilowatts, that is to say, that generating plant of that available capacity will have had to be provided. When it is remembered that these figures are based only upon the present population of the Commonwealth, some idea may be gathered of the magnitude of the problems which will confront the electrical engineers of this country when our population has expanded to numbers adequate to the capacity of the continent.

Taking, as an example, the State of Victoria, whose population is so disposed that almost the whole of it lies within the economic range of centralised electric supply, then the total installation which would be required in order to meet a consumption of the order speculated upon, would amount to a capacity of 370,000 kilowatts, or, roundly, half a million horsepower. This figure is more than three times the total capacity of all generating plants at present available or under construction in that State. Here, then, is a development problem of first-class magnitude in both its engineering and financial aspects.

The conclusion is obvious that the immediate attention of scientists, engineers and statesmen is required to the problem of satisfying the demands for electric services which is confronting Australia; that we must evolve far-reaching plans for meeting the situation; and that we shall have to take exhaustive stock of our various resources for power production and estimate their respective extent and capacity.

Sources of Power.

Until very recent times, man had few sources of power beyond himself. These few, known since the dawn of history, were confined to his beasts of burden, to a limited and very local use of flowing streams for turning his mill-wheels, and to the precarious wind for grinding his corn. To a relatively small extent, fuel was used to produce light and heat; but its transportation in large quantities and over long distances was practically unknown. The invention of steam-power began the revolution, and ushered in the era of mechanism. Energy in a transportable form then became essential to the convenient conduct of human affairs, but the only form of energy which has been available to us, until very recent times, for the purpose of such transportation, has been the chemical energy stored in fuel.

Throughout all the ages, and until the very end of the nineteenth century, the potential energy of a bounteous rainfall had, in default of our ability to effect its transportation, remained unavailable. It was the growth of electrical science which transformed the situation. By its aid, the transportation of energy, by the transference of fuel from its source to the place of its utilisation, is steadily giving place to the transmission of energy through the medium of the electric current.

Water and Fuel.

The two great sources from which, therefore, the world's requirements of electrical energy can be drawn, are water and fuel of all grades. A competition between these respective sources necessarily arises, and it is appropriate to compare both the extent to which they are available, and their relative economy.

Much popular misapprehension exists upon both questions, particularly in Australia. It seems a fascinating proposition to harness the water sources of energy because the necessary machinery can operate with little labor and therefore at a minimum of cost, and because the utilisation of river water for power generation does not diminish its quantity in the same manner as does the combustion of fuel; and because, therefore, by the use of water power, the world's available resources are in no way diminished.

Both propositions are misleading. Water-power is not necessarily, nor even generally, cheaper than heat-power. Nor can the whole available water-power resources of the world provide, even fractionally, for the ultimate needs of mankind.

There is adequate authority for the estimate that the whole available water-power of the world does not exceed 500 million horse-power. This amounts to about one-third of one horse-power per head of the world's present population. Australia's share of this, excluding Tasmania, has been competently assessed at not more than one million horse-power, which, with the present population of, roundly, six millions, gives a result which is about one-half of the average water horse-power per capita of the world's available supply. It is clear that Australia must look principally to its fuel resources to meet the all-important demands for energy which are developing.

Definite Limitations.

There are, moreover, other considerations which must be kept in view, and these are of special significance in Australia. There is always a wide disparity in the volume of the flow of streams, as between the rainy and the dry seasons of the year. In some countries, and particularly in Australia, this disparity is very wide indeed. Hydro-electric schemes, to be of any great practical value for the complete service of any given community, must be capable of producing an almost constant output of electrical energy during the whole period of every day of the year; because the seasonal fluctuations in the public demand are not so great.

If, therefore, any schemes of supply were to be based upon the minimum summer flow of the stream in question, the total production of energy from that river would be only a small fraction of the total which it could yield throughout the year. If, on the other hand, the scheme were based upon the average annual flow, then extensive works of water conservation would be necessary in order to store the surplus water of the wet months to make up the deficiency of the dry months. Such conservation works are always costly, and often [illegible], and there are many instances where, owing to the absence of favorable topographical conditions, storages of the requisite capacity are not, and cannot be made, available.

It will be seen, therefore, that there are very definite limitations to the extent to which the potential energy of the rain and snow fall upon high lands can be harnessed either at all, or at such a reasonable cost that the resulting energy can compete commercially with fuel-power. These limitations are especially severe in Continental Australia. The continental stream flow conditions bear no analogy to those of the Great Lakes scheme in Tasmania, or to the extensive hydraulic resources of New Zealand, or to the huge hydro-schemes associated with the falls of Niagara. That is why the energetic advocacy (by a section of the community interested) of the development of hydro-electric schemes in Victoria, in preference to the development of huge power stations based upon that State's very extensive brown coal deposits, is doomed to failure.

Fuel Resources.

As regards the world's fuel resources, estimates have been made from time to time of the visible supply, but these have been repeatedly falsified, not only by the discovery of new resources, but also by the consideration already referred to, that low-grade fuels, formerly ignored as of little practicable commercial value, must nowadays be taken into serious account. In short, the limits of the world's total fuel resources are not known and cannot be even approximately surmised.

As to actual production of fuel in the form of coal, lignite, and fuel-oil, there has been no material increase throughout the world in recent years. Since the war, the world's annual production of fuel of all classes has ranged about 1,200 million tons per annum. To this total the three principal coal-producing countries have contributed, on the average over the last four years, as follows:—

Country.	Million tons.	Per cent.
United States	[illegible]	33
Germany	[illegible]	22
United Kingdom ..	[illegible]	21

Australia's contribution to the total was 13 million tons, or 1 per cent.

It is interesting to note that the fuel produced in Germany comprised black coal and lignites in almost equal proportions, although the output of lignite in that country is rapidly overhauling and outdistancing that of black coal, as the following figures will show—The increase in the consumption of electricity in Germany, from 1914 to 1922, was 3.2 times. In the same period the increase in that portion of this supply which was generated by the use of black coal was 2.5 times, while in that generated from brown coal the increase was 5.1 times. This growing ascendancy of brown over black coal is due not to any deficiency of supplies of the latter, but because the methods of production and utilisation of the brown coal—though of relatively poor grade—enable it successfully to compete commercially with black coal.

Peak of Production.

Indeed, when the climax of the electrical era has been reached, that is, when the possibilities of serving human needs, by the exclusive use of electric energy have reached their maximum, the demand for electricity is likely to exceed, by many times, the most sanguine expectations of to-day.

This revolution in our treatment of fuel energy resources, which, as has been said, is developing with accumulating force, from year to year, is based not merely upon the greater convenience, flexibility, and labor economy which electricity brings in its train, but also upon the motive of economising those resources. It is not improbable that the proportion of the world's population which is employed in mining for fuel has reached a maximum, and that therefore the peak of production of fuel energy, in the "raw" form of coal and oil, has been reached. I have already indicated that this production has been practically stationary for the last five years. The only hope, then, of meeting our increasing future needs is by seeking and practising methods of far greater economy than are in use at present. These economies lie in two entirely distinct directions, firstly, in lowering the cost of production of fuel by an ever-increasing substitution of mechanical processes for physical labor in the winning of the fuel; and secondly, in a progressive increase in fuel economy by improvements in furnace, boiler, and turbine efficiency, or the possible discovery of means for converting the chemical energy of fuel direct into electric energy. Here, surely, is a fascinating field of research for the physicist, the chemist, and the engineer.

Experience in the United States.

A forecast of the future requirements of energy in Australia may be conveniently based upon the actual experience of the United States. In that country, the production of black coal per capita per annum was in 1850 one-half of one ton. It rose comparatively slowly in succeeding decades, until in 1890 it had reached 2½ tons per capita per annum. This is a little more than the production of Australia at the present day. By 1900 it had risen, in the United States, to 3½ tons, in 1910 to 5½ tons, and in 1920 to 6½ tons of black coal per capita per annum. If we look forward to the time when the population of Australia will have reached 30,000,000, and if we assume that by that time our continent shall have reached a demand per capita no greater than that of the United States to-day, then we must predict that our population will then require the production of energy amounting to the equivalent of 200 million tons of black coal per annum. This problem is, happily, already receiving more than casual attention, and it is upon the labors of the scientist, more than upon any other agency, that we must depend for meeting the imperative requirements of our future state.

Fuel Economy.

The president drew attention to the more technical aspects of this subject, and said the two major problems were, firstly the economic production or generation of electrical energy, and secondly, its transmission to the places of its use. He dealt in an interesting way with the subject of fuel economy and said:—

Before leaving the subject of heat energy, mention should be made of developments in pre-treatment of the fuel itself. The pulverisation of coal, and its introduction in a pulverised form into the furnace by means of a jet of air, has received a considerable impetus during the last six or seven years. By such means, it has been found possible to produce economic results with fuels which had often previously to be discarded. Indeed, even in locations where high-grade fuel is obtainable, there are some notable instances of power stations employing pulverised fuel with commercial advantage, in spite of the high cost of its preparation. The resulting advantages of flexibility in operation and closeness of regulation have led to particularly high efficiencies. The whole procedure is analogous to the burning of oil under boilers, which made such great advances during the war, owing to its small bulk for a high heat content.

The net result of researches and experiments now in progress in many countries may well be to cut by half the quantity of fuel consumed per unit of electrical energy generated. Signs are not wanting that the production of fuel, in the most usual form of coal, by underground mining, being an extremely distasteful form of labor, will in future be tolerated only with limitations even more closely drawn. Its increased cost is a symptom of this, and this is a consideration which is exercising a potent influence in directing the energies of many investigators.

To indicate that the labors of electrical engineers have not been fruitless in this direction, I take the following figures from the report of the Electricity Commissioners of the United Kingdom, which were issued as recently as last May. They show that, as compared with the preceding year (1922), the total annual output of electric energy in the United Kingdom disclosed an increase of 11 per cent. over the immediately preceding year, but that the corresponding increase in the total consumption of fuel for the purpose had been only 3 per cent. The average consumption in coal-fired stations had been 3.11 lb. of coal per kilowatt hour in 1922, but only 2.78 lb. of coal per kilowatt hour in 1923, or a saving of 10.6 per cent. within a period of twelve months.

Generation and Transmission.

Much might be said, did space and time permit, of the developments in the design of the generator and of the combined turbo-generator unit. This component part of the system is also variously referred to as the "dynamo," or the "alternator." It is essentially an electro-magnet, that is, an apparatus which provides for the rapid revolution of a closed conductor in a magnetic field, which motion sets up, in the conductor, an electric current. The modern generator is nothing more than a high development of this simple, but epoch-making discovery made nearly a hundred years ago by Michael Faraday, who may be truly honored as the father of the science of electro-magnetism. Suffice it to say that it is in this apparatus that the kinetic energy of the steam turbine, actuated by the heat energy of the steam, is converted into electric energy, capable of instantaneous transmission for hundreds of miles.

It cannot be said there have been any very revolutionary principles in the design of "generators" as practised for the last ten or fifteen years. But, nevertheless, a great amount of effort has been applied to a closer investigation and understanding of the metallic and diverse other materials employed in their construction, which has resulted in definite progress. For example, the production of rustless steel alloys, following upon prolonged laboratory investigation, has placed in the hands of designers a material of very special value. The behaviour of materials both solid and fluid under very high temperatures, when studied by the methods of experimental physics, has been an essential preliminary to the state of the present-day art of manufacturing these plants.

Individual Control.

The time available will not permit of a closer survey of recent progress in the hundred and one minor adjuncts of a modern power scheme. But there is a feature of surpassing interest which deserves particular mention. I refer to the equipment by means of which a whole great system may be controlled at the will of an individual operator.

In a separate building, located in the immediate proximity of the switch-gear of a power-house, or of a switching station, are assembled the paraphernalia of "control." In the control room itself are situated the control panels with their associated bewildering array of automatic measuring and recording instruments, the control bench itself being studded with innumerable keys or plugs like those of some mammoth musical instrument, so that by the touch of delicate finger-tips tens of thousands of horse-power may be manipulated with consummate ease.

The opening and closing, by means of the giant switches already referred to, of circuits carrying high voltages and currents is in itself an operation requiring considerable mechanical force. This force is provided by intermediate electrically-operated mechanism, and it is this latter mechanism which is actuated in the simplest manner, by merely depressing or raising the stops on the "key-board" of the control bench. The control officer has, ready to his hand and eye, the numerous instruments for recording electric pressures, quantities, and performances throughout the whole system. He can observe the temperatures in all the important electrical apparatus of the power-house and the switchyard, both moving and static; he can control the speed and governance of the whole turbo-generator plant. From the boilers to the distant sub-stations of the territory served his sway is supreme. The whole cobweb of distribution is under his command. He is "a modern, impassive Jove, distributing benignant thunderbolts." (Applause.)

The modern control equipment is, in its entirety, a beautiful manifestation of the ingenuity and insight of the human mind, applied, as in this case, not to small or circumscribed purposes, but to the silent manipulation of stupendous forces. The design and manufacture of such equipment is a business of such intricacy that it must necessarily remain in the hands of those very few manufacturing concerns who have the financial strength and enterprise to maintain extensive research laboratories and to employ, continuously, staffs of highly qualified investigators.

Automatic Operation.

We may indulge in a bird's-eye view of power generation as now developed, and may dwell upon its outstanding features. Perhaps the most striking of these are the largely automatic character of the whole operation, and the consideration that its magnitude, at any moment of the day, is under the control, not of the power-house staff or the control engineer, but of the consumers themselves.

If the terminals of an electric circuit are in contact, no current can "flow." It is only by closing the circuit, i.e., colloquially by "switching-on," that a transmission of energy can take place; and only then by the interposition, in the circuit, of an electricity consuming device, such as a lamp, a motor, or a heating unit. All, therefore, that the power-house staff can do towards the generation of energy is to put and keep the generating machinery in motion. So long as the switches of the community served remain open, then so long will the transmission circuit remain inert, even though energised, and no further energy can be generated. The machinery will be running under "no load." But, as and when the consumers, in their collective demands for service, close their switches, then energy will be generated at the power-house automatically and without further intervention by the power-house staff, and in quantity in exact accordance with the consuming power of the totality of the electrical device which have been put into circuit by the consumers, at their own will and pleasure.

The Public Needs.

Though this may seem a triviality to electrical experts, it is nevertheless important for the public to realise that it is they alone, in their multifarious collective needs, and not the authority controlling the generating plant, who actually operate the system, and who determine, from moment to moment, the amount of energy which requires to be generated. This is the very antithesis of the crude belief, so commonly held, that electricity is something in the nature of a commodity, which can be produced beforehand by the generating authority and held available for distribution and sale, like so much merchandise. The truth is that it can be produced only at the precise moment that the user elects to demand it.

When this is grasped, the miracle which has been wrought in this field by the application of science comes out into clearer relief. It is a translation far more wonderful than any that was ever dreamed of by the mediaeval alchemist. A dross and uncleanly substance, such as coal, is transmitted, through several intermediate stages, into energy in a form which can be transmitted for hundreds of miles, and placed at our service for any purpose that we may desire, by the mere pressing of a button.

Human Intervention.

This service is now accomplished with a very minimum of human intervention at any stage of the long and complex chain. The variations in the demand for service from moment to moment automatically vary the load upon, or resistance to be overcome by, the revolving turbine motor. As the load varies, so the valves admitting the steam to the turbine are automatically operated in order to admit more or less steam from the boilers. These, in their turn, make a corresponding demand upon the mechanical stokers for more or less fuel. Human intervention is confined to the mere supervision of the mechanical operations and to the manipulation of the few adjustments occasionally required therein. To exemplify this, it may be mentioned that the generating room of a power-house, capable of an output of, say, 100,000 horsepower, will require at any one time no more than 12 attendants.

It is, indeed, a far cry from the primal pumping engine that Watt devised to drain a Lancashire coal-pit, to the whirring efficiency of the modern turbine plant, snoring along, almost noiselessly, and without appreciable vibration, at a peripheral speed of 500 feet a second.

Economic Questions.

There remain some interesting economic questions which have a very direct bearing upon the industry of power supply and upon the manner in which it must progress in the future. These centre mainly about two significant characteristics of civilised life. The first of these is that the demand by a given community for electric service varies widely throughout the twenty-four hours, and, within narrower limits, throughout the days of the year; the other is that the multifarious needs of the community are extraordinarily diverse in character and in point of time.

It would be a happy state for the electrical engineer if the many and diverse demands for electric service could be so adjusted during the twenty-four hours that at every moment and during every hour the demand upon his plant and equipment would remain uniform. Such a hypothetical condition would provide a "load factor" of 100 per cent. But he finds himself under the necessity of providing capital in the installation of plant on a scale which has [illegible] the peak demand, but [illegible] [illegible] as three times that which could generate the same number of units, if the demand for them could be equally distributed throughout each moment of the day. This disability is naturally reflected in the increased interest charge per unit of electrical energy generated and sold.

Diversity of Demand.

It is to the "diversity" of the public demand that the engineer must look for relief from the possibility that his installation may be called upon to supply, simultaneously, a maximum demand made up of the sum of the separate maximum demands of each of all the individual users. To the extent that the daily needs of the population concur or overlap in point of time, to that extent is the total maximum demand increased. The greater the diversity in point of time, the less will be that total maximum. There are many simple and obvious, and some more subtle phenomena of this diversity. In domestic lighting, for example, there are installed in any one residence many more lamps than are ordinarily simultaneously switched on. On rare occasions, any one householder, by switching on many lamps, may make a maximum demand for service; but the probability that very large numbers of householders, in any one street, or suburb, or power area will simultaneously do this is very remote indeed. This is an example of diversity among members of one and the same class of consumers.

Another example of the same kind may be found among industrial consumers. Factories of one type, such as flour mills, make an almost uniform demand for electric energy throughout the 24 hours. Those of another type, such as iron rolling mills, make sudden large demands, for short periods only, at certain hours of the day; but at different hours for different industries with respect to each other. Then there is diversity as between different classes of consumers. The transportation services are at their maximum, when the lighting services are at their minimum. The special stress upon transportation services, as on the occasion of public holidays, coincides with a considerable cessation of industry.

There is also seasonal diversity. Some industries, especially those associated with agriculture and pasture, are the more active during the summer months, others during the winter months. The more widespread, territorially, are the electrical services drawn from one and the same supply system, the greater the number of separate consumers, and the more varied the occupations of the people—then the greater will be the diversity experienced. And that implies a lessening of the "peak" load, an improvement of the "load factor," and a reduction in the capital investment in generating machinery, and in the earning power of this capital, per head of the population.

An Ambitious Project.

It will be appreciated that the several economic considerations to which I have referred, furnish a cumulative and irresistible argument in favor of co-operation on the largest scale; and of the amalgamation of power supply undertakings, for the express purpose of effecting the electrical linking up of power-houses; and also a rigid standardisation of voltage, phase and frequency, so as to permit of free interchange of electrical energy between the several systems. In this way alone can we achieve the desideratum that an electric supply super-system, covering large territories and serving a large population, may attain the highest practical economies of operation.

So ambitious a project of co-operative effort is in most communities definitely beyond the financial resources of private enterprise. Few authorities, other than the State, can usually provide the finance or the legislative or administrative machinery necessary for the control of such a combination. The inference which I suggest is that in no field of applied science can the principle of State control of a public utility be so effectively supported by technical and scientific considerations as in the matter of power development. (Applause.)

The linking-up of power houses to which I have made frequent reference has already proceeded, upon a considerable scale, in the United States, and a beginning has been made with the application of the same principle in Great Britain. In the State of Victoria something has already been achieved on a modest scale in the same direction. Furthermore, during the last three years, a new and supremely important conception has taken possession of the minds of engineers in the United States. Stimulated by the success of the commercial operation of long-distance transmission lines, operating at the super-pressure of 220,000 volts, and exercised by the difficulties likely soon to confront the world in view of a practically stationary production of fuel in the face of a rapidly expanding demand for power, they have conceived a super-system of generation and distribution, designed to link into one vast network the entire energy producing an energy consuming loci of the whole of the United States. One cannot but be impressed by the boldness and magnificence of such a conception, and by the faith of those engineers in their ability to deal with the incidental problems of the technique of transmission and with the perfection of the requisite regulating machinery.

Australian Conditions.

Present-day conditions in Australia, having regard particularly to the distribution of population, are not favorable to a very extensive application of the principles which have been discussed. The most favored region for early development in these directions is undoubtedly the central portion of the State of Victoria. If, with Melbourne as a centre, a circle, having a radius of, say, 150 miles, be drawn, this circle will enclose a territory having, practically throughout its whole area, a population density sufficient to justify the establishment within it of a super-scheme of linked power-houses of the nature described. Within this region there exist the extensive brown coal deposits of Gippsland and elsewhere, the hydraulic resources of the Goulburn and Kiewa Valleys, already investigated and measured, and the possible further hydraulic resources of the Otway forest, and the Grampians, now under investigation. Base power houses sited in these several regions, together with peak power houses in the metropolis, will some day form an almost ideal combination for the intensified service of the territory in question.

As regards the reticulation of such a territory with trunk, sub-trunk, and branch transmission lines, much depends upon the actual distribution of the population. Apart from our capital cities, there is only a limited number of populous centres. The relatively small, but numerous, communities outside the large cities, which depend mainly upon rural industries, are, however, voicing, in no uncertain fashion, their desire to share in the widespread distribution of electrical energy. With rare exceptions, the system of small isolated direct-current plants which it has been the habit, during the last ten to fifteen years, to instal in Australian country towns, now prove to be economically unsuited to the advanced requirements of the present day. They are definitely restrictive of development, both in capacity and range, and have, for the most part, proved financially burdensome.

In several Australian States and in New Zealand a beginning has been made in the direction of emulating the American and Canadian examples of connecting the rural areas with centralised generating plants of major capacity, and it appears to be of interest to examine, in a general way, the extent to which capital expenditure upon a service of this nature is permissible.

The Estimated Cost.

Under present-day conditions, it is a deduction from experience that an average annual revenue of 40 shillings per capita of the population of districts of average prosperity may be expected, such figure covering revenue from electric services of all kinds. Upon the very moderate assumption of a density of consumption no greater than 100 kilowatt-hours per capita per annum (which is vastly less than may be postulated as a "saturation" of prosperous rural communities), the cost of power-house generation and of general management may be assessed at about 20 shillings per capita per annum, leaving another 20 shillings per capita per annum available to cover the annual charges of the transmission and distribution systems. At the present ruling rates of interest, and with provision for depreciation and maintenance, say, 10 per cent. in all, the deduction is that a capital expenditure upon transmission and distribution plant (including the incidental sub-station electrical equipment) amounting to £10 per capita of the population to be served is permissible. This is a simple and ready way of [illegible] [illegible] sympathy with the fluctuations in the current interest rate upon the capital required.

The outstanding problem suggested in this context is that of improving the technical methods of transmission, as known and practised, particularly in the direction of reducing the capital investment. I have already referred to the complete change of practice which has resulted in the introduction of the "constant pressure" alternating current system of transmission. The thoughts of physicists are now turning to the very recently invented "valves" and other devices, promising remarkable facilities for the conversion of electric energy from the alternating to the direct current form and vice versa. Is another readjustment in the practice of electric transmission impending? Will the near future witness a radical reconsideration of the design of our transmission systems, and the elimination of the influence of reactance and capacitance upon the economics of our difficult and complex transmission problems? At present the investment of Australia in electrical transmission is relatively negligible, and therefore a fruitful field for research lies open for the realisation of a beneficent advance before we are deeply committed by a more extended use of present methods.

Social Factors.

Density of population is a factor of paramount importance in determining the cost per capita of many public utilities. The people of these Southern Dominions esteem highly the social advantages of the relatively low density of the population in our urban communities. But these are advantages which increase the cost of very kind of community service. Such is the case, particularly, with electric service. The capital investment per acre or per square mile, in a metropolitan area, for example, requisite to effect the reticulation of it with overhead and underground electric "feeders," mains, and submains, with their associated transformer and switching sub-stations, varies but little with the actual population served. The denser the population, therefore, the lighter will be the burden of cost per capita. This is the chief reason why the ultimate cost of the service to the residential consumer, in a relatively sparsely occupied area, such as the residential suburbs of the Australasian capitals, is, when valued at per electrical unit consumed, much greater than the cost of rendering a similar service in the more congested industrial suburbs. It is not, moreover, generally realised that the capital invested in power-houses is only a portion, and sometimes a small portion, of the total cost of rendering electric service to an extended territory.

It is significant of the beneficent influence of applied science that, in spite of the war-time upheaval of the world's economic conditions and the consequent almost universal rise in prices, the cost of large-scale energy production has nowhere risen, but has, on the contrary, exhibited a downward tendency. This has meant much for industry. It is, however, not only the favorable price, but also the vastly greater convenience and economy of operating machinery by means of electric motors, that explains the rapid and widespread introduction of electricity into industrial life. It is no longer incumbent upon the factory-owner to expend capital in the installation of his own engine and boiler plant. It is no longer necessary to instal long lines of shafting throughout his works to keep them in continuous motion, so as to drive, by means of belt connections, the individual machines. Instead, each separate machine may now be furnished with its own electric motor, and may be put into or out of use by the touch of a finger. He has, moreover, the whole resources of the electric supply system to enable him to meet any occasional simultaneous demand by his machinery or processes. These considerations have exercised a profound influence in the direction of an entire reorganisation of manufacturing methods, to the great benefit particularly of the industrial classes. (Applause.)

Humanising the Factory.

The use of electricity in industry has probably done and is doing more to humanise the factory than any other agency of modern application. It is bringing to the worker many advantages of health and ease, removing the noise, the smoke, the dirt, and the physical toil which have dogged him in the past. The dignity of skilled and useful work, often hitherto obscured by the degradation of needless labor, is becoming better appreciated; the need in modern industry for a greater range of skill and training and for less reliance on mere physical effort, which follows in the train of electrically operated processes, is cutting across the lines which have separated class from class, and which has so long made strangers where friends should be, among men who are, in reality, partners in production. (Applause.)

The application of electricity for purposes of traction greatly increases the speed and frequency of the transportation services. This consideration alone has produced a much increased freedom of selection by urban populations of their places of residence and of the places of their daily activities. Again, in the home, the introduction of electric lighting, warming, water-heating, cooking, refrigerating, sweeping, washing, and ironing is reducing domestic labor, and increasing the standard of comfort.

But, most of all, it is into rural territories that the amenities of city life are steadily penetrating. Applications of electricity to farm operations and farm domestic life are rapidly spreading, as in dairying, in pumping, in agriculture, and in the driving of farm machinery in general. In this way, electricity may play an important role in the problems of decentralisation, and particularly so when industries not greatly affected by transportation considerations, of which there are many, may have for their establishment a wide range of selection of provincial localities, provided they are furnished with electric services.

Magnificent Achievements.

I must now close my recital of these magnificent achievements of science in the field of power development. The results which I have attempted to describe have been obtained by rational research into the laws of Nature, and by the application of the knowledge so gained to the practical affairs of life. Many workers in many fields have made their contribution to the general fund. Mathematics has supplied the fundamentals and has pointed the way to sound and far-reaching generalisations. Physical research, in the realm of electricity and magnetism, has established the laws without which sound design would have been impossible; in the realm of mechanics and thermodynamics it has taught engineers the modern economics of energy generation, and in the realm of hydraulics and hydro-dynamics has led to the already high efficiency of water-actuated machinery. Chemistry has played its part in determining the composition and characteristics of fuels, and the correct adaptation of raw materials and intermediate products to the multifarious purposes of mechanical and electrical equipment; while metallurgy has aided in perfecting both the manufacture and the mode of utilisation of the numerous metals and alloys so indispensable to every part of the process. But we have arrived at no halting-place. The future of power development presents, as I have tried to show, far vaster problems than any that have been successfully solved. It is to the laboratory of the investigator and in that direction alone that we shall have to look for the inspirations which will guide us on the path of future progress.

The engineer is merely an exponent of applied science, but he is the first to acknowledge his debt to pure science and to the research worker. It is not always so with public men, the press, or the general public. In many quarters, pure science is looked upon as merely academic, and of no immediate practical or commercial value. It may sometimes appear to be so, but history furnishes overwhelmingly numerous examples of pure research having led straightway to practical results of the greatest value to mankind.

To quote Huxley's aphorism: "What people call applied science, is nothing but the application of pure science to particular classes of problems." If, therefore, the privilege which has come to me of addressing you and the Australasian public, has enabled me to stimulate a just appreciation of the value of pure science, and a realisation of the supreme importance of rendering the most generous support, both sympathetically and financially, to scientific organisations throughout our land, so as to utilise to the utmost the undoubted aptitude of our men and women for scientific labors, then I shall feel that I have not misused my opportunity. (Applause.)

DRAPERS. PRINTING [illegible]