he did not survive to receive the honour of admission to the British Academy, to mark his signal services to his science in this country.

Rugby, King's College, Cambridge, and the British Museum, not to speak of the University of London, have lost in him one of their most distinguished members. H. R. HALL.

THE BOURNEMOUTH MEETING OF THE BRITISH ASSOCIATION.

WRITING on the day before the opening of the meeting at Bournemouth, it is not possible to give exact figures of the number of members and associates enrolled. The number is approximately one thousand, and steadily increasing. All day the Municipal College has been the scene of great activity, and the officials have had hard work to cope with the rush of applications and inquiries. The figures compare very favourably with those of previous years, and, while no new records are likely to be established, it is believed that the attendance will be in excess of that at any meeting held during the war.

Local enthusiasm has been late in manifesting itself, but has now reached a high pitch. The town's privilege in being the scene of so important and in many respects unique a meeting is at last fully appreciated. The greatest interest is being shown in the proceedings of the Association, and a most cordial welcome extended to the distinguished men of science visiting the town. The citizens' lectures arranged in co-operation with the Workers' Educational Association are also likely to be exceptionally well attended.

The great difficulties of securing accommodation have been successfully met, and the many visitors find the arrangements in every way excellent. The careful organisation of the local executive committee in other directions is in evidence on all sides, and its results meet with the keen appreciation of members and associates.

The weather is fine and warm, a fortunate circumstance in view of the numerous sectional excursions to points of interest in the neighbourhood taking place during the week.

Even at this early hour it is possible to pronounce the Bournemouth meeting a decided success.

(Tuesday evening.)

The weather to-day has been brilliantly fine, and with Bournemouth looking its best the meeting has opened under the happiest conditions.

More than 1200 tickets have been issued, and many fresh applications are still being received. The section lectures and discussions and the excursions to-day were exceedingly well attended. This evening the Winter Gardens Pavilion was crowded by a keenly appreciative audience on the occasion of the president's inaugural address. The attendances are not so large as at certain meet-

ings held before the war, but they are regarded here as most gratifying and quite equal to expectations.

The interest displayed in the citizens' lectures exceeds all anticipation, and the accommodation provided, based on the experience of previous years, has proved quite inadequate. All the tickets have been disposed of, and large numbers of intending auditors have been disappointed. This points to a useful development of the work of the Association in the future.

All the conditions are exceptionally favourable, and the "Peace" meeting is proving eminently successful in every way.

Prof. W. A. Herdman, who has been general secretary of the Association since 1903, has been elected to fill the office of president for the year 1920-21, beginning with the Cardiff meeting.

INAUGURAL ADDRESS BY THE HON. SIR CHARLES A. PARSONS, K.C.B., M.A., LL.D., D.Sc., F.R.S., PRESIDENT.

THREE years of anxiety and stress have passed since the last meeting of the British Association. The weight of the struggle which pressed heavily upon us at the time of the Newcastle meeting in 1916 had increased so much in intensity by the spring of 1917 that the council, after consultation with the local committee at Bournemouth, finally decided to cancel the summer meeting of that year. This was the first time in the history of the association that an annual meeting was not held.

We all rejoice to feel that the terrible ordeal through which the whole Empire has been passing has now reached its final phases, and that during the period of reorganisation, social and industrial, it is possible to resume the annual meetings of the association under happier conditions. We have gladly and with much appreciation accepted the renewed invitation of our friends and colleagues at Bournemouth.

We are gathered together at a time when, after a great upheaval, the elemental conditions of organisation of the world are still in flux, and we have to consider how to influence and mould the recrystallisation of these elements into the best forms and most economic rearrangements for the benefit of civilisation. That the British Association is capable of exerting a great influence in guiding the nation towards advancement in the sciences and arts in the most general sense there can be no question, and of this we may be assured by a study of its proceedings in conjunction with the history of contemporary progress. Although the British Association cannot claim any paramount prerogative in this good work, yet it can certainly claim to provide a free arena for discussion where in the past new theories in science, new propositions for beneficial change, new suggestions for casting aside fetters to the advancement in science, art, and economics have first seen the light of publication and discussion.

For more than half a century it has pleaded strongly for the advancement of science and its application to the arts. In the yearly volume for 1855 will be found a report in which it is stated that:—"The objects for which the association was established have been carried out in three ways: First, by requisitioning and printing reports on the present state of different branches of science; secondly, by granting sums of

money to small committees or individuals, to enable them to carry on new researches; and thirdly, by recommending the Government to undertake expeditions of discovery, or to make grants of money for certain and national purposes, which were beyond the means of the association." As a matter of fact it has, since its commencement, paid out of its own funds upwards of 80,000*l.* in grants of this kind.

Developments Prior to the War.

It is twenty-nine years since an engineer, Sir Frederick Bramwell, occupied this chair and discoursed so charmingly on the great importance of the next-to-nothing, the importance of looking after little things which, in engineering, as in other walks of life, are often too lightly considered.

The advances in engineering during the last twenty years are too many and complex to allow of their description, however short, being included in one address, and, following the example of some of my predecessors in this chair, I shall refer only to some of the most important features of this wide subject. I feel that I cannot do better than begin by quoting from a speech made recently by Lord Inchcape, when speaking on the question of the nationalisation of coal:—"It is no exaggeration to say that coal has been the maker of modern Britain, and that those who discovered and developed the methods of working it have done more to determine the bent of British activities and the form of British society than all the Parliaments of the past hundred and twenty years."

James Watt.—No excuse is necessary for entering upon this theme, because this year marks the hundredth anniversary of the death of James Watt, and in reviewing the past it appears that England has gained her present proud position by her early enterprise and by the success of the Watt steam-engine, which enabled her to become the first country to develop her resources in coal, and led to the establishment of her great manufactures and her immense mercantile marine.

The laws of steam which James Watt discovered are simply these:—That the latent heat is nearly constant for different pressures within the ranges used in steam-engines, and that, consequently, the greater the steam pressure and the greater the range of expansion, the greater will be the work obtained from a given amount of steam. Secondly, as may now seem to us obvious, that steam from its expansive force will rush into a vacuum. Having regard to the state of knowledge at the time, his conclusions appear to have been the result of close and patient reasoning by a mind endowed with extraordinary powers of insight into physical questions, and with the faculty of drawing sound practical conclusions from numerous experiments devised to throw light on the subject under investigation. His resource, courage, and devotion were extraordinary.

In commencing his investigations on the steam-engine he soon discovered that there was a tremendous loss in the Newcomen engine, which he thought might be remedied. This was the loss caused by condensation of the steam on the cold metal walls of the cylinder. He first commenced by lining the walls with wood, a material of low thermal conductivity. Though this improved matters, he was not satisfied; his intuition probably told him that there should be some better solution of the problem, and doubtless he made many experiments before he realised that the true solution lay in a condenser separate from the cylinder of the engine. It is easy after discovery to say, "How obvious and how simple," but many of us here know how difficult is any step of advance when shrouded by unknown surroundings, and we can

well appreciate the courage and the amount of investigation necessary before James Watt thought himself justified in trying the separate condenser. But to us now, and to the youngest student who knows the laws of steam as formulated by Carnot, Joule, and Kelvin, the separate condenser is the obvious means of constructing an economical condensing engine.

Watt's experiments led him to a clear view of the great importance of securing as much expansion as possible in his engines. The materials and appliances for boiler and machine construction were at that time so undeveloped that steam pressures were practically limited to a few pounds above atmospheric pressure. The cylinders and pistons of his engines were not constructed with the facility and accuracy to which we are now accustomed, and chiefly for these reasons expansion ratios of from twofold to threefold were the usual practice. Watt had given to the world an engine which consumed from five to seven pounds of coal per horse-power hour, or one-quarter of the fuel previously used by any engine. With this consumption of fuel its field under the conditions prevailing at the time was practically unlimited. What need was there, therefore, for commercial reasons, to endeavour still further to improve the engine at the risk of encountering fresh difficulties and greater commercial embarrassments? The course was rather for him and his partners to devote all their energy to extend the adoption of the engine as it stood, and this they did, and to the Watt engine, consuming from five to seven pounds of coal per horse-power, mankind owes the greatest permanent advances in material welfare recorded in history.

With secondary modifications, it was the prime mover in most general use for eighty years, *i.e.* until the middle of last century. It remained for others to carry the expansion of steam still further in the compound, triple, and, lastly, in the quadruple expansion engine, which is the most economical reciprocating engine of to-day.

Watt had considered the practicability of the turbine. He writes to his partner, Boulton, in 1784:—"The whole success of the machine depends on the possibility of prodigious velocities. In short, without God makes it possible for things to move them one thousand feet per second, it cannot do us much harm." The advance in tools of precision, and a clearer knowledge of the dynamics of rotating bodies, have now made the speeds mentioned by Watt feasible, and, indeed, common, everyday practice.

Turbines.—The turbine of to-day carries the expansion of steam much further than has been found possible in any reciprocating engine, and owing to this property it has surpassed it in the economy of coal, and it realises to the fullest extent Watt's ideal of the expansion of steam from the boiler to the lowest vapour pressure obtainable in the condenser.

Among the minor improvements which in recent years have conduced to a higher efficiency in turbines are the more accurate curvature of the blades to avoid eddy losses in the steam, the raising of the peripheral velocities of the blades to nearly the velocity of the steam impinging upon them, and details of construction to reduce leakages to a minimum. In turbines of 20,000–30,000 h.p., 82 per cent. of the available energy in the steam is now obtainable as brake-horse-power; and with a boiler efficiency of 85 per cent. the thermodynamic efficiency from the fuel to the electrical output of the alternator has reached 23 per cent., and shortly may reach 28 per cent., a result rivalling the efficiency of internal-combustion engines worked by producer-gas.

During the twenty years immediately preceding the war turbo-generators had increased in size from

500 kilowatts to 25,000 kilowatts, and the consumption of steam had fallen from 17 lb. per kw.-hour to 10.3 lb. per kw.-hour. Turbines have become the recognised means of generating electricity from steam on a large scale, although they have not superseded the Watt engine for pumping mines or the drawing of coal, except in so far as it is a means for generating electricity for these purposes. In the same period the engine-power in the mercantile marine had risen from 3900 of the *King Edward* to 75,000 of the *Mauretania*.

As regards the Royal Navy, the engine-power of battleships prior to the war had increased from 12,000 i.h.p. to 30,000 s.h.p., while the speed advanced from 17 knots to 23 knots, and during the war, in ships of the *Queen Elizabeth* class, the power amounted to 75,000 s.h.p., with a speed of 25 knots. In cruisers similar advances were made. The i.h.p. of the *Powerful* was 25,000, while the s.h.p. of the *Queen Mary* was 78,000, with a speed of 28 knots. During the war the power obtained with geared turbines in the *Courageous* class was 100,000 s.h.p., with a speed of 32 knots, the maximum power transmitted through one gear-wheel being 25,000 h.p., and through one pinion 15,500 h.p.; while in destroyers speeds up to 39 knots have been obtained. The aggregate horsepower of war and mercantile turbine vessels throughout the world is now about 35,000,000.

These advances in power and speed have been made possible mainly by the successive increase in economy and diminution of weight derived from the replacement of reciprocating engines by turbines direct-coupled to the propellers, and later by the introduction of reduction gearing between the turbines and the propellers; also by the adoption of water-tube boilers and of oil-fuel. With these advances the names of Lord Fisher, Sir William White, and Sir Henry Oram will always be associated.

The Work of Sir William White.—With the great work of the Royal Navy fresh in our minds, we cannot but recall the prominent part taken by the late Sir William White in its construction. His sudden death, when president-elect for 1913, lost to the nation and to the association the services of a great naval architect who possessed remarkable powers of prevision and dialectic. He was Chief Constructor to the Admiralty from 1885 to 1901, and largely to him was due the efficiency of our vessels in the great war.

White often referred to the work of Brunel as the designer of the *Great Eastern*, and spoke of him as the originator of the cellular construction of the bottoms of ships, since universally adopted, as a means of strengthening the hull and for obtaining additional safety in case of damage. Scott Russell was the builder of this great pioneer vessel, the forerunner of the Atlantic liners, and the British Association may rightly feel satisfaction in having aided him when a young man by pecuniary grants to develop his researches into the design and construction of ships and the wave-line form of hull which he originated, a form of special importance in paddle-wheel vessels.

So much discussion has taken place in the last four years as to the best construction of ship to resist torpedo attacks that it is interesting to recall briefly at the present time what was said by White in his Cantor lectures to the Royal Society of Arts in 1906:—"Great attention has been bestowed upon means of defence against underwater torpedo attacks. From the first introduction of torpedoes it was recognised that extreme watertight subdivision in the interior of warships would be the most important means of defence. Experiments have been made with triple watertight skins forming double cellular sides, the compartments nearest the outer bottom being

filled, in some cases, with water, coal, cellulose, or other materials. Armour-plating has been used both on the outer bottom and on inner skins." He also alludes to several Russian ships which were torpedoed by the Japanese, and he concludes by saying:—"Up to date the balance of opinion has favoured minute watertight subdivisions and comparatively thin watertight compartments, rather than the use of internal armour, the use of which, of course, involves large expenditure of weight and cost."

The present war has most amply confirmed his views and conclusions, then so lucidly and concisely expressed.

While on the subject of steamships, it may perhaps be opportune to say one word as to their further development. The size of ships had been steadily increasing up to the time of the war, resulting in a reduction of power required to propel them per ton of displacement. On the other hand, thanks to their greater size and more economical machinery, speeds have been increased when the traffic has justified the greater cost. The limiting factor to further increase in size is the depth of water in the harbours. With this restriction removed there is no obstacle to building ships up to 1000 ft. in length or more, provided the volume and character of the traffic are such as to justify the capital outlay.

Tungsten Steel.—Among other important pre-war developments that have had a direct bearing upon the war, mention should be made of the discovery and extensive use of alloys of steel. The wonderful properties conferred upon steel by the addition of tungsten were discovered by Muschet in 1868, who has not been sufficiently credited with his share in making the Bessemer process a practical success, and later this alloy was investigated and improved by Maunsel White and Taylor, of Philadelphia. The latter showed that the addition of tungsten to steel has the following effect:—That after the steel has been quenched at a very high temperature near its melting point, it can be raised to a much higher temperature than is possible with ordinary carbon tool-steel without losing its hardness and power of cutting metal. In other words, it holds the carbon more tenaciously in the hardened state, and hence tungsten-steel tools, even when red-hot, can cut ordinary mild steel. It has revolutionised the design of machine tools, and has increased the output on heavy munition work by 100 per cent., and in ordinary engineering by 50 per cent.

The alloys of steel and manganese with which Sir Robert Hadfield's name is associated have proved of utility in immensely increasing the durability of railway and tramway points and crossings, and for the hard teeth of machinery for the crushing of stone and other materials, and, in fact, for any purposes where great hardness and strength are essential.

Investigation of Gaseous Explosions.—Brief reference must also be made—and it will be gratifying to do so—to the important work of one of the committees of the British Association appointed in 1908, under the chairmanship of the late Sir William Preece, for the investigation of gaseous explosions, with special reference to temperature. The investigations of the committee are contained in seven yearly reports up to 1914. Of the very important work of the committee I wish to refer to one investigation in particular, which has proved to be a guiding star to the designers and manufacturers of internal-combustion engines in this country. The members of the committee more directly associated with this particular investigation were Sir Dugald Clerk, Prof. Callendar, and the late Prof. Bertram Hopkinson.

The investigation showed that the intensity of the

heat radiated by the incandescent gases to the walls of the cylinder of a gas-engine increases with the size of the cylinder, the actual rate of this increase being approximately proportional to the square root of the depth of the radiating incandescent gas; the intensity was also shown to increase rapidly with the richness of the gas. It suffices now to say that the heat in a large cylinder with a rich explosive mixture is so intense that the metal eventually cracks. The investigation shows why this occurs, and by doing so has saved enormous sums to the makers of gas- and oil-engines in this country, and has led them to avoid the large cylinder, so common in Germany before the war, in favour of a multiplicity of smaller cylinders.

Science and the War.

In coming to this section of my address I am reminded that in the course of his presidential address to Section G, in 1858, Lord Rosse said:—"Another object of the Mechanical Section of the association has been effected—the importance of engineering science in the service of the State has been brought more prominently forward. There seems, however, something still wanting. Science may yet do more for the Navy and Army if more called upon."

Comparatively recently, too, Lord French remarked: "We have failed during the past to read accurately the lessons as regards the fighting of the future which modern science and invention should have taught us."

In view of the eminent services which men of science have rendered during the war, I think that we may be justified in regarding the requirement stated by Lord Rosse as having at last been satisfied, and also in believing that such a criticism as Lord French rightly uttered will not be levelled against the country in the future.

Though British men of science had not formerly been adequately recognised in relation to war and the safety of their country, yet at the call of the sailors and the soldiers they whole-heartedly, and with intense zeal, devoted themselves to repair the negligence of the past, and to apply their unrivalled powers and skill to encounter and overcome the long-standing machinations of the enemy. They worked in close collaboration with the men of science of the Allied nations, and eventually produced better war material, chemicals, and apparatus of all kinds for vanquishing the enemy and the saving of our own men than had been devised by the enemy during many years of preparation planned on the basis of a total disregard of treaties and the conventions of war.

Four years is too short a time for much scientific invention to blossom to useful maturity, even under the forced exigencies of war and Government control. It must be remembered that in the past the great majority of new discoveries and inventions of merit have taken many years—sometimes generations—to bring them into general use. It must also be mentioned that in some instances discoveries and inventions are attributable to the general advance in science and the arts which has brought within the region of practical politics an attack on some particular problem. So the work of the men of science during the war has perforce been directed more to the application of known principles, trade knowledge, and properties of matter to the waging of war than to the making of new and laborious discoveries; though, in effecting such applications, inventions of a high order have been achieved some of which promise to be of great usefulness in time of peace.

The advance of science and the arts in the last century had, however, wrought a great change in the implements of war. The steam-engine, the internal-combustion engine, electricity, and the advances in

metallurgy and chemistry had led to the building up of immense industries which, when diverted from their normal uses, have produced unprecedented quantities of war material for the purposes of the enormous armies, and also for the greatest Navy which the world has ever seen.

The destructive energy in the field and afloat has multiplied many hundredfold since the time of the Napoleonic wars; both before and during the war the size of guns and the efficiency of explosives and shell increased immensely, and many new implements of destruction were added. Modern science and engineering enabled armies unprecedented in size, efficiency, and equipment to be drawn from all parts of the world and to be concentrated rapidly in the fighting line.

To build up the stupendous fighting organisation, ships have been taken from their normal trade routes, locomotives and material from the home railways, the normal manufactures of the country have been largely diverted to munitions of war; the home railways, tramways, roads, buildings and constructions, and material of all kinds have been allowed to depreciate. The amount of depreciation in roads and railways alone has been estimated at 400,000,000l. per annum at present prices. Upon the community at home a very great and abnormal strain has been thrown, notwithstanding the increased output per head of the workers derived from modern methods and improved machinery. In short, we have seen for the first time in history nearly the whole populations of the principal contending nations enlisted in intense personal and collective effort in the contest, resulting in unprecedented loss of life and destruction of capital.

A few figures will assist us to realise the great difference between this war and all preceding wars. At Waterloo, in 1815, 9044 artillery rounds were fired, having a total weight of 37·3 tons, while on one day during the last offensive in France, on the British front alone, 943,837 artillery rounds were fired, weighing 18,080 tons—more than 100 times the number of rounds, and nearly 540 times the weight of projectiles. Again, in the whole of the South African War 273,000 artillery rounds were fired, weighing approximately 2800 tons; while during the whole war in France, on the British front alone, more than 170,000,000 artillery rounds were fired, weighing nearly 3,500,000 tons—622 times the number of rounds, and about 1250 times the weight of projectiles.

However great these figures in connection with modern land artillery may be, they become almost insignificant when compared with those in respect of a modern naval battle squadron. The *Queen Elizabeth* when firing all her guns discharges 18 tons of metal and develops 1,870,000 foot-tons of energy. She is capable of repeating this discharge once every minute, and when doing so develops by her guns an average of 127,000 effective h.p., or more than one-and-a-half times the power of her propelling machinery; and this energy is five times greater than the maximum average energy developed on the Western Front by British guns. Furthermore, if all her guns were fired simultaneously, they would for the instant be developing energy at the rate of 13,132,000 h.p. From these figures we can form some conception of the vast destructive energy developed in a modern naval battle.

Engineering and the War.

With regard to the many important engineering developments made during the war, several papers by authorities are announced in the syllabus of papers

constituting the sectional proceedings of this year's meeting. Among them are "Tanks," by Sir Eustace d'Eyncourt; "Scientific Progress of Aviation during the War," by L. Bairstow; "Airships," by Lt.-Col. Cave-Brown-Cave; "Directional Wireless, with Special Reference to Aircraft," by Capt. Robinson; "Wireless in Aircraft," by Major Erskine Murray; "Wireless Telegraphy during the First Three Years of the War," by Major Vincent Smith; "Submarine Mining," by Comdr. Gwynne; "Emergency Bridge Construction," by Prof. Ingles; and "The Paravane," by Comdr. Burney. Accordingly, it is quite unnecessary here to particularise further except in the few following instances:—

Sound-ranging and Listening Devices.—Probably the most interesting development during the war has been the extensive application of sound-listening devices for detecting and localising the enemy. The Indian hunter puts his ear to the ground to listen for the sound of the footsteps of his enemy. So in modern warfare science has placed in the hands of the sailor and soldier elaborate instruments to aid the ear in the detection of noises transmitted through earth, water, air, or æther, and also in some cases to record these sounds graphically or photographically, so that their character and the time of their occurrence may be tabulated.

The sound-ranging apparatus developed by Prof. Bragg and his son, by which the position of an enemy gun can be determined from electrically recorded times at which the sound-wave from the gun passes over a number of receiving stations, has enabled our artillery to concentrate their fire on the enemy's guns, and often to destroy them.

The French began experimenting in September, 1914, with methods of locating enemy guns by sound. The English section began work in October, 1915, adopting the French methods in the first instance. By the end of 1916 the whole front was covered, and sound-ranging began to play an important part in the location of enemy batteries. During 1917 locations by sound-ranging reached about 30,000 for the whole Army, this number being greater than that given by any other means of location. A single good set of observations could be relied upon to give the position of an enemy gun to about 50 yards at 7000 yards' range. It could also be carried on during considerable artillery activity.

The apparatus for localising noises transmitted through the ground has been much used for the detection of enemy mining and counter-mining operations. Acoustic tubes, microphones, and amplifying valves have been employed to increase the volume of very faint noises.

For many years before the war the Bell Submarine Signalling Co., of which Sir William White was one of the early directors, used submerged microphones for detecting sound transmitted through the water, and a submerged bell for sending signals to distances up to one mile. With this apparatus passing ships could be heard at a distance of nearly a mile when the sea was calm and the listening vessel stationary.

Of all the physical disturbances emitted or produced by a moving submarine, those most easily detected, and at the greatest distance, are the pressure-waves set up in the water by vibrations produced by the vessel and her machinery. A great variety of instruments have been devised during the war for detecting these noises, depending on microphones and magnetophones of exceedingly high sensitivity. Among them may be particularly mentioned the hydrophones devised by Capt. Ryan and Prof. Bragg, being adaptations of the telephone transmitter to work in water instead of air. These instruments,

when mounted so as to rotate, are directional, being insensitive to sound-waves the front of which is perpendicular to the plane of the diaphragm, and giving the loudest sound when the diaphragm is parallel to the wave-front.

Another preferable method for determining direction is to use two hydrophones coupled to two receivers, one held to each ear. This is called the binaural method, and enables the listener to recognise the direction from which the sound emanates.

When the vessel is in motion or the sea is rough, the water noises from the dragging of the instrument through the water and from the waves striking the ship drown the noises from the enemy vessel, and under such conditions the instruments are useless. The assistance of eminent biologists was of invaluable help at this juncture. Experiments were made with sea-lions by Sir Richard Paget, who found that they have directional hearing under water up to speeds of six knots. Also Prof. Keith explained the construction of the hearing organs of the whale, the ear proper being a capillary tube, too small to be capable of performing any useful function in transmitting sound to the relatively large aural organs, which are deep set in the head. The whale therefore hears by means of the sound-waves transmitted through the substance of the head. It was further seen that the organs of hearing of the whale to some degree resembled the hydrophone.

The course now became clear. Hollow towing bodies in the form of fish or porpoises were made of celluloid, varnished canvas, or very thin metal, and the hydrophone suitably fixed in the centre of the head. The body is filled with water, and the cable towing the fish contains the insulated leads to the observer on board the vessel. When towed at some distance behind the chasing ship disturbing noises are small, and enemy noises can be heard up to speeds of fourteen knots, and at considerable distances. Thermionic amplifying valves have been extensively used, and have added much to the sensitivity of the hydrophone in its many forms.

After the loss of the *Titanic* by collision with an iceberg, Lewis Richardson was granted two patents in 1912 for the detection of above-water objects by their echo in the air, and under-water objects by the echo transmitted through the water. The principles governing the production and the concentration of beams of sound are described in the specification, and he recommends frequencies ranging from 4786 to 100,000 complete vibrations per second, and also suggests that the rate of approach or recession from the object may be determined from the difference in the pitch of the echo from the pitch of the blast sent out. Sir Hiram Maxim also suggested similar apparatus a little later.

The echo method of detection was not, however, practically developed until French and English men of science, with whom was associated Prof. Langevin, of the Collège de France, realising its importance for submarine detection, brought the apparatus to a high degree of perfection and utility shortly before the armistice. Now with beams of high-frequency sound-waves it is possible to sweep the seas for the detection of any submerged object, such as icebergs, submarines, surface vessels, and rocks; they may also be used to make soundings. It enables a chasing ship to pick up and close in on a submarine situated more than a mile away.

The successful development of sound-ranging apparatus on land led to the suggestion by Prof. Bragg that a modified form could be used to locate under-water explosions. It has been found that the shock of an explosion can be detected hundreds of miles

from its source by means of a submerged hydrophone, and that the time of the arrival of the sound-wave can be recorded with great precision. At the end of the war the sound-ranging stations were being used for the detection of positions at sea required for strategic purposes. The same stations are now being used extensively for the determination of such positions at sea as light-vessels, buoys which indicate channels, and obstructions such as sunken ships. By this means ships steaming in fog can be given their positions with accuracy for ranges up to 500 miles.

Among the many other important technical systems and devices brought out during the war which will find useful application under peace conditions as aids to navigation I may mention directional wireless, by which ships and aircraft can be given their positions and directed, and on this subject we are to have a paper in Section G.

Leader-gear, first used by the Germans to direct their ships through their minefields, and afterwards used by the Allies, consists of an insulated cable laid on the bottom of the sea, earthed at the further end, through which an alternating current is passed. By means of delicate devices installed on a ship, she is able to follow the cable at any speed with as much precision as a railless electric 'bus can follow its trolley-wire. Cables up to fifty miles long have been used, and this device promises to be invaluable to ships navigating narrow and tortuous channels and entering or leaving harbours in a fog.

Aircraft.—It may be justly said that the development in aircraft design and manufacture is one of the astonishing engineering feats of the war. In August, 1914, the British Air Services possessed a total of 272 machines, whereas in October, 1918, just prior to the armistice, the Royal Air Force possessed more than 22,000 effective machines. During the first twelve months of the war the average monthly delivery of aeroplanes to our Flying Service was 50, while during the last twelve months of the war the average deliveries were 2700 per month. So far as aero-engines are concerned, our position in 1914 was by no means satisfactory. We depended for a large proportion of our supplies on other countries. In the Aerial Derby of 1913, of the eleven machines that started, not one had a British engine. By the end of the war, however, British aero-engines had gained the foremost place in design and manufacture, and were well up to requirements as regards supply. The total horse-power produced in the last twelve months of the war approximated to eight millions of brake-horse-power, a figure quite comparable with the total horse-power of the marine-engine output of the country.¹

Much might be written on the progress in aircraft, but the subject will be treated at length in the sectional papers. In view of the recent trans-Atlantic flight, however, I feel that it may be opportune to make the following observations on the comparative utility of aeroplanes and airships for commercial purposes. In the case of the aeroplane, the weight per horse-power increases with the size, other things being equal. This increase, however, is met to some extent by a multiplicity of engines, though in the fuselage the increase remains.

On the other hand, with the airship the advantage increases with the size, as in all ships. The tractive effort per ton of displacement diminishes in inverse proportion to the dimensions, other things, including the speed, being the same. Thus an airship of 750 ft. length and 60 tons displacement may require a tractive force of 5 per cent., or 3 tons, at 60 miles per

hour; and one of 1500 ft. in length and $8 \times 60 = 480$ tons displacement would require only $2\frac{1}{2}$ per cent. $\times 480 = 12$ tons at the same speed, and would carry fuel for double the distance.

With the same proportion of weight of hull to displacement, the larger airship would stand double the wind-pressure, and would weather storms of greater violence and hailstones of greater size. It would be more durable, the proportional upkeep would be less, and the proportional loss of gas considerably less. In other words, it would lose a less proportion of its buoyancy per day. It is a development in which success depends upon the project being well thought out and the job being thoroughly well done. The equipment of the airsheds with numerous electric haulage winches, and all other appliances to make egress and ingress to the sheds safe from danger and accident, must be ample and efficient.

The airship appears to have a great future for special commerce where time is a dominant factor and the demand is sufficient to justify a large airship. It has also a great field in the opening up of new countries where other means of communication are difficult. The only limitation to size will be the cost of the airship and its sheds, just as in steam-vessels it is the cost of the vessels and the cost of deepening the harbours that limit the size of Atlantic liners.

Such developments generally take place slowly, otherwise failures occur—as in the case of the *Great Eastern*—and it may be many years before the airship is increased from the present maximum of 750 ft. to 1500 ft. with success, but it will assuredly come. If, however, the development is subsidised or assisted by the Government, incidental failures may be faced with equanimity and very rapid development accomplished.² In peace-time the seaplane, aeroplane, and airship will most certainly have their uses. But, except for special services of high utility, it is questionable whether they will play more than a minor part as compared with the steamship, railway, and motor transport.

Electricity.—The supply and use of electricity has developed rapidly in recent years. For lighting it is the rival of gas, though each has its advantages. As a means of transmitting power over long distances it has no rival, and its efficiency is so high that, when generated on a large scale and distributed over large areas, it is a cheap and trustworthy source of power for working factories, tramways, suburban railways, and innumerable other purposes, including metallurgical and chemical processes. It is rapidly superseding locally generated steam-power, and is a rival to the small- and moderate-sized gas and oil engines. It has made practicable the use of water-power through the generation of electricity in bulk at the natural falls, from which the power is transmitted to the consumers, sometimes at great distances.

Fifteen years ago electricity was generated chiefly by large reciprocating steam-engines, direct-coupled to dynamos or alternators, but of late years steam turbines have in most instances replaced them, and are now exclusively used in large generating stations because of their smaller cost and greater economy in fuel. The size of the turbines may vary from a few thousand horse-power up to about 50,000 h.p. At the end of last year the central electric stations in the United Kingdom contained plant aggregating 2,750,000 kilowatts, 79 per cent. of which was driven by steam turbines.

Much discussion has taken place as to the most economical size of generating stations, their number,

¹ See Lord Weir's Paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders, July, 1919.

² The literature on this subject includes an article which appeared in *Engineering* on January 3, 1919.

the size of the generating units, and the size of the area to be supplied. On one hand, a comparatively small number of very large or super-stations, instead of a large number of moderate-sized stations dotted over the area, results in a small decrease in the cost of production of the electricity, because in the super-stations larger and slightly more economical engines are employed, while the larger stations permit of higher organisation and more elaborate labour-saving appliances. Further, if in the future the recovery of the by-products of coal should become a practical realisation as part of the process in the manufacture of the electric current, the larger super-stations present greater facilities than the smaller stations. On the other, super-stations involve the transmission of the electricity over greater distances, and consequently greater capital expenditure and cost of maintenance of mains and transmission apparatus, and greater electrical transmission losses, while the larger generating unit takes longer to overhaul or repair, and consequently a larger percentage of spare plant is necessary.

The greatest element in reducing the cost of electricity is the provision of a good load factor; in other words, the utilisation of the generating plant and mains to the greatest extent during the twenty-four hours of each day throughout the year. This is a far more important consideration than the size of the station, and it is secured to the best advantage in most cases by a widespread network of mains, supplying a diversity of consumers and users, each requiring current at different times of the day. The total load of each station being thus an average of the individual loads of a number of consumers is, in general, far less fluctuating than in the case of small generating and distributing systems, which supply principally one class of consumer—a state of affairs that exists in London, for instance, at the present time. It is true that there may be exceptional cases, such as at Kilmarnock, where a good load factor may be found in a small area, but in this case the consumers are chiefly mills, which require current for many hours daily.

There is no golden rule to secure cheap electricity. The most favourable size, locality, and number of generating stations in each area can only be arrived at by a close study of the local conditions, but there is no doubt that, generally speaking, to secure cheap electricity a widespread network of mains is in most cases a very important, if not an essential, factor.

The electrification of tramways and suburban railways has been an undoubted success where the volume of traffic has justified a frequent service, and it has been remarkable that where suburban lines have been worked by frequent and fast electrical trains there has resulted a great growth of passenger traffic. The electrification of main-line railways would no doubt result in a saving of coal; at the same time, the economical success would largely depend on the broader question as to whether the volume of the traffic would suffice to pay the working expenses and provide a satisfactory return on the capital.

Municipal and company generating stations have been nearly doubled in capacity during the war to meet the demand from munition works, steel works, chemical works, and for many other purposes. The provision of this increased supply was an enormous help in the production of adequate munitions. At the commencement of the war there were few steel electric furnaces in the country; at the end of last year 117 were at work, producing 20,000 tons of steel per month, consisting chiefly of high-grade ferro alloys used in munitions.

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The Future.

The nations which have exerted the most influence in the war have been those which have developed to the greatest extent their resources, their manufactures, and their commerce. As in the war, so in the civilisation of mankind. But, viewing the present trend of developments in harnessing water-power and using up the fuel resources of the world for the use and convenience of man, one cannot but realise that, failing new and unexpected discoveries in science, such as the harnessing of the latent molecular and atomic energy in matter, as foreshadowed by Clerk Maxwell, Kelvin, Rutherford, and others, the great position of England cannot be maintained for an indefinite period. At some time more or less remote—long before the exhaustion of our coal—the population will gradually migrate to those countries where the natural sources of energy are the most abundant.

Water-power and Coal.—The amount of available water-power in the British Isles is very small as compared with the total in other countries. According to the latest estimates, the total in the British Isles is less than 1,500,000 h.p., whereas Canada alone possesses more than 20,000,000 h.p., of which more than 2,000,000 h.p. have already been harnessed. In the rest of the British Empire there are upwards of 30,000,000 h.p., and in the remainder of the world at least 150,000,000 h.p., so that England herself possesses less than 1 per cent. of the water-power of the world. Further, it has been estimated that she only possesses 2½ per cent. of the whole coal of the world. To this question I would wish to direct our attention for a few minutes.

I have said that England owes her modern greatness to the early development of her coal. Upon it she must continue to depend almost exclusively for her heat and source of power, including that required for propelling her vast mercantile marine. Nevertheless, she is using up her resources in coal much more rapidly than most other countries are consuming theirs, and long before any near approach to exhaustion is reached her richer seams will have become impoverished, and the cost of mining so much increased that, given cheap transport, it might pay her better to import coal from richer fields of almost limitless extent belonging to foreign countries, and workable at a much lower cost than her own.

Let us endeavour to arrive at some approximate estimate of the economic value of the principal sources of power. The present average value of the royalties on coal in England is about 6d. per ton, but to this must be added the profit derived from mining operations after paying royalties and providing for interest on the capital expended and for its redemption as wasting capital. After consultation with several leading experts in these matters, I have come to the conclusion that about 1s. per ton represents the pre-war market value of coal in the seams in England.

It must, however, be remembered that, in addition, coal has a considerable value as a national asset, for on it depends the prosperity of the great industrial interests of the country, which contribute a large portion of the wealth and revenue. From this point of view the present value of unmined coal seems not to have been sufficiently appreciated in the past, and that in the future it should be better appraised at its true value to the nation.

This question may be viewed from another aspect by making a comparison of the cost of producing a given amount of electrical power from coal and from water-power. Assuming that 1 h.p. of electrical energy maintained for one year had a pre-war value of 5l., and that it requires about eight tons of average

coal to produce it, we arrive at the price of 6s. 3d. per ton, *i.e.* crediting the coal with half the cost. The capital required to mine eight tons of coal a year in England is difficult to estimate, but it may be taken approximately to be 5*l.*, and the capital for plant and machinery to convert it into electricity at 10*l.*, making a total of 15*l.* In the case of water-power the average capital cost on the above basis is 40*l.*, including water rights (though in exceptionally favoured districts much lower costs are recorded).

From these figures it appears that the average capital required to produce electrical power from coal is less than half the amount that is required in the case of water-power. The running costs, however, in connection with water-power are much less than those in respect of coal. Another interesting consideration is that the cost of harnessing all the water-power of the world would be about 8,000,000,000*l.*, or equal to the cost of the war to England.

Dowling has estimated the total coal of the world as more than seven million million tons, and whether we appraise it at 1s. or more per ton its present and prospective value is prodigious. For instance, at 6s. 3d. per ton it amounts to nearly one hundred times the cost of the war to all the belligerents.

In some foreign countries the capital costs of mining are far below the figures I have taken, and, as coal is transportable long distances and, generally speaking, electricity is not so at present, therefore it seems probable that capital will in the immediate future flow in increasing quantity to mining operations in foreign countries rather than to the development of, at any rate the more difficult and costly, water-power schemes. When, however, capital becomes more plentiful the lower running costs of water-power will prevail, with the result that water-power will then be rapidly developed.

As to the possible new sources of power, I have already mentioned molecular energy, but there is another alternative which appears to merit attention.

Bore Hole.—In my address to Section B in 1904 I discussed the question of sinking a shaft to a depth of twelve miles, which is about ten times the depth of any shaft in existence. The estimated cost was 5,000,000*l.*, and the time required about eighty-five years.

The method of cooling the air-locks to limit the barometric pressure on the miners and other precautions were described, and the project appeared feasible. One essential factor has, however, been queried by some persons: Would the rock at the great depth crush in and destroy the shaft? Subsequent to my address I wrote a letter to NATURE, suggesting that the question might be tested experimentally. Prof. Frank D. Adams, of McGill University, Montreal, acting on the suggestion, has since carried out exhaustive experiments, published in the *Journal of Geology* for February, 1912, showing that in limestone a depth of fifteen miles is probably practicable, and that in granite a depth of thirty miles might be reached.

Little is at present known of the earth's interior, except by inference from a study of its surface, up-turned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity, and it seems reasonable to suggest that some attempt should be made to sink a shaft as deep as may be found practicable and at some locality selected by geologists as the most likely to afford useful information.

When we consider that the estimated cost of sinking a shaft to a depth of twelve miles, at present-day prices, is not much more than the cost of one day of the war to Great Britain alone, the expense seems

trivial as compared with the possible knowledge that might be gained by an investigation into this unexplored region of the earth. It might, indeed, prove of inestimable value to science, and also throw additional light on the internal constitution of the earth in relation to minerals of high specific gravity.

In Italy, at Lardarello, bore-holes have been sunk which discharge large volumes of high-pressure steam, which is being utilised to generate about 10,000 h.p. by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be, in the future, obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

While on the subject of obtaining power, may I digress for a few moments and describe an interesting phenomenon of a somewhat converse nature, *i.e.* that of intense pressure produced by moderate forces closing up cavities in water?

A Committee was appointed by the Admiralty in 1916 to investigate the cause of the rapid erosion of the propellers of some of the ships doing arduous duties. This was the first time that the problem had been systematically considered. The Committee found that the erosion was due to the intense blows struck upon the blades of the propellers by the nuclei of vacuous cavities closing up against them. Though the pressure bringing the water together was only that of the atmosphere, yet it was proved that at the nucleus 20,000 atmospheres might be produced.

The phenomenon may be described as being analogous to the well-known fact that nearly all the energy of the arm that swings it is concentrated in the tag of a whip. It was shown that when water flowed into a conical tube which had been evacuated a pressure of more than 140 tons per square inch was recorded at the apex, which was capable of eroding brass, steel, and, in time, even the hardest steel. The phenomenon may occur under some conditions in rivers and waterfalls where the velocity exceeds 50 ft. per second, and it is probably as great a source of erosion as by the washing down of boulders and pebbles. Then again, when waves beat on a rocky shore, under some conditions, intense hydraulic pressures will occur, quite sufficient of themselves to crush the rock and to open out narrow fissures into caves.

Research.—The whole question of the future resources of the Empire is, I venture to think, one which demands the serious attention of all men of science. It should be attacked in a comprehensive manner, and with that insistence which has been so notable in connection with the efforts of British investigators in the past. In such a task some people might suggest we need encouragement and assistance from the Government of the country. Surely we have it. As many here know, a great experimental step towards the practical realisation of Solomon's House as prefigured by Francis Bacon in the *New Atlantis* is being made by the Government at the present time. The inception, constitution, and methods of procedure of the Department, which was constituted in 1915, were fully described by Sir Frank Heath in his paper to the Royal Society of Arts last February, and it was there stated by Lord Crewe that, so far as he knew, this was the only country in which a Government Department of Research existed.³

It is obvious that the work of a Department of this kind must be one of gradual development with small beginnings in order that it may be sound and

³ The Italian Government are now establishing a National Council for Research, and a Bill is before the French Chamber for the establishment of a National Office of Scientific, Industrial, and Agricultural Research and Inventions.

lasting. The work commenced by assisting a number of researches conducted by scientific and professional societies which were languishing as a result of the war, and grants were also made to the National Physical Laboratory and to the Central School of Pottery at Stoke-on-Trent. The grants for investigation and research for the year 1916-17 totalled 11,055*l.*, and for the present year are anticipated to be 93,570*l.* The total income of the National Physical Laboratory in 1913-14 was 43,713*l.*, and, owing to the great enlargement of the laboratory, the total estimate of the Research Department for this service during the current year is 154,650*l.*

Another important part of the work of the Department has been to foster and to aid financially associations of the trades for the purpose of research. Nine of these associations are already at work; eight more are approved, and will probably be at work within the next two months; and another twelve are in the earlier stage of formation. There are also signs of great increase of research by individual factories. Whether this is due to the indirect influence of the Research Department or to a change in public opinion and a more general recognition of the importance of scientific industrial research it is difficult to say.

The possibility of the uncontrolled use on the part of a nation of the power which science has placed within its reach is so great a menace to civilisation⁴ that the ardent wish of all reasonable people is to possess some radical means of prevention through the establishment of some form of wide and powerful control. Has not science forged the remedy by making the world a smaller arena for the activities of civilisation, by reducing distance in terms of time? Alliances and unions, which have successfully controlled and stimulated republics of heterogeneous races during the last century, will therefore have become possible on a wider and grander scale, thus uniting all civilised nations in a great league to maintain order, security, and freedom for every individual and for every State and nation liberty to devote their energies to the controlling of the great forces of Nature for the use and convenience of man, instead of applying them to the killing of each other.

Many of us remember the president's banner at the Manchester meeting in 1915, where Science is allegorically represented by a sorrowful figure covering her eyes from the sight of the guns in the foreground. This year Science is represented in her more joyful mien, encouraging the arts and industries. It is to be sincerely hoped that the future will justify our present optimism.

SUMMARIES OF ADDRESSES OF PRESIDENTS OF SECTIONS.

AGRICULTURE.

IN his address to Section M, Prof. Somerville pointed out that during the war the area of land in the United Kingdom under grass was reduced by more than three million acres, with a corresponding increase of the area under tillage crops. Even were this increase of cultivated land maintained there would still remain more than 30 million acres under permanent and temporary grass, exclusive of about 16 million acres of mountain land used for grazing. Several attempts have been made to discover a relationship between the botanical composition and the feeding properties of permanent pastures, but the results have been largely negative; neither has it been possible by chemical analysis to differentiate between grass of poor and of high quality.

⁴ For instance, it might some day be discovered how to liberate instantaneously the energy in radium, and radium contains 2,500,000 times the energy of the same weight of T.N.T.

The only trustworthy test of quality that can be applied would appear to be through the agency of animals consuming the produce of the meadows or pasturing the fields. This work was initiated at Cockle Park in Northumberland in 1897, and has been extended to some twenty other experimental stations in various parts of the United Kingdom and in New Zealand. It has been conclusively proved that poor grass land is susceptible of rapid and profitable improvement, especially through the agency of phosphates. In many cases the stock-carrying capacity of land has been more than doubled, while the progress of the individual animals has also been largely increased, so that the output of meat or milk from land suitably manured has often been trebled or quadrupled with advantage to the nation and substantial profit to the farmer. One conspicuous result of experiments on manuring-for-meat has been the long-continued action of dressings of phosphate, 200 lb. per acre of phosphoric acid in the form of basic slag still producing very marked effects at the end of nine years. Nitrogen, potash, and lime as an addition to phosphates have been tried at several stations, but in most cases with comparatively little effect. Indirect manuring through feeding stock with cake has also given unsatisfactory results.

Research during recent years has been directed towards discovering how the marked improvement secured by an initial dressing of phosphate can be maintained, and it has been found that in no way can the maintenance of fertility of pasture be better secured than by means of supplementary dressings of phosphate.

ANTHROPOLOGY

Prof. Arthur Keith, as president of Section H, devoted his address to "The Differentiation of Mankind into Racial Types." It was maintained that an overwhelming majority of anthropologists were convinced that all varieties of living human races were descendants of a common ancestral stock, and that some varieties had departed less from the original pattern than others. There was no agreement, however, as to how the differentiation had come about. Natural and sexual selection were certainly parts of the evolutionary machinery which had given the Negro, the Chinaman, and the European their distinctive features of face, skull, and body, and also certain characteristics of mind, but it was clear that they did not constitute the whole of the machinery. Nothing was more desired by anthropologists at the present time than a rational explanation of how mankind has come by its racial characteristics.

There were many indications that the key to such problems was to be obtained by a close study of the disturbances or disorders which occasionally affect the development and growth of the human body. The disorders of growth are of many kinds; some are definitely proved to result from a functional derangement of one or more of the glands of internal secretion—the pituitary, thyroid, pineal, adrenal, and genital glands. In a manner which we are only beginning to perceive, the functions carried on in these glands regulate, not only the dimensions of the body, but also the shape and size of each individual part.

The machinery of race differentiation is resident in the growth-controlling glands of the body. The mistake is sometimes made of regarding each gland as carrying on a simple function, whereas each carried on a multitude of functions. Substances contained in the secretion of the pituitary gland not only could affect the size and proportion of the body, but also might pick out and emphasise the growth of one or