The Influence of Engineering on Civilisation.[1]

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ENGINEERING in its many branches has taken, and is still taking, a very extensive part in connexion with the amenities which are associated so closely with our domestic life, and indeed our happiness. Each branch of engineering has added its quota to the comfort of our lives, and I think it may be claimed that no other profession has so direct an association with our modern civilisation. The enormous increase in population during the nineteenth century, coupled with the segregation of that population in industrial centres, arising out of the extraordinarily rapid development of industry in Great Britain and other countries during that period, has introduced new problems in connexion with health and transport, and it has been the task of engineering in its many branches to deal with these problems.

The introduction of railways and of steamers during the first half of that century led the way to an enormously increased demand for coal, iron, and steel, and as the inventions of Sir Henry Bessemer and Sir William Siemens for making steel were developed, the necessity was evident to engineers and chemists for training schools to deal with the physical and technical problems involved in engineering and metallurgy, so as to arrive at a far greater accuracy, both in design and construction, than had hitherto been considered necessary or possible.

We have to admit, however, that the progress of industry depends very largely on the enterprise of deep-thinking men who are ahead of the times in their ideas. I may quote Dr. Clifton Sorby as such an instance. He introduced by his researches the microscopy of steel, and yet it was many years before this became a recognised method of gauging the quality of all classes of steel. Another great inventor, whom we all respect and are delighted to have still in active work, is Sir Charles Parsons, and I look back many years to the early 'eighties when Sir Charles put in years of research work in connexion with high speed engines before he successfully produced the steam turbine. Since that time he has devoted a large portion of his life to developing improvements both in the design of the turbine and the machinery for producing it, which have ultimately brought about its world renown.

CIVIL ENGINEERING.

The point which appears to me to stand out prominently in this branch of the profession is the fact that the structures to be dealt with are in many cases of an enormously costly nature, and have to be carried out with such careful study and comprehension of the varying problems to be dealt with so as to ensure permanent efficiency and safety in the future.

The great reservoirs and harbours of the world may be regarded as the cathedrals of engineering. The varying natural problems to be dealt with involve a very high level of technical education. In the construction of reservoirs, docks, and harbours, a considerable knowledge of geology is essential, and in harbour construction the varying effects of tides, which have to be studied minutely, have an important influence on the work to be undertaken. Throughout the world will be found monuments to the skill of the civil engineer, and the very existence of the population in our large cities in health and comfort is the result of his work, for without an ample and reliable supply of water of good quality, both for personal and industrial use, and an efficient drainage control, our death-rate would indeed be very different from what it is. If we turn for a moment either to India, with its great barrage enterprise, or Egypt, with the noble Assuan and Sennaar dams, truly outstanding works of the civil engineer, we find the prosperity of these countries largely resulting from the magnificent irrigation works which have been carried out there. Special development of produce growing in many countries is only being limited by the fact that insufficient irrigation works have so far been carried out. New Mexico and Arizona are two great provinces with potentially fertile land available for agricultural development, but they are so short of water that irrigation is an absolute necessity.

The large increase in tonnage of ocean-going vessels has resulted in the necessity for larger docks and harbour basins, and the development of railways all over the world, many of them in difficult mountainous countries, has given the civil engineer a great opportunity in designing bridges for carrying this heavy traffic. Many will appreciate the magnitude of the new bridge over Sydney Harbour which is now being constructed by British engineers, and the Forth Bridge still holds its own as a masterpiece of British engineering skill and the construction was in the hands of a Scotch firm well known in Glasgow. The new high-level bridge at Newcastle and the new Mersey tunnel are, I suppose, the most interesting civil engineering works at present in progress of construction in Great Britain, in addition to the considerable dock extensions now proceeding at Southampton, whilst in Canada a very noble bridge is now being thrown across the St. Lawrence River at Montreal.

TRANSPORT.

It may truthfully be said that the development of the potential wealth of any country depends mainly on the means of transport, both personal and industrial. I would allude especially to the great corn-growing countries where the home consumption bears only a small relation to the possible production. The knowledge that there is efficient transport both by rail and for export by sea is the greatest incentive to the farmers to spend money in extensive cultivation with the certainty of a ready market for such production.

[1] From the presidential address to Section G (Engineering) of the British Association, delivered at Glasgow on Sept. 7.

The comparison of travel to-day, both by land and sea, with my early journeys in Europe nearly fifty years ago, emphasises in my mind how much we are indebted to the engineer, in the way of personal safety and comfort and also prompt delivery of our products. A journey in the Balkans in the winter of 1881, when sleeping cars and restaurant cars were almost unknown, and when the largest vessel sailing from Mediterranean ports was in the neighbourhood of 4000 tons, compares very unfavourably in speed and personal comfort with the facilities which are available to-day. The comfort and safety of modern travel is to my mind one of the glories of modern civilisation. The 40,000 to 50,000 tons Atlantic liner, embracing as it does almost every class of engineering skill, is not only an example of artistic beauty, but is also one of the finest example of human power combating the forces of Nature. To be on one of these vessels driving into a gale at twenty knots is an experience never to be forgotten, and we are glad to realise what a large share the shipbuilding firms of Glasgow have had in the development of these large Atlantic liners.

Railway transport has also made great progress in all measures affecting personal safety and the efficient carrying of our various products. The railway engineers have every reason to be proud of their management of the complex organisation represented by the great railway systems all over the world. We are personally much safer travelling in an express train than we are crossing the streets of a great city, and I think we may justly be satisfied by the fact that in no country do the railways afford more comfortable or more rapid travelling facilities than in our own.

Naval Architecture.

This comprises shipbuilding and marine engineering and represents a very important part of my subject, dealing, as it does, with the transport by sea and lakes of food and materials, and with the comfort and safety of the many thousands of passengers travelling to and from Great Britain. The wooden vessel in the early part of last century held its own very stubbornly against the introduction of iron or steel vessels, and the mechanically propelled vessel had to fight very hard to oust the very efficient sailing vessels which were then carrying the trade of the world. I imagine that some with artistic tastes will not be willing to admit that the beauty of the present type of machanically propelled vessel is comparable with the picturesque five- and six-mast sailing vessels which we used to see in our earlier days.

Great Britain has undoubtedly been the pioneer in the building of large warships and passenger liners, also in the development of the very large horse-power therefor. The considerable increase in the tonnage of ships brought with it the necessity for a corresponding increase in the mechanical appliances in connexion with their construction. The trial runs carried out before a new ship is taken over by her owners are a severe test of the excellence of workmanship. They are a necessary test to ensure that long voyages of five to six weeks with machinery running continuously at nearly full power can be undertaken without fear of trouble arising from heated bearings or other causes. A new ship may be exposed to such rough weather on her first voyage that, unless her plating and riveting are carried out in a first-rate manner, she may arrive in her first port in a damaged condition. Glasgow has taken a leading part providing men who, in all weathers and under conditions rendered difficult by the magnitude of modern vessels, maintain the high level of efficiency which is represented in the manufacture of these large hulls. The vessels of the greatest tonnage built on the Clyde have been the *Aquitania* (46,000 tons) and the *Lusitania* (32,500 tons). Other large vessels built in the British Isles have been the *Olympic* (46,439 tons) and the *Mauretania* (30,696 tons). Since the War there has been a lull in the building of liners of large tonnage and horse-power, caused, no doubt, by financial considerations.

Shipbuilding is especially interesting inasmuch as it combines in one structure the varied efforts of almost every class of artisan dealing with both iron and steel and cabinet making and woodworking generally, in addition, of course, to the large and varied amount of mechanical engineering. High and low pressure triple expansion engines held their own for a considerable period, and it was, I suppose, the interesting trials of the *Turbinia* which brought about the first change from this method. It is an interesting fact that our fellow-member, Sir Charles Parsons, to whom I have already alluded, should live to see such successful development of his patent, and a recent paper read by him and his co-workers describes in a very interesting manner the gradual developments and changes in design in turbines up to the present time. Such developments range from the *Turbinia*, which had a displacement of 44½ tons with 2100 h.p., to the battle cruiser *Hood* of 41,200 tons and more than 150,000 h.p.

The introduction of geared turbines, so as to arrive at relatively efficient speed as between engine revolutions and propeller revolutions, has brought about valuable economies and helped the turbine principle to maintain its reputation. The development of internal combustion engines for marine purposes has made great strides in recent years. Various types of these engines are already in active service, and a horse-power of 36,000 on four propellers has already been achieved with efficiency; probably the limit has not yet been reached. The use of oil instead of coal on board ship, especially for passenger purposes, represents many advantages, and anyone who has visited the stokehold of a large passenger liner with the hundreds of men stoking with coal must realise the immense advantage, both physical and otherwise, which results from oil burning directly on the boilers. All inconvenience caused by dust in re-coaling is avoided, and the boiler tenting is carried out by young mechanical engineers, doing away with all the labour required by coal burning. In a vessel of large tonnage the saving in wages and maintenance of several hundreds of stokers represents an enormous economy in many directions. The question of larger horse-power and/or electrically driven ships is one of the problems to which marine engineers are at present turning their minds.

A new development which is now being introduced is the use of considerably higher steam pressures in boilers. The first application of this was the *King George V.*, a boat built recently on the Clyde, and our section has been favoured with a paper from Mr. Harold Yarrow dealing with some of the problems which have arisen in introducing high pressures. As will have been gathered from his paper, these problems are not solely those of the engineer who has to build the boilers. They are also closely associated with steel and metallurgical questions incident to the special manufacture of parts of the boilers owing to the much greater strength required.

MECHANICAL ENGINEERING.

It is difficult to regard mechanical engineering literally as a separate branch of engineering, for although numerically, I suppose, the mechanical engineers exceed the numbers of any other branch, nearly all their duties are associated with other types of engineering.

In connexion with civil engineering, all the plant occupied in harbour, dock, and railway construction is in the hands of the mechanical engineer. Also in transport and marine engineering the mechanical engineer is largely engaged in the engine building of both locomotives and marine engines and other types of auxiliary machinery for these purposes.

In electrical engineering, although this branch no doubt includes engineers without mechanical training, I would venture to say that the engineer is in an infinitely stronger position if he has received some training first as a mechanical engineer and specialised in electrical engineering afterwards.

A further important branch of the mechanical engineer's work is represented by the maintenance of machinery in the large steel works throughout the country and in the mills and factories of all descriptions. The directors of these companies are largely dependent on the advice of the engineer-in-charge in giving consideration to developments and the introduction of new types of plant to maintain production on an economic basis.

In mechanical engineering I must include the very important subject of machine-tool construction, a branch of engineering which has made very great strides and introduced many changes of design to meet new requirements in the last thirty years. Mass production on an economical basis in many industries has been the direct result of various tool-makers being able to produce special tools confined to the production of thousands of identical articles of a complicated design. I refer to articles produced at a cost of one-tenth to one-twentieth of what would be possible without machine tools specially designed for the purpose.

The introduction of high speed tool steel enabling far heavier cuts to be taken both by lathes and planing machines has rendered obsolete a large quantity of machine tools throughout the country, and the introduction of the electric drive has also brought about great changes in the design of machine tools. We hear to-day of some works in other countries without a single machine tool at work of pre-War date, a most desirable state of things, but one which, unhappily, the economic circumstances in Great Britain have rendered impossible up to the present time.

May I make a suggestion to the tool-makers in Great Britain ? When we are putting down an important new machine tool I find the makers will give every possible help in meeting our requirements in design and output, but they rarely follow up and ascertain what the real performance of the tool has been. To many of them 'no news is good news.' I think this is a mistake on their part. How many improvements and modifications, probably saving their clients money, could be made if they would periodically send the designer or chief draughtsman round to the works where these machines are actually at work and ascertain at first hand from the foreman and even the workman what criticisms they have to make, and accept for careful consideration any suggestions that may be put forward based on personal knowledge of the output of the machine.

MINING ENGINEERING.

In dealing with this section I propose to confine myself to coal mining, so as to shorten what I have to say, and also to be able to apply myself more closely to the development of coal mining as affecting civilisation.

Prior to the introduction of modern means of transport and the development of the iron and steel trade, the production of coal in Great Britain, both in the aggregate and per colliery, was very small, and consequently the amount of virgin coal face exposed at any one time in a colliery was quite moderate. Therefore the effusion of gas was not sufficiently large as to introduce a serious danger to men working with naked lights. Ventilation was carried out by means of a furnace in the bottom of the upcast shaft, the draught being sufficient for ventilating the moderate area of the workings. Increased production necessitated the adoption of mechanical means of ventilation and large fans were installed. Science had a large share in making colliery development on a big scale possible by the introduction of the Humphry Davy and other safety lamps. These warned the miners of the presence of gas and consequent danger. The much heavier tonnage produced in a given time necessitated the introduction of large horse-power winding engines, and also of wire ropes which would be sufficiently pliable to pass over the pulleys and headgear, and also be strong enough to carry not only their own weight, which in a shaft of 500 yards is not inconsiderable, but, in addition, a loaded cage involving a weight of thirty tons or more.

A sufficient supply of coal at a moderate price is a matter of interest to every inhabitant and manufacturer in the country, and therefore any engineering devices which have been introduced to ensure comfort and safety of the miners, and at the same time to give us our coal supply for manufacturing and domestic purposes at a moderate price, are of interest to everyone. Although we unhappily know that colliery explosions occasionally occur with very dire results, and regret the many accidents to miners arising out of falls of roofs, etc., those of us who are conversant with coal mining matters realise how much science and engineering have done to lessen the risk under which the miners work. Underground haulage has been everywhere adopted, so that the use of men for this arduous work, and, to a great extent, ponies also, has been abandoned. This underground haulage is largely carried out by compressed air engines placed underground, as in many pits it has not been felt safe to introduce electric power for the purpose except in the immediate neighbourhood of the shafts. It is true that the electrical engineer has gone a long way in lessening the liability to sparking, and in enclosing the motors so as further to lessen this risk. We are still left, however, with possible danger caused by the cables along the main roads, which, however carefully placed, are still liable to be damaged by unexpected falls of roof, thereby introducing a potential danger which is difficult to eliminate.

ELECTRICAL ENGINEERING.

This branch of engineering covers a very wide range of subjects and affects our social life almost more intimately than any other type of engineering, except perhaps the supply of good water and efficient drainage installations. Telegraphy, telephony, wireless, electric lighting, electric heating, electric driving, and electric power in their various ranges all enter into and affect the comfort of our domestic life. In considering this branch of engineering as a whole, I find it very difficult fairly to divide the credit for its development between the pure scientist and the electrical engineer. It is interesting at this meeting in Glasgow to recall that it was at the British Association meeting in this city in 1876 that Graham Bell, in conjunction with Lord Kelvin, brought to the Association's notice the telephone, and, further, the fact that at the Plymouth meeting of this Association in 1877, I shared with many eminent members of the British Association the interesting privilege of telephoning from the saloon to the bridge on the excursion steamer, with Prof. Graham Bell on board, going to and from the Eddystone Lighthouse. I allude to this fact because in those days it was regarded as a wonderful scientific invention which fascinated the most eminent scientific men. Yet to-day we take it all for granted, and scarcely realise the comfort and convenience that the introduction of the telephone has brought into our lives.

I admit that the introduction of wireless telephony and telegraphy has amazed the world to a greater extent than that of the telephone, and it is certainly more within the capacity of the pure scientist than of the engineer to explain the scientific problems involved. It is impossible to say what number of lives have already been saved by boats in distress having been able to secure help from other vessels by means of wireless communication.

The development of electricity as a mechanical driving power was very slow up to a certain date. For example, I went by electric train from Berlin to Charlottenburg in the spring of 1882. The running of the railway appeared to be quite satisfactory, and yet it was at least ten, and I think fifteen, years before any real development took place in the way of electric railways or trams, the difficulty, I believe, being in producing satisfactory dynamos on an economic basis.

In Great Britain considerable developments are taking place on the various main lines, but engineers are at present concentrating on the use of electric driving mainly for suburban traffic, and not at present on main line long distance expresses. It is probable that the great extension of high power installations throughout the country contemplated by the Electricity Commissioners will render possible a more extensive use of electric trains on our main lines.

The application of electricity for driving purposes in the various large works in Great Britain made very rapid strides as soon as electrical machinery for the purpose was available. Apart from the economy represented by its introduction, the change enabled the management to register the amount of power used by each type of machine under varying loads of service, a circumstance which was impossible with belt-driven machines, when the power varied according to the tightness and width of the belt.

The public, I think, fails to realise that electric lighting for domestic purposes, if charged at a reasonable rate, does not represent any real charge on the household. It is so clean in its application that, in my opinion, the necessity for cleaning and decorating which is avoided in many cases represents a greater saving than the amount paid for electric light. In addition we have the great advantage that it does not burn oxygen, and therefore we have more healthy conditions in our rooms compared with any other method of lighting.

Since I roughed out this address it has been my privilege to make a journey across America from New York to the Pacific Coast, and return through the Rocky Mountains and Canada, and throughout my journey I could not help realising how large a share engineering in its broadest sense has taken in developing these wide regions. Those of us who are spending our lives in engineering work may justly be proud of the large share the members of our profession are taking in promoting and advancing the civilisation of the world.