Alloys and their Importance in Engineering.

In an interesting and suggestive presidential address delivered to the Institution of Mechanical Engineers on Oct. [illegible], Sir Henry Fowler paid a tribute to the help that mechanical engineering has received, in the solution of many of its most difficult problems, from the work of the man of science. Particularly he attributed the remarkable changes that have taken place since Stephenson built the *Rocket* to new materials and the physical states in which they can be supplied; and in large measure these have been the outcome of scientific research. The whole profession of mechanical engineering is to-day dependent on metals. "Although many ingenious contrivances have been made from wood and stone, mechanical engineering only commenced when metals became available for use."

In the middle of the nineteenth century, railways were developing very rapidly and the makers of iron rails could not cope with the demand, but the truly scientific work of Bessemer and his production of steel relieved the situation. Between 1850 and 1926 the world's production of cast iron grew from 4½ million tons to 77 million tons. In 1870 the total steel produced was less than ½ million tons; in 1927 more than 90 million tons were made. Only three metals were used for the manufacture of the *Rocket*; to-day, on the L.M.S. railway, fifty-five specifications for metals are used, and the British Engineering Standards Association has prepared standard specifications for more than 100 varieties of steel. Sir Henry Fowler pointed out that the work of Bessemer and of Siemens and Martin insured for many years a sufficient quantity of steel, but the work of two other men of science, Thomas and Gilchrist, who in 1876 discovered that phosphorus could be very appreciably diminished by using a basic lining in the melting furnace, increased enormously the possible supplies.

The improvement and control of the quality of steels by improved methods of manufacture and the development of new alloy steels for tools and other purposes have revolutionised not only the methods of the machine and fitting shops, but also the designs of all types of machines and structures. The development of photomicrography and the pyrometer have contributed in no small measure to the success that has been achieved. Michael Faraday a century ago in England, and Berthier in France, experimented on alloys of nickel and chromium, but it was not until 1857 that Mushet alloyed tungsten with iron and made self-hardening steel; the remarkable developments in cutting speeds and in automatic machinery; consequent upon the new alloy tool steels, has almost entirely taken place, however, during the last twenty-five years. In 1882, Hadfield produced the manganese steel, so largely used to-day, because of its hardness, for points and crossings and dredger buckets, and later produced the silicon steel which has had very remarkable effects upon the construction of transformers and other magnetic and electrical apparatus.

During the twentieth century the nickel and nickel-chromium steels and the so-called molybdenum and vanadium steels made by the addition of small quantities of these metals to the nickel-chromium steels have not only played a considerable part in the development of the automobile and the aeroplane, but steels have also been produced having remarkable magnetic, or non-magnetic, properties and others which resist both corrosion and high stresses at normal and high temperatures in a remarkable manner. Some of these alloys resist the action of the strongest acids and are proving of the greatest service in the chemical industry. Others are not only valuable for case-hardening boxes and heating pots but also give promise of helping in the solution of difficulties in superheater elements, in the development of high temperature - high pressure vessels for distillation and synthetic processes and the gas turbine.

Turning from steels to the non-ferrous metals, the developments in the copper alloys, bronzes and brasses, and in the aluminium alloys, have been equally remarkable. Muntz metal was the first of the alloys of copper that could be forged and extruded, but it was not until mass production became important that full advantage of this alloy was taken. To-day the British Engineering Standards Association specifications demand for high tensile brass a breaking strength of 45 tons per sq. inch, and for brass bars 28 tons per sq. inch, and an elongation per cent. of 25 per cent. on a gauge length of not less than four diameters.

Alloys of copper—brasses and bronzes—of greater strength than these are possible. In these developments the work of contributors to the reports of Alloys Committee of the Institution of Mechanical Engineers has played an important part.

Aluminium in the commercial form has only been known for thirty-five years. In 1913 the world's production of aluminium was 64,000 tons, but in 1926 this had risen to 235,000 tons. In the pure state it is of comparatively little use to the engineer, but when alloyed with zinc and copper, with copper, manganese, and magnesium (4 per cent. Cu, ½ per cent. Mn, ½ per cent. Mg as duralumin), with copper, nickel, and magnesium (4 per cent. Cu, 2 per cent. Ni, 1½ per cent. Mg as Y alloy), with copper and silicon (a 4 per cent. Cu, 4 per cent. silicon is a good casting alloy for sund or die), and with other metals, a remarkable series of light alloys having specific gravities from 2·8 to 3·1 have been produced. Duralumin can be forged, extruded, and cold drawn, and by suitable heat treatment can be made to give a breaking stress of 32 tons per sq. inch with from 6 to 10 per cent. elongation. The Y alloy can be hot rolled and heat treated to give 24 tons per sq. inch and 23 per cent. elongation; all the other alloys can be cast into intricate shapes, and some of them make admirable die castings. For many parts of aeroplanes, aeroplane engines, and automobiles these alloys have proved invaluable. In the United States of America railway carriage frames are being constructed of duralumin, thus diminishing the dead weight, as compared with the net weight carried, very considerably. Die castings of intricate shapes, such as gear wheels, are now being made, to a remarkable degree of accuracy, of aluminium bronzes—alloys of copper and aluminium, containing more than 80 per cent. of copper.

The rapidity with which these alloys have been developed and have won the confidence of engineers is a tribute to the careful scientific work that has been done in connexion with their constitution and physical properties. The success achieved by the aluminium alloys has encouraged a number of workers to investigate the possibilities of alloying magnesium, which has only a specific gravity of 1·7 as compared with 2·67 for aluminium, with other metals, and already some success has been achieved in the application of magnesium alloys, containing more than 90 per cent. of magnesium, to the manufacture of high-speed pistons for internal combustion engines and other purposes.

Sir Henry Fowler paid a tribute to the important research work done in the great works, at the National Physical Laboratory, and also at the universities, but he emphasised the necessity for researches conducted jointly by men of science and engineers. Unfortunately, he did not suggest any method whereby the ability at present in the universities, which owing to pressure of teaching and other routine duties is not able, except at the cost of health, to apply itself to the solution of many problems with which industry is faced, can be given the necessary time and means to carry out research. The only hope seems a more generous provision of funds for the direct assistance of research in the engineering and metallurgical departments of the universities, in order that the condition of the apt quotation with which the address concluded may be fulfilled : " The wisdom of the scribe cometh by the opportunity of leisure ; and he that hath little business shall become wise."

Scientific Aspects of Intense Magnetic Fields and High Voltages.[1]

By Sir ERNEST RUTHERFORD, O.M., Pres.R.S.

IN the past our laboratories have had to be content with the comparatively weak magnetic fields provided by the ordinary electro-magnets and the voltages supplied by simple electrostatic machines and induction coils. In order to push further our investigations in many directions, much stronger magnetic fields and higher voltages are required in the laboratory. Scientific men thus naturally follow with great interest advances in these directions, whether undertaken for purely scientific or for technical uses.

By means of modern electrostatic machines it is not difficult to produce weak direct currents at potentials from 200,000 to 300,000 volts, while a large well-insulated induction coil can give momentary voltages of a similar magnitude. The wide use of X-rays for diagnostic and therapeutic purposes has led to a marked improvement in apparatus for exciting intense X-rays. The requirement of very penetrating X-rays for deep therapy in our hospitals has led to the construction of comparatively light transformers, which will supply the requisite small currents at voltages between 300,000 and 500,000.

One of the simplest ways of producing very high voltages is by the Tesla transformer, in which the oscillatory discharge of a Leyden jar is passed through the primary of an air transformer. In this way it is not difficult to produce voltages in the secondary of the order of a million volts, and I understand as much as five million volts have been obtained in the Carnegie Institution of Washington. The striking effects produced by these rapidly oscillating discharges from a Tesla coil, and the immunity with which long sparks may be taken through the body, are well known to all. The rapid frequency of the oscillations and the comparatively small energy given to the secondary of a Tesla coil has, however, restricted its use for general technical purposes as a source of high voltages, although it is now finding an application for the testing of insulating materials.

In order to transmit electrical power economically over long distances, there is a continuous tendency to raise the voltage in the transmission lines. This increase of the operating voltage has led to the need of very high voltages to test the insulating properties of these lines and their transformers and the effect of electric surges in them. In the course of the last few years a number of high-voltage plants have been installed for testing purposes in various countries, which give from one to two million volts. These voltages may be obtained either by a very large well-insulated power transformer or more generally by a cascade method employing several transformers in which the secondary current of one transformer passes through the primary of a second, and so on, the cores of the successive transformers being mounted on insulating pedestals. This cascade method is very advantageous for the purpose, since it allows a great reduction in weight and dimensions of the transformers. Such a high-tension plant in full operation is a striking sight, giving a torrent of sparks several yards in length and resembling a rapid succession of lightning flashes on a small scale. Actually the highest voltage so far obtained by these methods is very small compared with the voltage in a normal lightning flash from a cloud to the earth, where the difference of potential may be as high as a thousand million volts.

There appears to be no obvious limit to the voltages obtainable by the cascade arrangement of transformers, except that of expense and the size of the building required to install them. I am informed that the General Electric Company of

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[1] From the presidential address delivered at the anniversary meeting of the Royal Society on Nov. 30.