The Rugby Wireless Station.

By Dr. W. H. Eccles, F.R.S.

The Government wireless station at Rugby, now almost completed, is the only one of its class in the British Empire, and is the most powerful wireless station in the world. It was designed by the Wireless Telegraphy Commission and erected by the Wireless Section of the Engineering Department of the Post Office. During design and erection many new problems arose, partly because thermionic valves had not been used on so large a scale before, and partly because extreme efficiency was imperative in order to meet the Government's demand that the station should communicate with every part of the Empire. Many features of the station are novel and of wide interest.

The station occupies a site one and a half miles long and nearly a mile wide, containing about 900 acres, at 340 feet above sea-level. It has twelve masts, each 820 feet high, spread round the edges of the site a quarter of a mile apart. In the middle of the site are the buildings. The machinery hall is 185 feet long × 47 feet wide × 32 feet high, and contains electrical machinery of total power 800 kilowatts, fed from the public supply. A parallel hall measuring 103 feet × 40 feet × 68 feet contains the thermionic triode valves on the ground-level, the condensers on the next level, and the inductances on a still higher level. There are a number of smaller rooms for auxiliary machinery, together with offices, workshops, and testing rooms.

As a rule the steel lattice masts at big wireless stations are earth-connected at their bases and, in consequence, the oscillatory current in and out of the antenna induces oscillatory current up and down the masts. This induced current diminishes the radiation. To ameliorate this defect, insulated masts have been proposed. In fact, insulated masts have been erected in two or three cases, but after being tried have ultimately been connected to earth. The Commissioners thought these failures with insulated masts were due partly to the large electrical capacity between the foot of the mast and the foundation, and partly to bad insulation. They therefore arranged to erect masts on platforms 16 feet above the ground, and made a search for good insulators of small dielectric loss at high frequency. This work was started at Finsbury Technical College by aid of a grant from the Research Department, was continued with more powerful plant at the Admiralty Signal School, Portsmouth, and was concluded at the Post Office arc station at Northholt. As a result, the Commission selected Norwegian granite for the bulky portion of the insulating foot, and porcelain 'cheeses' for the part requiring the greatest electrical strength. As a mast weighs 180 tons, and as the downward component of stress from the stays amounts to more than 100 tons in a gale, these insulators were put through crushing tests as well as high-frequency insulation tests before being accepted for use. The insulation is designed for a quarter of a million volts; the measured voltage during the test of the station has reached 185,000 volts without causing trouble.

The antenna is of novel construction. The traditional 'flat top aerial' consists of a large number of parallel wires running across horizontal triatics which are slung between pairs of symmetrically placed masts; the antenna at Rugby consists merely of one conductor running round nearly the whole circumference of the site by passing from one mast top to the next. The underlying idea is that the electrical capacity to earth of a conductor round the edge of a horizontal elevated area is little less than that of the whole area—that is to say, the interior area adds little to the capacity. A study of the formation of the radiant field enables one to extend the idea to the emission of energy from an antenna. The results achieved by the Rugby station in recent months justify this departure from established practice. Actually, the conductor running round the edge of the site is a composite one consisting of eight phosphor bronze wires arranged as the generators of a cylinder 12 feet in diameter, of which the axis is a steel rope. The wires are supported by the rope on spiders resembling bicycle wheels 12 feet in diameter, which are threaded at equal intervals upon the rope. This skeleton cylinder has an electrical capacity about equal to that of a solid continuous cylinder 7 feet in diameter. It is supported from the masts by halyards each worked by an electric winch near the bottom of the mast. The winches each possess a slipping device set at 10 tons, so that when in a gale or snowstorm the tension in a halyard reaches this figure, the halyard is automatically paid out until the tension is lessened. Rehoisting is done after the storm. Although there is about three miles of this composite conductor hanging in flat festoons each a quarter mile long at a height of 800 feet between the consecutive masts, the slipping device has saved the aerial from breakdown several times during the heavy weather of the past winter.

The method of supplying the antenna with oscillatory current is new and has been developed entirely within the Wireless Research Section of the Post Office. The source of the oscillations is a tuning-fork of frequency 2000 per second, sustained in vibration by a small triode valve such as is used in broadcast receiving apparatus. The sustaining current is distorted by applying a constant negative potential to the grid, and is magnified by passing through two small triodes in cascade with about 150 volts on the anodes. The eight-fold harmonic, that is to say, the oscillation of frequency 16,000 per second, is selected by resonance in a circuit of that natural frequency. The oscillatory current, still very feeble, is now passed through a three-step amplifier using T30 triodes with 1000 volts on the anodes; and the strengthened oscillations then pass to a 600-watt glass triode with 10,000 volts on the anode. The oscillations now go to the grids of three water-cooled metal-glass triodes, from the anodes of which 30 kilowatts of high-frequency power can be drawn. This power is applied to the grids of fifty-four similar water-cooled triodes, also working in parallel, which deliver about 540 kilowatts to the main high-frequency circuit. The anodes of these triodes are supplied with direct current at 10,000 volts by means of motor generators delivering 1000 to 1500 kilowatts at a voltage variable from 10,000 to 18,000 at will. The thermionic current may exceed 100 amperes.

It will be seen that the magnification of the original harmonic in the tuning-fork circuit is enormous; in fact, if we assume that the harmonic is only a few microwatts to start with, the magnification is of the order of magnitude 10^{11} (one hundred thousand million times). Obviously the screening of each circuit from the more powerful one succeeding it in the chain is of the utmost importance and must be carried out thoroughly.

At Rugby the fork has a frequency of 2000 per second and can be slightly adjusted by the inertia effects of small set screws in the prongs. When the temperature in the fork box alters by 1° C. the frequency of the final oscillations changes from 16,000 to 16,001·5, an amount imperceptible in the ordinary receiving apparatus of wireless telegraphy. The advantages of constant frequency are many; but the principal one is that exceedingly selective receiving apparatus can be employed, and all the refinements of accurate note tuning can be utilised, in order to prevent interference by other wireless stations working on nearly the same wave-length.

The design of the high-frequency circuits has presented many problems. These circuits comprise an inductance coil and condensers forming a closed circuit, which is connected on one hand to the anodes of the bank of fifty-four triodes, and on the other hand excites the antenna by means of mutual inductance.

The condensers must withstand a quarter million volts, must pass a thousand amperes at high frequency, and must not cause appreciable loss of energy. Condensers using thoroughly dry and clean oil would probably be best, as oil has a power factor less than one-twentieth of one per cent.; but, in order to save space, mica condensers were adopted, and these have a power factor less than a quarter of one per cent. They weigh more than ten tons. They are carried on a partial flooring about 20 feet above the ground floor on which the triodes stand.

The high-frequency coils in the closed circuit and in the antenna are made of stranded cable containing 6561 separately insulated copper wires of 36 gauge made up by twisting in threes. The coils are of various sizes; the antenna tuning coil, for example, consists of five flat spirals of eight turns each, the outer turn of each spiral being 15 feet 6 inches in diameter. The total weight of the coils is about 6 tons. They are carried on great beams of fir 20 feet above the level of the condensers, and are flanked by flying galleries along which men can pass for inspecting and adjusting the coils. This isolated position is chosen for the coils because the inductive effects of the large high-frequency currents they carry might lead to great energy losses and even to destructive rises of temperature, if any metallic masses were near. The roof trusses, the beams, the supporting framework of the coils, are all of selected wood. The most suitable wood for this purpose, that is to say, the wood with the smallest dielectric loss at high frequencies, is American white wood—a discovery made after long and close investigation in the Post Office laboratories.

The features above described are only a small selection of the numerous novel details with which the station abounds. But the space available permits of no further descriptions. There is just room for a few remarks upon the performance of the station as judged by observers who happened to be listening in at great distances during the tests of the past few months. For example, Newfoundland reported "signals thundering in"; New York said "signals readable through heavy atmospheric and jamming" and "copyable at 75 words per minute"; Cape Town reported "note good and steady"; in the Red Sea "Rugby effectively drowns all interference"; Java reported "key action excellent, frequency very constant"; Dutch East Indies said "Rugby splendidly received, far more distinct than any other European station." The Commander-in-Chief of the China station stated "all ships report note good, clear and steady." Among other Australian stations, Sydney reported "Rugby was only European station readable through atmospherics." These results, it should be noted, have been obtained with less than the full power available. For up to this date only eight of the twelve masts have been utilised on these telegraphic tests, owing to the other four masts being temporarily set aside for the trans-Atlantic telephony trials. The eight mast aerial will take only about 600 amperes without exceeding a voltage of 200,000, and at this rate only about two-thirds of the possible high-frequency power is being drawn from the triodes. But the complete equipment will doubtless be required to ensure communication at all hours of the twenty-four and under severe conditions.

The Stratigraphical Value of Micro-organisms in Petroleum Exploration.

By Henry B. Milner.

During the last decade of rapid development of technique of petroleum geology, problems of sub-surface stratigraphical correlation have forced themselves to the front, and have engaged the closest attention of geologists operating principally in late Cretaceous and Tertiary oil-fields all over the world. Formerly, and to some extent now, drillers' recognition and classification of rock-chips collected either from bailer or sample box served as a crude guide to underground conditions, though the limited vocabulary and superficial petrological knowledge of the average driller led to some quaint determinations and technically to still more fanciful structural interpretations. 'Gumbo' and 'shell,' for example, cover a multitude of geological shortcomings, while clay, shale, silt, and sand vary in diagnosis largely according to their degree of wetness when they arrive at the surface; anything productive of white powder to the bit is termed 'chalk,' and so on. Such casual nomenclature and equally casual sampling has been part of the long-established code of the oil-well driller, and sufficed until the advent of a more exacting petroleum geology signified the impending and much-to-be-desired change.

The closer study of productive rocks and sub-surface structures concerned with the preservation of petroleum pools has gradually led to the adoption of