CHAPTER 4

Electricity

The phenomenon which Thales had observed and recorded five centuries before the birth of Christ aroused the interest of many scientists through the ages. They made various practical experiments in their efforts to identify the elusive force which Thales had likened to a "soul" and which we now know to have been static electricity.

Of all forms of energy, electricity is the most baffling and difficult to describe. An electric current cannot be seen. In fact it does not exist outside the wires and other conductors which carry it. A live wire carrying a current looks exactly the same and weighs exactly the same as it does when it is not carrying a current. An electric current is simply a movement or flow of electrons.

Section 4.1: The Early Scientists

4.1.1 The Nature of Electricity

Benjamin Franklin, the American statesman and scientist born in Boston in 1706, investigated the nature of thunder and lightning by flying a child's kite during a thunderstorm. He had attached a metal spike to the kite, and at the other end of the string to which the kite was tied he secured a key. As the rain soaked into the string, electricity flowed freely down the string and Franklin was able to draw large sparks from the key. Of course this could have been very dangerous, but he had foreseen it and had supported the string through an insulator. He observed that this electricity had the same properties as the static electricity produced by friction.

But long before Franklin many other scientists had carried out research into the nature of electricity.

In England William Gilbert (1544-1603) had noticed that the powers of attraction and repulsion of two non-metallic rods which he had rubbed briskly were similar to those of lodestone and amber – they had acquired the curious quality we call magnetism. Remembering Thales of old he coined the word "electricity."

Otto von Guericke (1602-1686) a Mayor of Magdeburg in Germany, was an amateur scientist who had constructed all manner of gadgets. One of them was a machine consisting of two glass discs revolving in opposite directions which produced high voltage charges through friction. Ramsden and Wimshurst built improved versions of the machine.

4.1.2 Alessandro Volta

A significant breakthrough occurred when Alessandro Volta (1745-1827) in Italy constructed a simple electric cell (in 1799) which produced a flow of electrons by chemical means. Two plates, one of copper and the other of zinc, were placed in an acid solution and a current flowed through an external wire connecting the two plates. Later he connected cells in series (voltaic pile) which consisted of alternate layers of zinc and copper discs separated by flannel discs soaked in brine or acid which produced a higher electric pressure (voltage). But Volta never found the right explanation of why his cell was working. He thought the flow of electric current was due to the contact between the two metals, whereas in fact it results from the chemical action of the electrolyte on the zinc plate. However, his discovery proved to be of incalculable value in research, as it enabled scientists to carry out experiments which led to the discoveries of the heating, lighting, chemical and magnetic effects of electricity.

4.1.3 Hans Christian Oersted

One of the many scientists and physicists who took advantage of the "current electricity" made possible by Volta's cells was Hans Christian Oersted (1777-1851) of Denmark. Like many others he was looking for a connection between the age-old study of magnetism and electricity, but now he was able to pass electric currents through wires and place magnets in various positions near the wires. His epoch-making discovery which established for the first time the relationship between magnetism and electricity was in fact an accident.

While lecturing to students he showed them that the current flowing in a wire held over a magnetic compass needle and at right angles to it (that is east-west) had no effect on the needle. Oersted suggested to his assistant that he might try holding the wire parallel to the length of the needle (north- south) and hey presto, the needle was deflected! He had stumbled upon the electromagnetic effect in the first recorded instance of a wire behaving like a magnet when a current is passed through it.

Section 4.2: Later Discoveries

A development of Oersted's demonstration with the compass needle was used to construct the world's first system of signaling by the use of electricity.

4.2.1 Sir Humphry Davy

Sir Humphry Davy (1778-1829) one of Britain's leading chemists of the 18th century, is best remembered for his safety lamp for miners which cut down the risk of methane gas explosions in mines. It was Davy who first demonstrated that electricity could be used to produce light. He connected two carbon rods to a heavy duty storage battery. When he touched the tips of the rods together a very bright white light was produced. As he drew the rods apart, the arc light persisted until the tips had burnt away to the critical gap which extinguished the light. As a researcher and lecturer at the Royal Institution Davy worked closely with Michael Faraday who first joined the institution as his manservant and later became his secretary. Davy's crowning honour in the scientific world came in 1820, when he was elected President of the Royal Society.

4.2.2 Charles Wheatstone and William Cooke

In 1837 Charles Wheatstone and William Cooke took out a patent for the world's first Five-needle Telegraph, which was installed between Paddington railway station in west London and West Drayton station a few miles away. The five copper wires required for this system were embedded in blocks of wood.

4.2.3 Carlisle and William Nicholson

Electrolysis, the chemical decomposition of a substance into its constituent elements by the action of an electric current, was discovered by the English chemists Carlisle and William Nicholson (1753-1815). If an electric current is passed through water it is broken down into the two elements of which it is composed – hydrogen and oxygen. The process is used extensively in modern industry for electroplating. Michael Faraday (1791-1867) who was employed as a chemist at the Royal Institution, was responsible for introducing many of the technical terms connected with electrolysis, like electrolyte for the liquid through which the electric current is passed, and anode and cathode for the positive and negative electrodes respectively. He also established the laws of the process itself. But most people remember his name in connection with his practical demonstration of electromagnetic induction.

4.2.4 Andre-Marie Ampere

In France Andre-Marie Ampere (1775-1836) carried out a complete mathematical study of the laws which govern the interaction between wires carrying electric currents.

4.2.5 Georg Ohm

In Germany in 1826 a Bavarian schoolmaster Georg Ohm (1789-1854) had defined the relationship between electric pressure (voltage), current (flow rate) and resistance in a circuit (Ohm's law) but 16 years had to elapse before he received recognition for his work.

Scientists were now convinced that since the flow of an electric current in a wire or a coil of wire caused it to acquire magnetic properties, the opposite might also prove to be true: a magnet could possibly be used to generate a flow of electricity.

4.2.6 Thomas Alva Edison

In the U.S.A. the prolific inventor Thomas Alva Edison (1847-1831) who had invented the incandescent carbon filament bulb, built a number of electricity generators in the vicinity of the Niagara Falls. These used the power of the falling water to drive hydraulic turbines which were coupled to the dynamos. These generators were fitted with a spinning switch or commutator (one of the neatest gadgets Edison ever invented) to make the current flow in unidirectional pulses (D.C.) In 1876 all electrical equipment was powered by direct current.

4.2.7 Michael Faraday

Michael Faraday had worked on this problem for ten years when finally, in 1830, he gave his famous lecture in which he demonstrated, for the first time in history, the principle of electromagnetic induction. He had constructed powerful electromagnets consisting of coils of wire. When he caused the magnetic lines of force surrounding one coil to rise and fall by interrupting or varying the flow of current, a similar current was induced in a neighboring coil closely coupled to the first.

The colossal importance of Faraday's discovery was that it paved the way for the generation of electricity by mechanical means. However, the basic generator produces an alternating flow of current. (A.C.)

Rotating a coil of wire steadily through a complete revolution in the steady magnetic field between the north and south poles of a magnet results in an electromotive force (E.M.F.) at its terminals which rises in value, falls back to zero, reverses in a negative direction, reaches a peak and again returns to zero. This completes one cycle or sine wave. (1Hz in S.I. units).

In recent years other methods have been developed for generating electrical power in relatively small quantities for special applications. Semiconductors, which combine heat insulation with good electrical conduction, are used for thermoelectric generators to power isolated weather stations, artificial satellites, undersea cables and marker buoys. Specially developed diode valves are used as thermionic generators with an efficiency, at present, of only 20% but the heat taken away from the anode is used to raise steam for conventional power generation.

Section 4.3: The Achievements of Nicola Tesla

Today mains electricity plays a vital part in our everyday lives and its applications are widespread and staggering in their immensity. But we must not forget that popular demand for this convenient form of power arose only about 100 years ago, mainly for illumination.

Recent experiments in superconductivity, using ceramic instead metal conductors have given us an exciting glimpse into what might be achieved for improving efficiency in the distribution of electric power.

Historians of the future may well characterize the 20th century as "the century of electricity & electronics". But Edison's D.C. generators could not in themselves, have achieved the spectacular progress that has been made. All over the world we depend totally on a system of transmitting mains electricity over long distances which was originally created by an amazing inventor whose scientific discoveries changed, and are still changing, the whole world. His name was scarcely known to the general public, especially in Europe, where he was born.

Who was this unknown pioneer? Some people reckon that it was this astonishing visionary who invented wireless, remote control, robotics and a form of X-ray photography using high frequency radio waves. A patent which he took out in the U.S.A. in 1890 ultimately led to the design of the humble ignition coil which energizes billions and billions of spark plugs in all the motor cars of the world. His American patents fill a book two inches thick. His name was Nicola Tesla (1856-1943).

4.3.1 Young and Inspired

Nicola Tesla was born in a small village in Croatia which at that time formed part of the great Austro-Hungarian Empire. Today it is a northern province of Yugoslavia, a state created after the 1914-1918 war. Tesla studied at the Graz Technical University and later in Budapest. Early in his studies he had the idea that a way had to be found to run electric motors directly from A.C. generators. His professor in Graz had assured him categorically that this was not possible. But young Tesla was not convinced. When he went to Budapest he got a job in the Central Telegraph Office, and one evening in 1882, as he was sitting on a bench in the City Park he had an inspiration which ultimately led to the solution of the problem.

Tesla remembered a poem by the German poet Goethe about the sun which supports life on the earth and when the day is over moves on to give life to the other side of the globe.
He picked up a twig and began to scratch a drawing on the soil in front of him. He drew four coils arranged symmetrically round the circumference of a circle. In the center he drew a rotor or armature. As each coil in turn was energized it attracted the rotor towards it and the rotary motion was established. When he constructed the first practical models he used eight, sixteen and even more coils. The simple drawing on the ground led to the design of the first induction motor driven directly by A.C. electricity.

4.3.2 Patents and Contracts

Tesla emigrated to the U.S.A. in 1884. During the first year he filed no less than 30 patents mostly in relation to the generation and distribution of A.C. mains electricity. He designed and built his "A.C. Polyphase System" which generated three-phase alternating current at 25 Hz. One particular unit delivered 422 amperes at 12,000 volts. The beauty of this system was that the voltage could be stepped down using transformers for local use, or stepped up to many thousands of volts for transmission over long distances through relatively thin conductors. Edison's generating stations were incapable of any such thing.

Tesla signed a lucrative contract with the famous railway engineer George Westinghouse, the inventor of the Westinghouse Air Brake which is used by most railways all over the world to the present day. Their generating station was put into service in 1895 and was called the Niagara Falls Electricity Generating Company. It supplied power for the Westinghouse network of trains and also for an industrial complex in Buffalo, New York.

After ten years Tesla began to experiment with high frequencies. The Tesla Coil which he had patented in 1890 was capable of raising voltages to unheard of levels such as 300,000 volts. One of Tesla's patents related to a system of lighting using glass tubes filled with fluorine (not neon) excited by H.F. voltages. His workshop was lit by this method. Several years before Wilhelm Roentgen demonstrated his system of X-rays Tesla had been taking photographs of the bones in his hand and his foot from up to 40 feet away using H.F. currents.

More astonishing still is the fact that in 1893, two years before Marconi demonstrated his system of wireless signaling, Tesla had built a model boat in which he combined power to drive it with radio control and robotics. He put the small boat in a lake in Madison Square Gardens in New York. Standing on the shore with a control box, he invited onlookers to suggest movements. He was able to make the boat go forwards and backwards and round in circles. We all know how model cars and aircraft are controlled by radio today, but when Tesla did it a century ago the motor car had not been invented, and the only method by which man could cover long distances was on horseback!

It is believed that in the pursuit of his life's ambition to send power through the earth without the use of wires, Tesla had achieved a small measure of success at E.L.F. (extremely low frequencies) of the order of 7 to 12 Hz. These frequencies are at present used by the military for communicating with submarines submerged in the oceans of the world.

Tesla's career and private life have remained something of a mystery. He lived alone and shunned public life. He never read any of his papers before academic institutions, though he was friendly with some journalists who wrote sensational stories about him. They said he was terrified of microbes and that when he ate out at a restaurant he would ask for a number of clean napkins to wipe the cutlery and the glasses he drank out of. For the last 20 years of his life until he died during World War II in 1943 he lived the life of a semi-recluse, with a pigeon as his only companion. A disastrous fire had destroyed his workshops and many of his experimental models and all his papers were lost for ever.