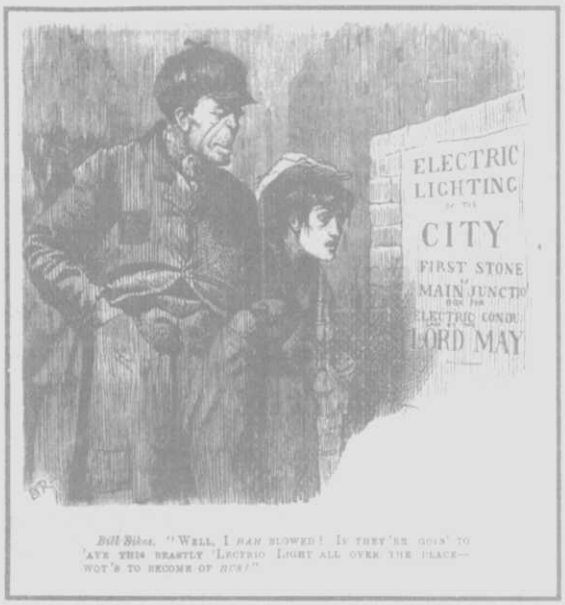
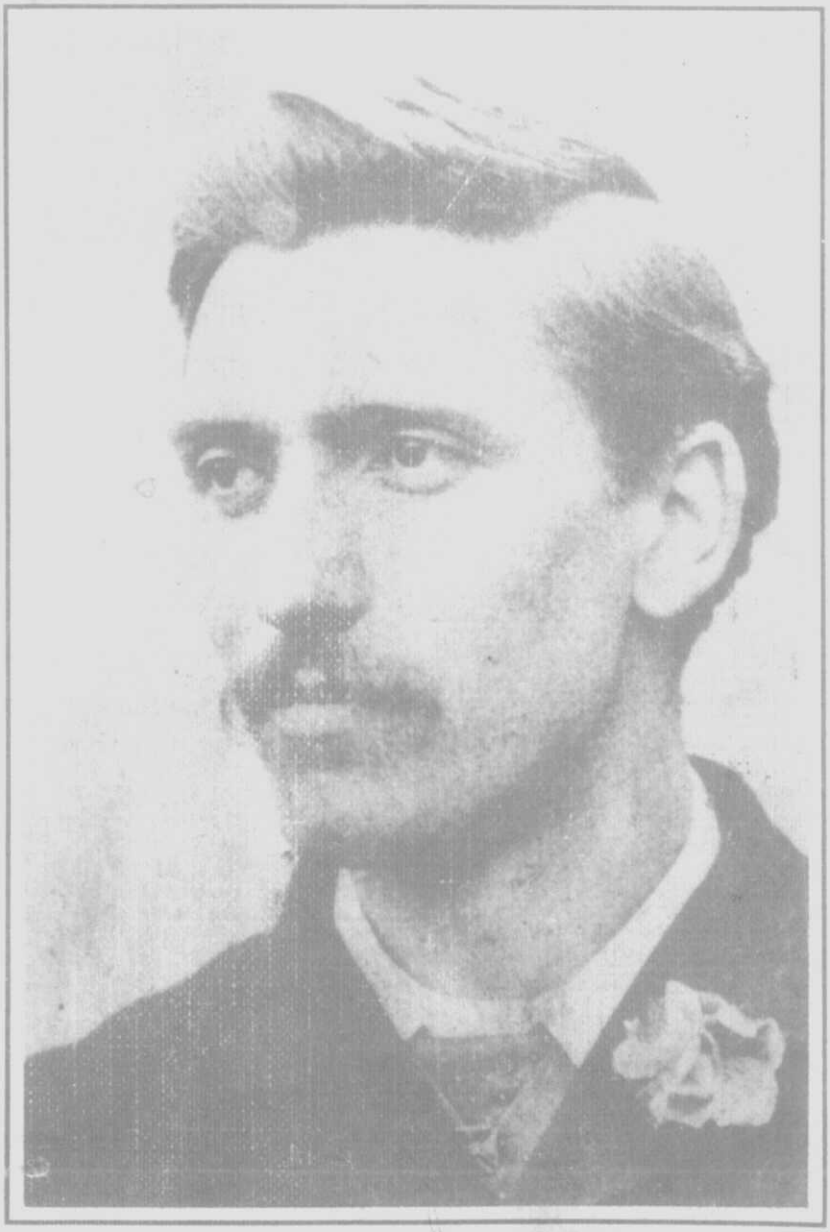
ELECTRICITY·SUPPLY
in the United Kingdom



Bill Sikes. "WELL, I *DAM* BLOWED! IS THEY'RE GOIN' TO 'AVE THIS BEASTLY 'LECTRIC LIGHT ALL OVER THE PLACE—WOT'S TO BECOME OF *US*?"



A·CHRONOLOGY

Front Cover
Sebastian Ziani de Ferranti age 25. (Courtesy Ferranti Archives)
Cartoon from "Punch" 21 February, 1891.
Hastings Electricity Works, Babcock & Wilcox boilers 1909. (E. C. Archives)

Back Cover
Cartoon by W. M. Duffey, showing "experiment" to demonstrate the safety of Ferranti's 10 kV cable. (Courtesy Ferranti Archives)
Lord Hinton of Bankside OM, KBE, FRS, FEng. (E. C. Archives)
Lahmeyer flywheel alternator, Bow Power Station 1902.
50 hp AC generator, 1891. (E. C. Archives)
Polo match by electric light at the Ranelagh Club ("The Illustrated London News", 5 June, 1886).

Electricity Supply in the United Kingdom

A Chronology—From the beginnings of the industry to 31 December 1985

The Electricity Council

The day must come when electricity will be for everyone, as the waters of the rivers and the wind of heaven. It should not merely be supplied, but lavished, that men may use it at their will, as the air they breathe. In towns it will flow as the very blood of society. Every home will tap abundant power, heat and light like drawing water from a spring. And at night it will light another sun in the dark sky, putting out the stars. There will be no more winter, summer will be eternal, warmth will return to the old world, melting even the highest snow.

Émile Zola, "Travail" (Book III, Ch II) pub. 1901.

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Preface

This annotated chronology records the principal developments in the technology of electricity supply and utilisation; legislation and reports of official committees; regulations governing electricity; and organisations of the electrical industry.

Although primarily concerned with the United Kingdom, it also includes references to some of the outstanding developments abroad. It is necessarily highly selective.

In dealing with 'official' information, such as annual reports and reports of Select Committees, the original sources have been consulted wherever possible. But some reliance has had to be placed on other 'authoritative' sources.

Among the large number of publications that have been consulted are those set out at the end of the chronology. Grateful achnowledgment is made to the authors and publishers concerned.

Supporting the chronology is a comprehensive Alphabetical Index (p. 171).

REMINISCENCES

From Proceedings at Commemoration Meetings, 1922. IEE Journal Vol. 60, April 1922.

Colonel R. E. B. Crompton

During 1886–1887 a very brilliant young man appeared on the scene: Ferranti. He took up the AC transformer method of distribution and soon he and I became the captains of two opposed schools of electric distribution. At the time I was starting at Kensington-court and canvassing householders to take the electric light. Ferranti, with Lord Crawford, started the Grosvenor Gallery and many interesting things occurred. As I at Kensington-court always had accumulators in reserve I never had any extinctions or stoppage of the light, whereas the difficulties with alternating currents, which no doubt Ferranti will describe to you, caused many extinctions at the Grosvenor Gallery. I could tell many amusing stories of the horror of chaperones when Mayfair ball-rooms were suddenly plunged into darkness, and it can be realised how difficult it became for me to preach safety and continuity of electric supply at Kensington when such proceedings went on in Mayfair.

Dr S. Z. de Ferranti

The position of electric lighting in those days (*c. 1881*) was that many installations consisted of a dynamo supplying a single arc-lamp. There were, of course, at that time installations just beginning of Brush machines, supplying 16 arc lamps in series. The City of London, however, was so uncertain as to the best way to do its street lighting that it divided the contract between three concerns. There was the Brush Company, with a number of 16-lamp circuits; there was also the Maxim Company who used Weston machines, and who did, I think, very much the same sort of thing, and there was the Siemens installation consisting of a number of masts carrying very big lamps which were each fed from their own dynamos. The smaller streets were lit by means of alternating-current lamps with a few lamps on each circuit. . . . . .

I ought to finish, but I cannot do so without attacking my dear friend Colonel Crompton. He said, during the controversies that went on as between the advocates of alternating high-tension and direct low-tension current, the most shocking things, such as could not be repeated in a scientific meeting like this. He attacked me in every way he could, and on one occasion, I think, worked himself up sufficiently to threaten me with personal violence. But he fought fairly and, although hard hit, I recovered, and appreciated him more and more after each attack.

Mr F. Bailey (Telegraph Construction and Maintenance Co., later proprietor of Whitehall Electric Supply Co.; Chief Engineer of Metropolitan Electric Supply Co. and City of London Electric Lighting Co.).

The works at Greenwich had been equipped with a large Gordon flywheel alternator, and owing to no voltmeter being available—as nothing of this kind had then been made in a satisfactory form—the pressure of supply was regulated by a photometer which was placed in a dark room close to the engine, and the man sat near the stop valve of the exciter engine and kept his eye on the photometer.

Sir Daniel Gooch, chairman of the Great Western Railway Co. and also of the Telegraph Construction and Maintenance Co., arranged a contract for supplying electric light to the Railway from Westbourne Park to Paddington station, and the works were commenced in 1884 by placing the generating plant in a central position and using the Gordon divided main for transmission to the various local centres. There were three alternators, each connected direct to a compound engine made by Messrs Rennie, these being the last engines constructed by this firm in London. In starting up these works in June 1885 it was soon found that the design required considerable alteration, as the engine indicated 600 hp when supplying only 4 arc lamps, and when in desperation I placed the machine on short-circuit the engine ran away. By alterations to the field-magnet poles, which were too wide, and also to the coils, we were soon able to obtain a better result and secured an efficiency of about 55 per cent. . . . . .

The record of the output of these machines was obtained by the only instrument available at that time, namely a Siemens dynamometer, and although we knew that the machines gave a different result when supplying an inductive load, such as arc lamps with their choking coils, as compared with a similar load when supplying incandescent lamps, we had no knowledge of power factor, and this point was discussed with Lord Rayleigh and others who frequently visited the works. . . . . .

After the first trials of this plant in 1885, complaints were received from the adjoining residential property of annoyance from smoke, smell, noise, and vibration. These complaints soon culminated in an action and injunction, and Mr Justice North was so surprised at the extraordinary allegations made that he personally inspected the generating plant, and although he granted this injunction he gave time for certain alterations to be carried out. A writ of sequestration being applied for was refused, and when carried to the Appeal Court the application was dismissed. . . . . .

It is difficult at this date to realise the condition of electrical work at that time. The abortive Chamberlain Act of 1882 suggested a recognition of the possibilities of electric lighting, only to kill them by very limited encouragement. A Select Committee of the House of Lords, with Lord Camperdown as chairman, sat for 9 days taking evidence which emphasised that the state of electrical science was not then satisfactory for investment of capital, and two large corporations sent their town clerks to protest against further concessions to electric lighting as they had bought up the local gas works—in one case paying £2,000,000 for them. Sir George Elliott, M.P., told me at that time it was hopeless to expect Parliament to foster a rival to gas, but fortunately, as we all know, the 1888 Act was passed and assisted progress, but in a limited parochial manner. . . . .

In 1887–8 we carried out a direct-current station at Whitehall, and with the consent of the St Martin's Vestry laid mains (Messrs. Callenders being our contractors) up to St Martin's Church and on to the Garrick Theatre, and then to Messrs. Hamptons along the front of the National Gallery. We had deposited a Bill to obtain the necessary Parliamentary powers, and this was made an Act in 1889. The Garrick Theatre, which was then being opened, was supplied from a separate battery in the rear of the premises; and we carried out the lighting of St Martin's Church. . . . . .

It was difficult, even in 1888, to obtain a satisfactory direct-current dynamo of 100 kW output, and our first machines were a failure and had to be replaced. Howell batteries were put in as an experiment, but soon failed, as the plates either buckled or expanded, breaking the jars and causing the acid to short-circuit the whole thing with a wonderful display of fireworks. We put in three Willans engines of the then new central-valve type, these engines being the first to have the solid crank-pin eccentric, as the separate keyed-on eccentric used at Vienna had not proved satisfactory. . . . . .

For the next 6 years we had a constant struggle against all kinds of difficulties, and erected plant in four other stations, all of which gave more or less trouble, either in operating the plant or in fighting injunctions for vibration, etc.

The works at Sardinia-street were started at the end of 1889 with Westinghouse plant, single-phase, 1,000 volts, 133 frequency, and 50-volt transformers, overhead mains being used until we had time to lay underground mains. . . . . .

Complaints were soon made of annoyance from noise and vibration, and after purchasing a public house which complained of loss of trade owing to the noise or the vibration causing the beer to become cloudy, we were left with a long-continued bombardment from the adjoining solicitors' offices in Lincoln's Inn Fields, but these never culminated in an action for injunction, thus showing the wisdom of the law in not taking the risk of a legal action. . .

The Drury Lane Theatre was anxious to obtain a supply in the winter of 1889 and, as we could not complete the laying of the underground mains in time for the pantomime, the first supply was given by means of overhead mains. Sir Augustus Harris was so pleased with the opportunity of adopting novel stage effects that he tried to dress the ballet with incandescent lamps, but the heat given off by the lamps, at 4 watts per candle, was so great that the rehearsal produced a dance of agony and the victims objected to being grilled. . . . . .

The Rathbone-place works were started in 1890, using Babcock boilers, Willans engines, and Parker alternators of 100 kW each. This station worked well for about 16 years.

The Manchester-square works were also started in 1890 with a similar plant, but with 5 years' anxiety owing to vibration troubles. Complaints were soon received from adjoining residents of noise and vibration. At this time none of the Parker alternators would work in parallel, and a system of changing over circuits had to be adopted, but the noise was difficult to control, as the sound waves varied in amplitude as the machines varied in speed, and varied from quick waves to a prolonged drone. Many attempts were made to mitigate the vibration, but on examination it was found that the site covered the original course of the Tyburn Brook, and the subsoil, while apparently firm on the surface, soon developed into a muddy silt and we did not reach clay until we bored down from 30 to 40 feet. These borings were made through cast-iron cylinders of about 3 ft. diameter, the lower cylinder being provided with a cutting edge. A large number of these piers were bored through the existing foundations with lateral columns, the base being excavated to form a heavy shoe, and the whole of the columns were filled in with concrete. The Willans engines, however, still continued to give annoyance to the neighbours, and, although the applications for an injunction were suspended from time to time, the judge finally intimated that some drastic cure must be adopted. Sir Charles Parsons then offered to construct turbines of the then unknown output of 350 kW and a large number of these machines were ordered. The anxieties of maintaining the supply under these conditions were very great, and the preparation of affidavits necessitated frequent journeys to Newcastle, with a rush to write the affidavit and get it sworn in time for the court in order to secure a further suspension of the injunction.

In these early turbines the armature was the rotor, and fortunately they worked with a great reduction in the humming noise and a freedom from vibration. I do not like to refer to the many breakdowns of this plant, as they were obviously inevitable in the early trials of such a large departure from existing practice, and our gratitude at being saved from the ruin of an injunction enabled us to praise even the most defective turbine.

After this experience Messrs Parsons were able to build even larger turbines with a remarkable freedom from stripping and fractures, as everything that could break down had already done so at these works. . . . . .

The Amberley-road works commenced to run in 1901, using plant supplied by Messrs. Johnson & Phillips consisting of Hornsby locomotive boilers and horizontal engines with Kapp rope-driven alternators. These locomotive boilers were soon afterwards changed to Babcock boilers, and the rope-driven plant worked for many years without any trouble, and was exhaustively tested by our then superintendent of the works, Mr R. A. Chattock, the steam consumption being 56 lb per kilowatt-hour non-condensing, and the thermal efficiency of the plant about 4 per cent.

During all these anxious times, the cheery optimism of the chairman of the company, Sir John Pender, carried us through many difficulties, and he was always pleased to discuss any matter, particularly at breakfast, as he appreciated the advantage of catching one's fish early, getting him fresh, and having him for breakfast.

The Willesden site was then purchased, and I sent out specifications for the plant in June 1897, the works being started about 1900. At that time no English maker submitted an offer to supply three-phase plant, and Dr John Hopkinson advised me not to take the risk of such a new departure, while Lord Kelvin protested that I was unwise in going for such a large machine as 1,500 kW, as he thought 500 kW was a much safer size. The Westinghouse Company undertook, however, to repeat a successful example of a two-phase machine of 1,500 kW.

In 1895 I was invited to become Engineer-in-Chief of the City of London Electric Lighting Co. Feeling that a multitude of worries would cancel out, I took up this work, and may briefly refer to some of the early history of this Company.

The capital required for the pioneering work of the City Company was difficult to obtain, as the prospects were considered problematical and the investing public had no confidence in electrical undertakings at this time. Mr J. B. Braithwaite therefore secured the support of Messrs. Rothschild, and difficult technical progress was therefore successfully financed.

The Brush Co. supplied engines of the marine type driving alternators of 400 to 500 kW; and the Thomson-Houston Co., through the Laing, Wharton & Down Syndicate, supplied Willans engines and Thomson-Houston alternators of 400 kW each. In the first set Willans, having some difficulty in making an engine of this size, supplied two engines to drive one alternator, with a magnetic clutch (which did not work well) connecting the second engine. This part of the plant worked well for a number of years, the success being largely due to the efforts of Sir (then Mr) James Devonshire and Mr A. L. C. Fell, who, with the assistance of Mr Grove (later of the Central London tube and now of Australia) and a young pupil named Mr C. H. Merz, succeeded in making the plant work well in parallel in spite of the large amount of iron in the armatures; and there was no difficulty also in running it in parallel with the former pioneering works at Wool Quay at a distance of about one mile.

The Brush plant was well constructed, but the armature coils were a failure and we secured the assistance of Mr Ferranti in applying his corrugated coil, which was such a marvel of construction. . .

In 1898 we commenced to run the first Ferranti engine with tripping spring valve-gear. This engine gave 1,500 kW, and it was soon found to work better with a direct-driven valve, but the engine rocked considerably and caused enough vibration to remove the statue of St George and the Dragon, which at that time was placed on the front of the main building, and we remarked at the time that Ferranti had killed the dragon but his engine had destroyed the horse.

Electricity Supply in the United Kingdom

A Chronology—From the beginnings of the industry to 31 December 1985

c. 600 BC *Attraction of small bodies by amber* may have been first observed by Thales, one of the seven sages of Greece.

1269 *"Epistola ad Sigerum de Foucaucourt Militem de Magnete"*, by Petrus Peregrinus de Maricourt (Peter the Pilgrim from Maricourt sometimes called Peter the Strange), a French crusader, described how an iron needle suspended from various parts of a lodestone (a magnetic variety of natural iron oxide known as magnetite or Fe_3O_4 which seeks to align itself in a north/south direction) responded in different directions. Movements of the needle were plotted and found to converge on two points at opposite ends of the lodestone which he called the poles of the magnet. Peregrinus thought that they were directed by the Pole Star or some other object in the heavens.

1600 *First English book of physics* "de Magnete, Magneticisque Corporibus et de Magno Magnete Tellure, Physiologia Nova", by William Gilbert. He coined the term "electricity" from "elektron" the Greek for amber. His *one-fluid theory*—a simple effluvium theory—explained the attraction of live objects in terms of an invisible fluid which carried them along.

1648 Sir Thomas Browne used *the term "electricity"* to mean amber-like quality.

1663 *First electric machine* produced by Otto Von Guericke—it applied friction against a revolving ball of sulphur.

Late C17 *Electrical luminosity* observed by Picard—mercury agitated in an imperfectly exhausted barometer tube produced electricity which caused the mercury vapour and remaining air to glow. Francis Hawksbee tested Picard's observation by substituting an exhausted glass globe for Guericke's sulphur ball (*q.v.*) and obtained a glow and also sparks one inch long. He experimented with other substances and discovered that electricity was not always of the same kind.

1727 *Early long-distance current carrying conductor*—Grey, a Charterhouse pensioner, erected a wire 700 ft. long insulated by suspended silk thread, one end of which he charged with an electrically excited glass rod.

1729 *Conductivity* discovered by Stephen Gray—while experimenting with excited glass tubes closed with corks found that the corks which had not been rubbed still attracted and repelled small bodies.

1730's *Two distinct forms of electricity* discovered by Charles Francois de Cisternay Du Fay—electricity produced by rubbing glass etc differed from that produced by rubbing amber, resin, sealing-wax etc. He called the former vitreous electricity and the latter resinous, and their capability to conduct the "effluvium" of electricity.

Friction machine improvements—
—1733 Professor Johann Winkler of Leipzig mounted a cushion (rubber) of woollen material in contact with the glass held in position by metal catch springs.
—1742 Giessing, directed by Professor Andreas Gordon of Erfurt, substituted a glass cylinder for the glass globe.
—1762 Canton improved the rubber by the addition of amalgam.

1737 *Two-fluid theory*—two bodies charged with electricity generated by rubbing either amber or glass would repel each other, but a body charged with glass (vitreous) electricity would mutually attract one charged with amber (resinous) electricity.

1738 *Prime conductor* constructed by Professor George Mathias Bose—an iron tube held by a person standing on a cake of resin pressing a bare hand against a ball as it revolved.

c. **1740** *One fluid theory*—Benjamin Franklin supposed that an explanation for the phenomena of repulsion and attraction was an electrical fluid which consisted of mutually repelling particles as against the particles of ordinary matter which were mutually attracting (by gravitation). Thus if two bodies had an excess of electric fluid they would repel each other overcoming their gravitational attraction. But electric particles were supposed to attract ordinary matter so if only one of two bodies was electrified there would be strong mutual attraction eg a rubbed glass rod would attract and pick up pieces of paper, straw etc.

1745 *Storage of electric charges* discovered by Ewald Georg von Kleist. When he brought a medicine bottle with an iron nail in the neck close to his frictional machine he received a violent shock when he held the bottle in one hand and touched the nail with the other. Independently, Pieter van Musschenbroek of Leyden University in 1746 tried to collect static electricity in a bottle of water held by friend, who received a massive shock in the same manner as Kleist. Abbé Nollet in Paris repeated the experience by passing a shock around a circle one mile in circumference employing 200 Carthusian monks linked by iron wire. Nollet coined the term 'Leyden Jar'.

1754 *First electricity meter*—John Canton devised a means of measuring electricity based upon the repulsion of like-charged balls of pith suspended by threads when a charged body was brought near them.

1759 Robert Symmer wore two pairs of silk stockings at a time—one white, one black. Whenever he pulled one pair from the other he heard crackling noises which he attributed to electricity and found that *stockings of the same colour repelled each other and those of different colours attracted.*

1764 *Heat first became a useable form of power.* James Watt investigated the behaviour of steam in the model of a Newcomen steam engine and introduced fundamental design changes. Instead of the cylinder and piston being cooled at every stroke, he kept them as hot as possible by means of a steam jacket and led the exhaust steam into a separate cooled vessel called the condenser, with considerable improvements in efficiency. Reliable engines could not be pro-

duced until 1781. By 1800 some 500 Watt engines were in industrial use and the cost of steam power had fallen by 75 per cent.

1767 *Joseph Priestley* published his *"History and Present State of Electricity"* in which he reported that when he electrified a hollow sphere there was no charge inside. He anticipated the inverse square law of electric attraction.

1769 *Thermoelectric effect*—Sulzer described the sensation of taste produced by the contact of lead and silver with the tongue in "Théorie Générale du Plaisir".

1777 *Lichtenberg* introduced the term + and −. He showed that electrical (charged) dust assumed different shapes when produced by *positive and negative electricity.*

c. **1780** Charles-Augustin de Coulomb, while investigating Joseph Priestley's law of electrical repulsion invented a torsion balance to measure the electrical forces involved and formulated *Coulomb's Law*—the force between two electrical charges is proportional to the product of the charges and inversely proportional to the square of the distance between them.

1786 *"Galvanic electricity"*—first study of current electricity—in the laboratory of Luigi Galvani, a Professor of anatomy at Bologna, where research into the muscular reaction of nerve stimulation was taking place, a pair of frogs legs, still attached by the sciatic nerve to the vertebral column, was touched by the point of a scalpel and immediately all the muscles of the legs contracted in violent convulsion. A frictional machine had been in use close by. Galvani thought that the convulsion was produced when an electric charge induced in the dissected frog by the machine was allowed to escape. He performed a large number of experiments to test his hypothesis and published the results in 1791 in his "De Viribus Electricitatis in Motu Musculari Commentarius".

c. **1800** *First continuous electric current: first electric battery*—Alessandro Volta, a Professor of Physics at Pavia, assembled a "pile" of pairs of silver and zinc plates separated by discs of paper soaked in a salt solution and obtained an electric shock by touching the first silver plate and the last zinc plate. His research was prompted by Galvani's De Viribus Electricitatis. Galvani supposed that nerves and muscles together acted like a Leyden jar. Volta concluded that Galvanic electricity was due to the juxtaposition of two different metals in contact with a liquid conductor, and that the "electric fluid" was set in motion and moved in a circuit. Volta first reported his discovery by letter to Sir Joseph Banks, President of the Royal Society. Humphry Davy referred to it as "an alarm bell to experimenters all over Europe".

1802 *"Outlines of a View of Galvanism"* by Humphry Davy, (Journals of the Royal Institution, Vol. I, 1802, pp. 51–66), included a reference to "The galvanic influence, when highly accummulated, produces very extraordinary chemical and physical effects, and, in many of its appearances, assumes the precise form of common electricity. When in a powerful battery (one, for instance, containing 200 series) the communication, after being broken, is again rendered complete, by the contact of two perfect conductors, a flash or spark of light is perceived, analogous to that produced by electricity. This spark, or flash, when the battery is most powerful, is capable of passing through a considerable stratum of air, and of inflaming mixtures of oxygene and hydrogene. When the metallic substances, by which it is transmitted, are of very small volume, it is possessed of the power of igniting them; and of making them enter into combustion when in contact with oxygene. The galvanic influence, when highly concentrated, effects the electrometer, and is capable of communicating weak charges to the condenser and Leyden Phial. In all compound circles of the first class, the most oxidable part of the metallic plates evolves the influence, appearing as positive electricity, whilst the least oxidable part seems negatively electrified. In the second class of circles it is, however, probable that

this order is reversed. Galvanism, moderately accumulated, affects the animal organs in nearly the same manner as common electricity. When the human body is made part of the circle, a shock is perceived at the moment of connection; and a subsequent numbness and tingling sensation denote the permanent circulation of the influence".
Frictional machines produced electricity of great intensity but lacked amperage. Voltaic cells produced electricity in quantity but not in intensity, although this could be increased by connecting cells in series.

1808 *Electric carbon arc* exhibited in experimental form. While experimenting with electro-chemistry using electric current from voltaic cells, Humphry Davy tried to enhance the tiny spark that occurred when two wires connected to a battery were separated by means of different materials and found that carbon produced a good result. He made use of the carbon arc as a source of high-temperature heat for chemical experiments. He appealed successfully to members of the Royal Institution for funds to build a powerful battery—it consisted of 200 connected 'instruments' each with ten double plates of 32 in^2 cells of porcelain i.e 2,000 double plates of aggregate surface 128,000 in^2. The cells were filled with 60 parts of water mixed with one part of nitric acid. Charcoal pieces one inch long and one-sixth of an inch in diameter brought near each other produced a bright spark which extended over four inches when the pieces of charcoal were withdrawn from each other.

1812 *First conductor with insulated covering* used by Baron Schilling to explode a mine in the River Neava.

1812 *What is electricity?—Berzelius* speculated that "the electricities" might be "matter, destitute of gravitation, but possessing affinity to gravitating bodies" to explain the disruptive effect of an electric discharge.

1820 Magnetic effects of an electric current—*Oersted* found that a pivoted magnetic needle tended to move in the presence of a 'live' conductor connected to a voltaic battery.

1820 *Ampere* founded and named the science of *electromagnetism*. He expounded the theory behind Oersted's discovery. He showed that when a current-carrying conductor was placed in parallel to a second conducting wire the two were attracted when the currents flowed in the same direction and repelled when the currents were in opposite directions. He reported his findings in "Annales de Chimie et de Physique". He experimented with wire wound around glass cylinders. Other experimenters soon found that when iron was used as the inner core it became a powerful magnet.

1821 Discovery of the *rotatory power of electric current*—news of Oersted's discovery reached England in October 1820. Michael Faraday thought that it ought to be possible to observe similar motion in a freely mounted conductor when it was brought into the field of a fixed magnet. In September he fixed a magnet upright in a piece of wax in a basin filled with mercury with a pole of the magnet just above the surface of the mercury. A wire, free to revolve around the magnet's pole, was connected to a voltaic battery and when the current flowed the wire rotated around the magnet. Similarly Faraday arranged the components so that the magnet revolved around the wire. By means of the rotatory power of the magnetic force surrounding a current-carrying wire he had demonstrated the first motion—he had invented the *"electric motor"*.

1821–22 *Faraday* published his *"Historical Sketch of Electromagnetism"* in the "Annals of Philosophy" which discussed his theories on Oersted's findings.

1824 *Carnot* announced his principle of the *efficiency of a perfect heat engine*. By taking heat from a source at a high temperature T1, and rejecting it at a lower temperature T2, thereby producing mechanical energy, the efficiency (ratio of

mechanical work produced to mechanical equivalent of heat taken in) is $\frac{T1-T2}{T1}$ which is the greatest possible efficiency.

1825 *Ohm* found that for an electrical conductor at constant temperature the ratio between the voltage across the ends and the current in the conductor is constant i.e.

$1\ V\ A^{-1} [m^2\ kg\ (s^3\ A^2)^{-1}]$

He published his findings in 1827 in "Die Galvanische Kette, Mathematische Bearbeitet" (The galvanic circuit investigated mathematically).

1830 *Long-distance transmission* of small amounts of energy became possible with *cotton-insulated conductors* soaked in paraffin wax.

1831 *Michael Faraday's discoveries—electromagnetic induction and magnetoelectric induction.* On 29 August he wound 72 feet of copper wire round one half of a soft iron ring (primary coil A), and 60 feet round the other half (secondary coil B) which was connected to a galvanometer (a form of ammeter). When A was connected to a battery the instrument's needle moved, and it did so again on breaking the connection—a current had passed in B when a current was set up in A (the principle of the transformer later used effectively with alternating current). Faraday intended this apparatus to detect a wave of magnetic force and he found that when wood was substituted for the iron the effect was small, and that it was the change in the "magnetic strain" that created the induced currents.

On 17 October he covered a hollow paper cylinder with eight coils of copper wire and the ends were connected to a galvanometer. When a bar magnet was thrust quickly into the cylinder the galvanometer needle moved, and when it was pulled out the needle moved in the opposite direction. Faraday called this "magneto-electric induction"—the creation of a wave of electrical force not by a wave of magnetic force, but from a "mere approximation of a magnet". For an electric current to be induced there had to be both a magnetic field and the relative motion of magnet and conductor. By substituting rotary motion for reciprocating he was able to produce steady currents instead of pulsating currents—by means of a copper disc rotated between the poles of a magnet. By the end of October this apparatus had been so improved that it could be said that Faraday had invented the dynamo. He presented his results on 24 November at Somerset House in his First Series of the "Experimental Researches in Electricity".

1832 Hippolyte Pixii, an instrument maker, demonstrated in Paris *the first mechanical generator,* a small hand-driven magneto-electric machine in which the field magnet revolved in relation to the coils. Although resembling a working model, it demonstrated Faraday's discovery. Shortly afterwards, at Ampere's suggestion, a simple commutator was fitted to convert the alternating output into a uni-directional current, permitting the generator to be used for electrolysis.

1832 *Electromagnets—William Sturgeon* reviewed the development of electromagnetics in the "Philosophical Magazine". Professor *Moll* of Utrecht purchased in London an electromagnet weighing 5 lbs consisting of round iron 1 inch in diameter carrying 83 turns of single copper wire—it could lift 75 lbs. In the USA Professor *Henry* coiled 800 ft. of wire in 26 strands round a soft iron bar weighing 60 lbs of horseshoe shape: it supported nearly 2 tons when supplied by a battery with "about 5 sq. ft. of galvanic surface". *Sturgeon* was able to lift 400 lbs with a 16 lb electromagnet supplied by a small battery of 150 in^2 of plate surfaces.

1832 *Sturgeon* built an *electromagnetic rotary engine* (electric motor)—the first contrivance capable of producing significant mechanical force by electric current. Two compound permanent magnets were rotated by the action of four electro-magnets.

1833 A small hand-driven generator in which the coils rotated in the field of a fixed magnet was demonstrated by Saxton before the British Association at Cambridge. A year later instrument makers such as E. M. Clarke were selling *first commercial models of hand-driven rotating coil generators.*

1836 *Daniel* introduced the *first practical primary cell* to produce a consistent voltage. A copper cylinder formed the positive plate and an inner porous cell within which was fixed a zinc rod the negative. The electrolytes were dilute sulphuric acid in the inner cylinder and a saturated solution of copper sulphate in the outer.

1836 *Dielectric* or insulating medium—Faraday introduced the term dielectric (suggested by William Whewell) into electrical science to express the non-conducting body interspersed between two inductive conductors. Whewell also gave him *'anode', 'cathode', 'anion', 'cation',* and *'ion'.* Dr Whitlock Nicholl gave him *'electrolyte'.*

1836 *First lathe turned by electromagnetic power* constructed by Devenport, a Philadelphia blacksmith.

1836 *Induction coil* developed by *Callan* which he used to test the power of his batteries through the reactions of his students. With 14 Wollaston cells (zinc, copper, sulphuric acid cell) the pupil felt the effect for some days. Nobody could be persuaded to take the shock from 16 cells. With few turns of thick wire in a primary winding and many turns of thin wire in a secondary an intermittent current to the primary produced intermittent high voltage in the secondary.

1837 *First electrical journal—"The Annals of Electricity, Magnetism and Chemistry; and Generation of Experimental Sources".* Conducted by W. Sturgeon, etc. in London from 1837 to 1843.

1837 The first practical electric truck (*"electro-magnetic locomotive"*) constructed by Robert Davidson of Aberdeen. Electricity supply was from primary batteries. In 1842 a number of successful runs were made on the Edinburgh and Glasgow railway.

1837 Professor M. H. Jacobi, a Russian, invented the process of *electroplating.*

1838 *Early insulated wires*—letter from G. Francis to the Editor of "The Annals of Electricity . . ." (issue 1838, 2, 396) stated that Mr Green of Quaker Street, Spitalfields, lately covered 2½ pounds of copper wire No. 16 with silk for 2s 6d making a total cost of 5s 7½d. By employing this "bonnet wire coverer" instead of the usual "optician" the cost of covering was reduced by more than two-thirds thus reducing the expense of electro-magnetic studies.

1839 *Electric boat*—in a letter to Faraday published in "Edinburgh Philosophical Journal" of September 1839, Jacobi mentioned experiments to propel a 10-oared shallop driven by paddle wheels powered by an electromagnetic machine—10-12 persons were carried at 4 mph.

1840 A *printing press driven by an electromagnetic machine* produced the "Electro-Magnet and Mechanics Intelligence" in New York.

1840 *Electromagnetic machine* demonstrated by W. H. Taylor—with seven armatures and four electromagnets it drove a lathe. Electromagnets were alternately magnetised and demagnetised without change of polarity so that they were always able to attract masses of iron.

1840 *James Prescott Joule's* paper to the Royal Society *"On the Production of Heat by Voltaic Electricity"* showed that the amount of heat produced per second in the wire by an electric current is proportional to the product of the electric

resistance of the wire and the square of the current—and the heat energy is equivalent to the electric power lost.

1843 *Electrical measurements*—because galvanometers were unstable instruments which could not be properly calibrated it was not easy to capitalise on Ohm's findings that the resistance of a conductor was proportional to its length. Charles Wheatstone considered that if a calibrated variable resistance, which he called a rheostat, could be used to keep the current constant it would avoid the need to calibrate a galvanometer. He placed an unknown resistance in a circuit with a galvanometer and noted its reading, then replaced it with a rheostat adjusted so that the same galvanometer reading was obtained. The scale on the rheostat gave a reading which represented the value of the unknown resistance. He also measured voltage by connecting a cell to the circuit and adjusting the rheostat to make the galvanometer needle deflect 45° and adjusted the galvanometer to deflect 40°. The difference in the two rheostat settings was proportional to the voltage.

1844 *Gustave Froment,* in Paris used *'electric motors'* to drive his precision instruments.

1844 John Woolrich, Professor of Chemistry at Birmingham, invented a large magneto-electric generator to generate uni-directional current for *the first large-scale exploitation of electroplating* (silver plating and gilding)—at the Birmingham factory of the firm of Elkington.
Like Pixii, Woolrich used coils in the form of bobbins, an inefficient arrangement because much of the coil did not intersect the magnetic field. Woolrich generated greater power by increasing the rate of rotations, using steam engines in place of manual rotation, and by using an iron core (bobbin) instead of wood, thus concentrating the magnetic field.

1845 *First linear motor*—Charles Wheatstone built an electromagnetic engine with an electromagnet arranged in a straight line and the armature in a curve.

1846–48 Development of the *carbon arc lamp* by W. E. Staite and W. Petrie. Many demonstrations were given including the lighting of the portico of the National Gallery, London, on 28 November 1848. The experiments failed because the primary cells from which the lamps were supplied were too costly in up-keep.

1847 *Siemens & Halske* founded in Berlin to manufacture electric telegraph cables using gutta-percha as insulation.

1847 *Gas Act,* including a clause giving rights to break up streets for the construction of repair of pipes. (cf. "Electric Lighting Act", 1882)

1849 James Prescott Joule's "Memoir on the *Mechanical Equivalent of Heat",* delivered before the Royal Society on 21 June, gave his final estimate "with exactness"—a rise in temperature of 1°F of 1 lb of water required the expenditure of 772 ft. lbs of work. His first estimates of the equivalent had been published in 1843. The mechanical equivalent had great practical value in assessing the efficiency of steam engines. It provided the most convincing evidence of the first law of thermodynamics—in the countless conversions of energy from heat to work and vice versa nothing is ever lost. The nature of heat and the nature of energy are the same. Joule calculated that the efficiency of a steam engine could be improved at least ten times.

1852 William Thomson (later Lord Kelvin) put forward the principle of the reverse Carnot heat engine ("Collected Papers", vol. 1, p. 515) i.e. *the heat pump.* If mechanical energy is supplied to pump heat from a low (T2) to a high (T1) temperature, heating efficiency (ratio of heat produced to the heat equivalent of the electrical energy supplied) is $\frac{T1}{T1-T2}$. This is equal to 9.33 if heat is delivered at 100°F (310·92 K) and taken in from the atmosphere at 40°F (277·59 K). The most familar type of heat pump is the refrigerator which pumps heat from a rela-

tively cold to a relatively hot source, but because cooling is of prime importance the leakage of heat into the cold source is discouraged and no attempt is made to prevent the escape of heat from the hot source. By reversing the priorities—encouraging the leakage of heat into the cold source and discouraging leakage from the hot source the refrigerator becomes a heat pump.

1852 *Joule—Thomson effect*—Joule and Thomson discovered that when a gas is allowed to expand without performing external work the temperature of the gas falls (the basis of refrigeration)—in performing internal work to overcome the mutual attraction of its molecules the gas cools itself (but it depends on 'inversion temperature' e.g. hydrogen and helium cool upon expansion only if the initial temperatures are very low).

1853 *First company to manufacture electric machines* (generators) was probably la Societé Générale d'Electricité of Paris. The machines were for the production of hydrogen and oxygen by electrolysis for making limelight—*see* plate 3.

1852–1887 *What is electricity?*—early laws in electricity and magnetism, such as Coulomb's Law (*q.v.*) were based upon the Newtonian concept of 'action-at-a-distance', i.e. the forces between electric charges or magnetic poles being due to instantaneous action at a distance—the space around these charges being just the same as other space and involving nothing but distance. But to *Faraday* the charges or poles were but the starting point of a series of lines—the lines of force—spreading from them through the surrounding space, which probably possessed definite physical properties that, for example, they were in a state of tension, and it was this tension which produced the forces between electric charges or magnets. In 1852 Faraday announced his concept of the forces arising from an electromagnetic field by visualising his "tubes of force" as exerting longitudinal tensions and lateral pressures. In 1855 *James Clerk Maxwell* read a paper to the Cambridge Philosophical Society *"Faraday's Lines of Force"* in which he put Faraday's ideas into mathematical form, pointing out the analogy between the lines of force and "stream lines" (paths along which particles of water flow in a current), the intensity of the electric force being analogous to the velocity of the water. During 1861–62 he published papers in the "Philosophical Magazine" on *"Physical Lines of Force"* in which he represented the magnetic field by the rotation of a number of equal cylinders, the axes of the cylinders being parallel to the magnetic force, and their velocity of rotation proportional to that force. By introducing the notion of elasticity of the medium Maxwell was able to give a quantitive description of how a disturbance could be transmitted outwards through its source at a finite velocity. In these papers he formulated the basic laws of electromagnetism—*"Maxwell's Equations"*— which prompted Boltzmann to quote Goethe "Was it God who wrote these lines . . .". *Faraday's Law* stated that changes in magnetic force produced electric force; by Maxwell's theory change in electric force produced magnetic force. A striking consequence of *Maxwell's Theory* is that changes in electric or magnetic force are propagated as waves, at a velocity equal in a vacuum to the ratio of the electromagnetic to the electrostatic units of electricity, which was found to be 3×10^8 m/s, the same as the velocity of light.

He set out his electromagnetic theory of light in *"A Dynamical Theory of the Electromagnetic Field"* (Phil. Trans. 1865). This naturally suggested the theory that waves of light are waves of electric and magnetic force. Newtonian mechanics could not describe the behaviour of these fields since action-at-a-distance theory did not lead to a theory of light. Maxwell demonstrated that the electric current induced in a circuit by changing lines of force represented a transfer of energy to the circuit and that the process was reversible i.e. energy could be transferred to the space surrounding a circuit by passing a current around the circuit; with the resulting lines of force being propagated through space as transverse waves of electric and magnetic force.

Hertz developed laboratory equipment that corroborated Maxwell's work and *Lodge* and *Marconi* demonstrated it in practical terms by the turn of the century. Both Maxwell and Hertz were puzzled and disturbed by the question

of what might be the carrier of the electric and magnetic fields in regions free of any known matter. Maxwell called the mysterious carrier of electromagnetic waves the ether. Experiments by the Americans, Michelson and Morley, in 1887 rendered untenable this hypothesis by demonstrating that the ether has no measurable properties. Einstein's special theory of relativity (*q.v.*) resulted from the acceptance of this experimental finding.
Maxwell's great progress report, *"Treatise on Electricity and Magnetism"*, was published in 1873.

1856 *William Siemens* introduced the *armature*, a coil wound in slots in an iron cylinder placed between the poles of permanent magnets.

1856–70 Professor F. H. Holmes pioneered the *illumination of lighthouses* by carbon arc lamps, supplied by steam-driven magnetoelectric generators for which he took out a series of patents during those years. The lighthouses involved were:
1857 Experiments at Blackwall and South Foreland—*see* plate 4.
1862 Dungeness
1870 Souter Point, Nr. Sunderland. This installation remained in service until 1900
The Holmes machines were still too costly for general application.

1858 *Siemens & Halske & Co London* founded. The partners were William Siemens & Halske of Berlin and Newall & Co.

1859 *Rankine Cycle*—William John Macquorn Rankine explained how a liquid in a boiler vaporised by the addition of heat converts part of this energy into mechanical energy when the vapour expands in an engine. As the exhausted vapour is condensed by a cooling medium such as water heat is lost from the cycle. The condensed liquid is pumped back into the boiler.

1859 *Vulcanized rubber cable* introduced. W. T. Henley built his main cable factory at North Woolwich.

1859 G. Planté in Paris produced a lead secondary cell or *storage battery.* But this did not find much industrial application at the time and it was not until 1881 that a fresh impetus was given to the study of the secondary cell by the discovery of another French inventor, C. Fauré. (*q.v.*)

c **1860** Thomson (Kelvin) used one ft/sec as his *unit for resistance*, other experimenters quoted *potentials* as some number of cells, and *resistance* as lengths of copper or iron wire or of mercury.

1860 Westminster Bridge lighted by *limelight—see* caption to plate 3.

1861 *British Association Meeting in Manchester*—Sir Charles Bright and Latimer Clark indicated the needs for *standards of tension, quantity, current and resistance*—BA appointed a committee including Thomson, Clerk Maxwell, with Fleeming Jenkin as Secretary—in 1863 it adopted 'Ohm' as resistance and a 'standard' having a resistance adjusted to 10^7 m/s.

1861 *"Electricity"* journal first published in November but discontinued after 3½ years. In May 1878 a new *"Electricity"* was published—the first electrical weekly.

1864 *Clifton Suspension Bridge* was opened on 8 December and for the occasion was illuminated by four arc lamps, two limelights and four magnesium lamps.

1866 *Leclanché* developed a *cell* using ammonium chloride as electrolyte, a zinc cathode and a magnesium dioxide anode—the precursor of the modern dry battery.

1866–67 Development of the principle of *self-excitation of generators* independently by Dr H. Wilde, the brothers C. & S. A. Varley, Dr Werner Siemens (in Germany), and Sir Charles Wheatstone. To replace the heavy horseshoe magnet of magnetoelectric machines by the lighter and more powerful electromagnet, external batteries or other generators were at first used to activate ('excite') the field magnet. Although it had been known for some ten years that once generation started up, an electromagnet could be excited by diverting part of the electricity generated, there was the problem of starting. It was now realised that electromagnets possessed enough residual magnetism in their soft-iron cores to provide the magnetic field necessary for starting up a generator. Machines employing this electromagnetic field system became known as dynamos and because the majority of early machines were of direct current type the term dynamo became exclusively associated with this type of generator. Later on the term alternator was used for machines providing alternating current.

1870 *First nationalisation*—on 5 February the Post Office took over telegraphs.

1870 *The Tramways Act,* with its limitation of concessions to twenty-one years and subject to local authority consent, was to prove an unfortunate precedent for the first electricity legislation twelve years later.

1871 Z. T. Gramme—a Belgian—produced a dynamo with a ring-shaped armature (combination of coils)—the "Gramme Ring", which *brought matters to a point where the industrial generation of electricity became a practical proposition.* The machine, which intersected much more of the magnetic field, after many changes and improvements, became the first generator to be used commercially—*see* plate 5.

1871 Foundation of the Society of Telegraph Engineers. (In 1880 the title was broadened to the Society of Telegraph Engineers and Electricians, and in 1888 it became the *Institution of Electrical Engineers.*)

1872 Dynamos in wide use for *electroplating.*

1872 *"Telegraphic Journal & Monthly Illustrated Review of Electrical Science"* first published in November—became the weekly *"Telegraphic Journal and Electrical Review"* in 1881 and the *"Electrical Review"* in 1891.

1872 *Drum armature* invented by F von Hefner Alteneck, chief designer of Siemens & Halske. A technical advantage over Gramme's ring was that the greater part of the winding was usefully employed (ie intersected by more lines of magnetic force). It was developed over many years to the modern rotor.

1873 *First laboratory for teaching applied electricity* created by W. E. Ayrton at the new Imperial Engineering College, Tokyo.

1874 George Johnstone Stoney, Vice-President of the Royal Society of Dublin, in an address to the British Association, *first used the term "electron"*—to denote the positive or negative charge carried by ions in electrolytes. The existence of the electron as defined today was confirmed by J. J. Thomson in 1897 (*q.v.*).

1874 *First electric "automobile"*—David Lionel Salomans used Bunsen batteries to drive a tricycle.

1874 *"The Electrical World: An Illustrated Weekly Review of Current Progress in Electricity and its Practical Applications"* established in the USA.

1875 *Arc lighting of Gare du Nord,* Paris.

1875 *Public Health Act* authorised municipal ownership of waterworks—an example of measures to correct alleged mismanagement of private com-

panies that provided a stimulus to municipal participation in electricity supply (*q.v.* Electric Lighting Act 1882).

1876 P. Jablochkoff, a Russian officer working in Paris, invented his famous *"electric candle"*, consisting of two carbon rods placed side by side and an arc formed between them—the *first arc lamp* to be used on a large scale. An AC supply was necessary to prevent unequal consumption of the carbons.

1876–77 *Arc lighting* used in *Tay Bridge Yard.*

1877 In May the *Grands Magasins du Louvre*, Paris was *lit by 80 Jablochkoff lamps* supplied by Gramme generators powered by a steam engine in the basement.

1877 In June, *Jablochkoff lamps were tried out in the West India Docks.*

1877 *First high speed direct-coupled unit*—Peter Brotherhood's three-cylinder engine driving a dynamo from either end of the crankshaft used for experimental lighting of P.L.M. Railway terminus, Paris on 7 September.

1878 A de Meritens, in France, invented a magnetoelectric machine in which coils were replaced by a distributed winding to give a more uniform current. As there was no commutator the machine gave *alternating current*, which was *of vastly improved wave form* than hitherto possible.

1878 Over 20 *lighting installations* were in service in Britain.

1878 *Paris Electrical Exhibition.* Several hundred Gramme machines were in service in France, the latest type suppling alternating current which was more suitable for Jablochkoff lamps.
—By June *Avenue de l'Opera* lit by 46 lamps powered by three 20 hp engines; *Place de l'Opera* lit by 22 lamps; electric illumination of *Arc de Triomphe.*
—*In August the Gaiety Theatre* lit by six Lontin arc lamps installed by French engineers, *the first public building to be electrically lighted in London.*
—15 October, Messrs Wells and Co. of the Commercial Iron Works, Shoreditch, *introduced Jablochkoff lamps to Britain,* with four inside their showroom and two at the Works entrance, supplied by a Gramme generator.
—In October, according to "The Electrician", a *football match* was played under electric light before nearly 30,000 spectators at *Bramall-Lane Grounds, Sheffield;* and the "Illustrated Sporting and Dramatic News" of 16 November included a sketch of *football* by the new electric light at *Kennington Oval.*
—*29 November, inauguration of electric lighting of interior and exterior of Billingsgate Fish Market—the first demonstration of electric lighting by a public authority* (City Corporation) *in London.* 16 Jablochkoff lamps in opaline globes with power generated by a Robey engine were installed by Société Générale d'Électricité of Paris. It failed due to technical faults and high running costs.
—*Trials* to establish the competitiveness *of electric lighting* at *Westgate-on-Sea* in December. Six Jablochkoff lamps using a generator powered by a Garrett portable engine were lit for 96 hours at a running cost of £40 9s 5d compared with £16 15s 2d for gas lighting, and there were technical problems.
—Also in December the Commissioners of Sewers of the City of London tried out lighting of Société Générale d'Électricité along the *Holborn Viaduct* and in front of the *Mansion House.* 16 Jablochkoff lamps covering 473 yards were supplied by a Gramme dynamo driven by a Robey undertype engine. It closed down on 9 May 1879 as it could not compete with gas, costing four times as much.
—13 December, Metropolitan Board of Works contracted with Société Générale de l'Électricité to light the *Victoria Embankment* along the river wall between Waterloo and Westminster Bridges. 20 Jablochkoff lamps were supplied by a Gramme dynamo and exciter powered by a semi-portable Ransome, Sims and Head steam engine. On 16 March 1879 the system was extended to 40 lamps and on 10 October to 55. In June 1881 the Jablochkoff

Electric Light and Power Co. became responsible for the supply which then was 40 lights on the Embankment and 10 on Waterloo Bridge at a price of 1½d per lamp-hour. A Davey-Paxman engine replaced the original engine in August 1883. In June 1884 gas lighting was reintroduced as electricity was not competitive.
—By the end of the year *a variety of arc lamps were available* including Siemens, Lontin, Rapieff, Wallace-Farmer, Serrin etc.
—Industrial and private electric lighting installations included *"The Times" printing office, Pullar's Dye Works* at Perth, *Cammell and Wilson's steel works* at Dronfield, *Messrs Shoolbred* in London, *Woolwich Arsenal, Trafalgar Colliery* in the Forest of Dean for pit-head lighting, *London Bridge terminus* of London, Brighton and South Coast Railway, and Crompton arc lamps at *St. Enoch's Station* in Glasgow.

1878 The first practical *incandescent carbon filament lamp*—demonstrated by Sir Joseph Swan at a meeting of the Newcastle-on-Tyne Chemical Society on 18 December (his first lamp patent was January 1880). The intense, overbearing, flickering bright light of arc lights was quite unsuitable for domestic use and inventors were occupied with the problem of "sub-dividing" the electric light to produce smaller and more manageable light sources. The requirement was for a filament that would not melt when heated to incandescence and which could be contained in a high vacuum to prevent oxidation i.e. combustion. Davy had demonstrated some 70 years previously that carbon and platinum wires could be heated to incandescence by means of an electric current. Swan produced a carbon filament lamp in 1848 but its life was too short to be useful because it was difficult to obtain the necessary vacuum in the bulb and, in any case, the only source of electric power was the highly expensive primary cell. The invention of the mercury pump in 1865 and the Gramme dynamo in 1871 prompted him to resume research and, working in conjunction with C. H. Stearn who was experimenting with vacuum pumps, he succeeded in 1878.

1878 William Edward Ayrton gave his renowned lecture *"On the improvements science can effect in our trades and in the condition of our workmen"* to mark the inauguration on 1 November of the City and Guilds of London Institute for the Advancement of Technical Education.

1878 *Electrolytic meter* patented by Americans Thomas Edison and J. T. Sprague—two copper plates were in a solution of copper salt—the weight of copper deposited on the cathode measured the number of coulombs supplied to the consumer. It was only suitable for DC supplies (although AC did produce some electrolysis).

1878 Crompton found that Gramme machines imported from France were not able to stand the strain of continuous high speed work and he co-operated with Emil Burgin to develop the *Burgin dynamo machine* in which the heating of the windings in service was reduced.

1878 Thirty-four *Private Bills* were introduced in Parliament with the object of *seeking powers to supply electricity* in various towns and break up streets and lay the necessary mains.

1878–79 C. F. Brush of the USA produced an efficient form of *open-coil dynamo and electric arc lamp* suitable for working in series. He promoted the formation of district street-lighting companies, raising local capital and negotiating terms favourable to his company, particularly in respect of the use of Brush equipment. The first of these was the California Electric Light Company of San Francisco whose generating station, supplying street lighting exclusively, was in operation during 1879.

c. **1879** *Swan incandescent lamps first put on the market* at 25s each. About eight could be run in series from a generator such as that by de Meritens driven by a gas engine—breakages were frequent. There were no generators suitable for

running the lamps in parallel and no switches or other accessories on the market and no trained installation workmen.

1879 *First central station in the USA*—in San Francisco to supply an arc lamp system.

1879 *First electric lighting Act*—"The Liverpool (Corporation) Electric Lighting Act, 1879", provided powers for the Corporation to light streets by electricity.

1879 Appointment on 28 March of a *Parliamentary Committee under the chairmanship of Sir Lyon Playfair to consider all Private Bills seeking powers to supply electricity.* Their terms of reference were:
"to consider whether it is desirable to authorize Municipal Corporations or other local authorities to adopt any schemes for Lighting by Electricity; and to consider how far, and under what conditions, if at all, Gas or other Public Companies should be authorised to supply Light by Electricity."
The substance of the committee's recommendations, in a report published on 13 June, was to extend local authorities' power to break up streets for the laying of electricity mains—but that such power should not be given to companies in their own right, i.e. without local authority consent.
The committee also considered the application of the principle of a reversionary purchase right to local authorities. Their recommendation was incorporated in the subsequent legislation.

1879 *First fatal accident due to electric shock* reported in France through contact made with a 250 V AC circuit.

1879 *Electric arc furnace* constructed by Sir William Siemens for melting iron and steel. Siemens showed that the electric furnace could compete in economy with the gas regenerative furnace, but there were no further developments until 1898.

1879 The *City and Guilds of London Institute for the Advancement of Technical Education* founded at Cowper Street, City Road, Finsbury, London, in a building of Middle Class Schools Corporation. It was paid for by the City guilds who later funded two properly equipped colleges, Finsbury Technical College at Leonard Street in 1881 where W. E. Ayrton was Professor of Applied Physics until 1884; and a technical college—The Central Institution (now the City and Guilds College of the Imperial College of Science and Technology) in 1884 in Exhibition Road, South Kensington, where Ayrton was Professor of Physics and Electrical Engineering until his death in 1908.

1879 —18 September, *Blackpool's promenade* and pier lit by six Siemens lamps of von Hefner design. Two 16 hp Robey portable engines powered seven Siemens dynamos, one per lamp plus an exciter, belt-driven from an overhead countershaft. The "illuminations" were repeated for a number of seasons.
—28 October, electric lighting introduced in the *British Museum Reading Room;* four 4,000 candle power (cp) lights in the Reading Room and seven 400 cp lights in the halls and front. Four DC generators supplied the Reading Room, one AC machine the remaining lights, and a sixth machine served as exciter. They were driven by two 8 hp Wallis and Stevens engines.
—Other notable installations were—*Wills tobacco factory* at Bristol with Prof. Sylvanus P. Thompson of Bristol University as consultant, *Reform Club, Langham Hotel, St George's Pier Hotel* at Liverpool, *Avonmouth Docks.*

1879 *H.V. transmission*
—the *first to advocate main transmission* was W. E. Ayrton in "Electricity as a Motive Power" before the British Association.
—in evidence to the Playfair Committee (*q.v.*) William Thomson (later Lord Kelvin) forecast that 21,000 horsepower might be transmitted 300 miles through a copper wire 0·5 in. in diameter at 80 kV.

1879–1881 Development of *self-regulatory arc lamps* and generators by Brush, Crompton and others made possible series connection. There were also incandescent lamps by Edison, Swan, Maxim and Lane-Fox.

1879 Siemens and Halske exhibited an *electrically-driven locomotive* at the Berlin Exhibition, for transporting the visitors through the grounds.

1879 Thomas Edison (of the U.S.A.) patented his *incandescent carbon filament lamp* in the U.S.A. and in Great Britain, and began production on a commercial scale.

1880 Sir Joseph Swan's House, 99 Kells Lane, Low Fell, Gateshead was almost certainly the *first house in Britain, and possibly the first in the world, to be lighted by incandescent lamps.*

1880 *First commercial Edison incandescent lamps* shown in London in February. The first public demonstration of electric lighting on a large scale by means of incandescent lamps was given in Newcastle, 10 October.

1880 Sir (later Lord) William G. Armstrong had a small hydro-electric plant (6 hp) constructed to light his picture gallery at "Cragside", Rothbury, Northumberland, 1,500 yards away—possibly the world's *first hydro-electric installation*—and one of the *first houses to be lighted by incandescent lamps*—Swan lamps. In the daytime a supply was sometimes given to an electric motor to drive a sawmill.

1880–1885 *Carbon-arc welding* developed by Bernado (Russia) and Coffin (USA).

1881 Professors W. E. Ayrton and John Perry of the City and Guilds of London Institute invented the *surface contact system for electric railways.*

1881 Helmholtz proposed the name *'ampere'* as the name for a unit of current in place of weber, and *coulomb* (A s) was also introduced as a unit of quantity of electricity.

1881 *Electric launch* "Electricity" developed by Anthony Reckenzaum of the Electric Power Storage Co. driven by EPS batteries. His "Volta" crossed the Channel and back on 13 September 1886".

1881 *Vulcanised bitumin insulation*—William Marshall Callender used 20 per cent bitumin as an extender milled with cotton seed pitch to produce a material similar to rubber and gutta-percha which could be extruded. Cables comprising a standard copper conductor insulated with v.b. and tape and braid overall become popular for LV distribution. They were laid in compound-filled troughing (the "solid system").

1881 Invention by C. Fauré in France of pre-formed accumulator grids revolutionised the original Planté cell of 1859 and laid the foundation of the modern *lead accumulator.*

1881 Swan Electric Lighting Co. formed early in the year. Independently, the Edison Electric Light Co. of London was formed to exploit Edison's inventions in electric lighting. In 1883, the two companies merged to form the *Edison & Swan United Electric Light Co. Ltd.*

1881 *International Electrical Exhibition, Paris*—Edison, Swan, Lane-Fox, Maxim etc. showed the new incandescent lamp and Edison also his first "Jumbo" dynamo (his second and third machines were installed in Holborn Viaduct *q.v.*—they were presumably named after London Zoo's famous elephant.

1881 *Over 100 electric lighting installations in Britain had been reported—many were demonstrations or experiments lasting less than three months.*

1881 The Marquis of Salisbury had electric light installed in *Hatfield House*—the installation was very dangerous—the naked wires on the gallery ceiling were apt to break into flame. The family sitting beneath nonchalantly threw up cushions to put the fire out and then went on with their conversation. (From "The Cecils of Hatfield House", by Lord David Cecil.)

1881 *Norwich lighting trial*—in January R. E. Crompton and Co. lit Market Place, Norwich with two Crompton arc lamps. The plant was temporarily transferred to Norwich Fisheries Exhibition in the spring where nine Crompton arc lamps and 60 Swan incandescent lamps were lighted. Regular lighting of the town began in May. Crompton installed two circuits each including three large Crompton 4,000 cp arc lamps that lit the Haymarket, Market Place, Bank Plain and Post Office Plain; and two circuits totalling 12 Weston arc lamps of 800 to 1,000 cp that lit London Street and Prince of Wales Road right down to the railway station; there were two Crompton arc lights in St Andrew's Hall, and 50 Maxim incandescent lamps in the Free Library. The generating station was at Elm Hill behind St Andrew's Hall, with a 20 hp twin cylinder semi-portable steam engine driving two lengths of shafting working six Crompton-Burgin dynamos—four supplying the arc lights with one as spare, and one supplying the Library lamps. Norwich reverted to gas for street lighting in March 1883.

1881 *Experimental Lighting*—Crompton was awarded a contract for 12 months to light the Egyptian Hall and Saloon of the *Mansion House* for £425. The installation was powered by gas engines which were noisy and inefficient and the City of London did not take up the option to purchase the plant at the end of the experiment for £1,171 10s. A permanent supply was installed in 1891 by the Planet Electrical Engineering Co. for £995 which began on 16 December.

1881 Introduction of AC created new problems for the designers of electrical plant. *Professor J. A. Ewing* studied iron losses in magnetic circuits such as those encountered in the design of transformers and introduced the term *magnetic hysteresis* to explain the iron losses when changes in induction lagged behind changes in the magnetising force.

c. **1881** *Swan lamps* were selling for 5s each and suitable dynamos were available.

c. **1881** *Edison's Meter*—a zinc 'volta meter', consisted of plates of zinc in a solution of zinc sulphate. The weight of zinc deposited on the cathode directly measured the total number of coulombs supplied to the consumer and these multiplied by the volts and divided by 3.6×10^6 gave the number of Board of Trade units delivered.

c. **1881** *Electric lighting was being installed at country houses*—some 250 lamps might be supplied by a dynamo driven by gas engines. Storage batteries were not yet available on the market and the lights had to be shut off overnight.

1881 *Experimental lighting*—City of London's Commissioners of Sewers and Bridge House Estates awarded three contracts in July 1880, for commencement in 1881 viz:
—*Blackfriars Bridge*, that began 31 March and finished April 1883, used the Brush system installed and operated by the Anglo-American Electric Light Corporation;
—*Southwark Bridge and District* contract awarded to Electric and Magnetic Co. for the Jablochkoff system, but they withdrew and Electric Lighting and Power Generation Co. installed Lontin lamps, in service from April 1882.
—*London Bridge* where a Siemens installation started up on 31 March and lasted until April 1882.
William Haywood, Engineer and Surveyor, reported to the Commissioners in February 1882 that Blackfriars Bridge and London Bridge installations had suffered numerous interruptions, the most serious due to cable faults. Lighting at Blackfriars was no dearer than gas, at London Bridge 3¾ times as much. The Blackfriars installation comprised 33 Brush 1,000 cp lamps series connected, a

single 32 hp Brotherhood three-cylinder steam engine driving a 40 light Brush dynamo. At London Bridge Siemens used a separate DC generator for each of six large lamps, and two AC generators each supplying 14 of the smaller arc lamps, and two more to provide excitation. Power was provided by two 10 hp Marshall steam engines with a third in reserve. Commissioners decided to continue the experiment for another year, but only at Blackfriars because they were unable to reach agreement with Siemens.

1881 —On 6 August *Cockermouth* Local Board accepted a tender from Messrs John Whittle & Son, Whitehaven to provide seven 2,000 cp Brush arc lamps and to light the back streets with 40 gas oil lamps for £56 per season from 1 September to 30 April 1884. The 16-light 'dynamo-electric' machine was located in Mr Henry Peel's yard, Low Sand Lane powered by a portable 12 hp engine. "All the world" came to see the new light—some 6,000 visitors, but the system broke down. Even so the "West Cumberland Times" of 3 September reported "Either some check must be made to the present rate of progress or the end will come sooner than we calculate upon". The wires were carried over the tops of houses—at 19.30 "the electric fluid was turned on but one only of the lamps made response" ("Cumberland Times" 3 September 1881). On 23 September the successful illumination was accomplished at which time a semi-portable 12 hp Robey engine was in use.

1881 *Godalming was the first town to combine public and private lighting in one commercial undertaking.* When the contract for gas lighting expired at the end of September the Town Council considered electricity as an alternative. Calder and Barrett, a firm of electrical engineers and contractors, demonstrated electric lighting for a few hours each evening from Monday 26 September using Siemens differential arc lamps and Swan incandescent lamps. Generation was provided by a 10 hp Siemens generator driven by one of the waterwheels in R. and J. Pullman Brothers leather dressing mill (tannery) at Westbrook on the River Wey, a half a mile from the town centre.

On 30 September the Town Council accepted the contractor's tender for £195 (£15 cheaper than the gas quotation) to light the town for a year from 1 October. The intention was to make the supply available to shops and houses, and, possibly by November, some shops in the High Street were lit by the earliest commercial pattern of Swan incandescent lamps. The supply commenced on 1 October with three Siemens arc lamps on poles 22 feet high and incandescent lamps were installed on ordinary gas standards in the side streets, and eventually there were four arc and 27 incandescent lamps supplying the town and three arc and seven incandescent lamps at Westbrook Mill. Because Pullmans had the exclusive rights for the use of water at that part of the Wey, the Mill lighting was given free of charge as compensation for using their water rights. By mid-December Poncelet turbines had replaced the waterwheel, but had to be supplemented by an auxiliary steam engine from early December because whenever the river became swollen the fall was so reduced that power was inadequate. The Swan lamps near the generator (in the Mill and Mr Pullman's house) worked perfectly; but those in the town gave only a dull red glow. The single conductor was a naked copper wire suspended from houses by ordinary telegraph insulators and earth return was used. Late December, Calder and Barrett withdrew and water power was abandoned. Siemens kept the system going and in January 1882 accepted an offer to light the town, transferring the generating plant from the Mill to the town. At this time there were possibly six Siemens 300 cp arc and 29 Swan filament 30 cp lamps operating. Generation was by Siemens machines—a 10 hp alternator turning at 840 rpm excited by a self-excited DC generator working at 1,200 rpm. The AC machine supplied two separate circuits, one for the arc lamps at 12 A 250 V and the other for the incandescent lamps at 33 A 40 V. Both circuits needed 10 hp (7.46 kW) to supply a load of about 4·32 kW (3·0 kW arc and 1·32 kW incandescent). Siemens laid main cables in the gutter as there was no legal power to break up streets. The Swan lamps were now working satisfactorily. Some additional steam generation was installed in about March and July 1882. The supply was successful and continued on an annual contract until

April 1884, when Alexander Siemens reviewed the potential for private sales with a view to obtaining a license under the Electric Lighting Act 1882 (*q.v.*). He then had a few dozen consumers with about 160 lamps—probably four arc lamps and 60 or 70 Swan lamps for street lighting and 90 to 100 private lights in about a few dozen shops and houses. As there was no prospect of extending the system to the 400–500 private lights needed to make it economic the supply was shut down and gas lighting reintroduced on 1 May 1884.
Electricity supply did not return until 1901.

1881 —Another pioneering installation was at *Chesterfield*—claimed to be *the only town in England wholly illuminated by electricity.* On 12 August the gas company could not agree renewal terms with the Town Council's Watch Committee. Hammond & Co. had already installed some arc lamps locally—at the Dronfield Works of Wilson & Scammell some five miles away. On 8 October a three weeks' experiment began—Hammond lit the main streets with eight Brush arc lamps, supplied from a Brush 16 light dynamo driven by a Fowler eight hp compound engine located in the yard of the Theatre Royal, Low Pavement; and Lane-Fox demonstrated his incandescent lamps. On 28 October the Watch Committee accapted Hammond's offer to light the town for a year with 22 arc and 50 Lane-Fox lamps. By 14 December 11 all-night arc lamps were operating; on 23 December all 22 arc lamps were in service. Other parts of the town were lit by 73 gas-oil lamps because difficulties in finding a generating station site had delayed the incandescent lighting. By 4 July a power station had been built alongside the River Hipper with two 20 hp "Yorkshire" compound engines and two Brush dynamos, each capable of supplying 40 arc lamps and 320 incandescent lamps. There were 15 miles of overhead conductors. In September 1882 Hammond and four other companies applied for a Provisional Order under the Electric Lighting Act 1882, but they were opposed by the Town Council who themselves applied for a License. Hammond ceased operating in 1884 because public lighting did not pay and the lighting of shops and private houses was more profitable—they needed the machines elsewhere. On 1 April 1884 Chesterfield reverted to street lighting by gas and electric lighting was not reintroduced until 1901.

1881 By the end of the year there were many installations of Swan lamps. On 28 December the *Savoy Theatre* was lit by 1,200 lamps supplied by six Siemens alternators powered by two Fowler engines.

1881 The possibility of *solar sea power* from a thermal engine utilising the temperature differences between the warm surface layer and deeper colder layers in tropical waters was pointed out by D'Arsonval in "Révue Scientifique" (Paris) 17 September.

1882 Parliament passed the *Electric Lighting Act, 1882—the first public measure dealing with electricity supply. It received the Royal Assent on 18 August.* It enabled the Board of Trade by License or Provisional Order to authorise the supply of electricity in any area by any local authority, company or person—and to grant powers to install a system of supply, including breaking up streets. Thus intending suppliers could avoid the trouble and expense of promoting Private Bills to regularise their local monopoly powers. Licenses, which could not be granted without the consent of the local authority concerned, were to be for periods not exceeding seven years, although they could be renewed. The Act gave local authorities the right to take over the assets of companies after a period of twenty-one years. For this reason, it discouraged enterprise.
Regulations inserted in the Licenses and Provisional Orders prohibited the amalgamation of undertakers and the erection of overhead lines without local authority consent. The Act provided the first statutory right for an individual within an area of supply to demand a supply of electricity; and it prohibited undue preference between consumers. Although 74 Provisional Orders and 7 Licenses had been granted by the year 1888, the powers obtained were never exercised. Limited development did take place, however, by avoiding the Act,

e.g. by obtaining the consent of the local authority for the use of overhead lines. (It is of interest to note that in this and subsequent Acts, the ultimate public ownership of the supply industry was envisaged.)

1882 Edison Electric Light Station at *No. 57 Holborn Viaduct*—claimed to be *the first public steam power station in the world* to cater for the private consumer as well as for public lighting. On 2 January E. H. Johnson, representing Thomas Edison, obtained permission to light the Holborn Viaduct district with Edison incandescent lamps, and plant was running by 12 January. This was a commercial technological experiment aimed at demonstrating the new incandescent lamp for both street lighting and private use. A three months' free trial was given, starting 24 April, and thereafter the rates charged were the same as for gas. In March the system was purchased by a specially formed English Edison Co. with a capital of £1M. The station was formally opened for inspection on 11 April. The initial installation comprised 968 lamps, mostly 16 cp, but some were 8 cp, with 164 lighting streets from Holborn Circus along the Viaduct and Newgate Street as far as the General Post Office, which had 50 interior lamps, but later installed a further 400 in the Telegraph Operating Room. The City Temple had 161 lamps, *the first church to be electrically lighted*, the Viaduct Tavern 31. The London, Chatham and Dover Railway station had nine lamps; and hotels, stores, restaurants and other private buildings a total of 321. The balance of 232 were in the power station. Generation was by two Edison American built "Jumbo" dynamos, the first could supply 1,000 Edison 16 cp lamps, the second 1,200. Each was directly driven by a 125 hp Porter-Allen horizontal steam engine on the same base plate, the unit weighing 22 tons. Another 1,200 light set was installed at 35 Snow Hill, and a 250 light set driven by an Armington and Sims engine was installed to meet the day load of private consumers. Steam was supplied by Babcock and Wilcox water-tube boilers (i.e. 'proper' power station boilers and not portable steam engines, agricultural engines etc. used previously). Distribution was DC at about 110 V by the two-wire system. Holborn Viaduct had roomy subways that carried the mains without the expense and legal problems of digging up streets. The two copper conductors were fixed in insulating material and carried in wrought iron pipes. Current for street lamps and for private consumers was taken from them by insulated cables via distribution boxes. Each consumer had an electrolytic meter designed by Edison whereby the supply was metered by the gain in weight of a copper cathode. The new Edison and Swan United Electric Light Co. Ltd, created by a merger on 26 October 1883, took over the undertaking in 1884 and by November were reporting that the system was running at a serious annual loss. Edison was satisfied that his experiment had accomplished its purpose and closed it down in September 1886. The station was on Crown property and could not be extended and, in any case, the reversionary purchase provision in the Electric Lighting Act of 1882 was a disincentive. The Viaduct reverted to gas lighting for a second time.

1882 Between January and May many electrical companies were established—with total capitalisation of £9M, including many subsidiaries of the Anglo-American Brush Electric Light Corporation (established 1880). The concessionaire that came closest to success was the Hammond Electric Light Co.

1882 Brighton power station of the Hammond Electric Light Co. opened on 27 February—*to provide the first permanent (and first viable) public supply.* Robert Hammond successfully demonstrated Brush arc lighting in December 1881 and during one week from 21 January 1882 operated an experimental circuit of 1¾ miles in the town centre with 16 arc lamps supplied by a Brush dynamo driven by a Robey engine in the yard of Reed's Iron Foundry, Gloucester Road. Response to Hammond's offer to light a lamp for a week for 12s, was sufficient to justify a permanent supply and soon all 16 lamps were lighted from dusk to 11 p.m. A further dynamo powered by a Marshall engine entered service in the spring of 1883 to supply a 40 lamp circuit, and the price was now 6s per lamp per week plus 1s 6d for each carbon consumed—possibly *the first example of a two-part tariff.* Although the arc lighting current of 10·5 A was too

high for incandescent lamps, the company's engineer, Arthur Wright, was able to introduce these lamps in groups of ten in parallel, with each group in series with the mains, since each lamp now took about 1 A. A protective system ensured that the failure of a single lamp did not cause the whole group to fail, and although not being able to use individual lamps greatly hindered the growth of domestic lighting, by January 1886 there were 1,000 filament lamps on eight miles of arc circuits. By 1887, 34 arc lamps and 1,500 filament lamps were being supplied from five Brush dynamos over 15 miles of overhead lines of No. 7 bare copper wire and extending up to three miles from the power station. Electrolytic house meters were introduced in 1884, charging 1s per kWh. Hammond Electric Light and Power Co. went into voluntary liquidation in 1885 and a new company, the Brighton Electric Light Co., registered on 16 December 1885, purchased their system. A new station on the same site started up in 1885 with three Brush 40-lamp dynamos belt-driven from a countershaft powered by a semi-portable compound Fowler engine, later extended by two Brush dynamos and a second Fowler engine. In 1887 it was decided to provide a day-time supply and a 16-light dynamo powered by a semi-portable Hornsby engine was installed to meet the day load. That year the system was converted from DC to AC with generation at 1,800 V by single-phase Elwell Parker and Mordey alternators driven by two large Fowler engines, reduced to 100 V by Lowrie-Hall transformers on consumers' house-tops, in cellars or street boxes. In 1890 the company became the Brighton and Hove Electric Light Co. Statutory authority had been unnecessary while mains were overhead. The local authority, Brighton Corporation, had obtained a Provisional Order under the Electric Lighting Act 1882 but had never exercised their powers, which they refused to transfer to the company. An application by the company for their own Provisional Order so that they could underground their system was opposed by the Corporation. A Board of Trade inquiry under Major Marindin refused the company's application and threatened to revoke the Corporation's Order if they did not make use of it. A municipal undertaking started up in competition, with a new station at North Road that opened on 14 September 1891. It bought out the company in January 1894. The supply was a 115 V DC two-wire system. Generation was from four Willans-Goolden sets—two × 45 kW and two × 120 kW, steamed by three Lancashire boilers at 150 lb pressure. A 230/115 V three-wire system was introduced in 1893. Two Willans engines driving 240 kW Latimer Clark dynamos were later installed. By 1904, generation capacity was 5,935 kW from 19 Willans engines directly coupled to DC generators and steamed by six Lancashire and ten Babcock and Wilcox boilers. In 1906 a new power station opened at Southwick, generating three-phase 50 Hz AC and North Road was shut down in 1908.

1882 W. E. Ayrton and J. Perry produced a range of *portable electric measuring instruments*, including an ammeter, in the laboratories of the City and Guilds of London Institute. Their inventions often used a flat spiral spring which yielded a relatively great rotation for a small axial elongation, and served as prototypes for many instruments in use today.

1882 L. Gaulard and J. D. Gibbs obtained British patents for *alternating current distribution* by means of transformers connected in series. It was adopted by the Eastbourne undertaking and London's Metropolitan Railway in 1883 (*q.v.*) and by the Sir Coutts Lindsay Co. Ltd for their supply network based on the Grosvenor Gallery station in 1884–85 (*q.v.*). Each consumer had a transformer in his house to reduce the voltage from 2,500 V to the working voltage and the transformer was designed to cater for a range of voltages. The system was unsatisfactory and Ferranti altered it in 1885 by installing transformers for working in parallel across the mains.

1882 *Hammond's installations at Eastbourne and Hastings* also became established permanently. Until 1890, they were 'non-statutory', proceeding under agreement with their local authority who allowed their cable to be laid in the streets.

Hastings and St Leonards-on-Sea commenced their supply in March. Their

power station in Earl Street had Brush dynamos driven through countershafts by 'Undertype' locomotive engines. The supply voltage was 2 kV right up to the consumer's installation for both arc and incandescent lamps which, by 1886, numbered 27 and 576 respectively. The latter were arranged on consumers' premises in groups of twenty in series; public street lamps were arranged in series. In 1890 the plant was replaced by a Brush single-phase AC generator supplying through transformers on consumers' premises. Hastings Corporation acquired the system on 1 July 1898.
Eastbourne Electric Light Co. started up on 4 September, illuminating The Parades with 22 Brush arc lamps. Generation was by two 25-light Brush arc machines driven by 'Undertype' engines and Robey boilers located at the Bedfordwell Waterworks. Shortly afterwards incandescent lamps lighted the interiors of several large shops in the town, running in series with the arc lamps, and the Gildridge Hotel, adjacent to the railway station, had an installation of incandescent lamps supplied from a battery of accumulators charged from one of the arc lighting circuits. An AC system with Lowrie-Hall transformers on consumers' premises (*Gaulard and Gibbs system*) was introduced in 1883. The generating plant was transferred to a building of The Old Brewery in Junction Road in 1884. By 1888 there were 1,700 lamps on supply. New plant added up to 1899 comprised a 30 kW Elwell Parker alternator, a 200 hp Fowler engine driving through leather belts and countershaft two 75 kW Elwell Parker alternators, a 250 hp Marshall engine driving through ten cotton ropes a 100 kW Lowrie-Hall alternator, and three direct-coupled sets with Electric Construction Co. alternators of 50 kW, 150 kW and 200 kW respectively. Generation then was at 1,800 V, taken to a double-pole Lowrie-Hall switchboard and distributed via five circuits to different parts of the town. Distribution was by rubber insulated cables drawn into cast iron or wrought iron pipes but because of the deterioration of the rubber after a few years faults were frequent. First dividend was paid in 1893. Eastbourne Corporation purchased the undertaking on 1 January 1900. The original "Electricity Works" were shut down on 24 July 1902.

1882 Dr John Hopkinson, Professor of Electrical Engineering at King's College, London, and consulting engineer to English Edison Electric Light Co., patented his three-wire system of DC distribution. It enabled two two-wire main circuits to be supplied from a single generator at double the voltage of either circuit. At first the voltages were 220 V between the outer wires and 110 V between each outer wire and the middle wire. Savings in copper ranged from 25 to 50 per cent according to voltage levels.

1882 Coleman Defries patented the bayonet cap for lamps. Gimingham repatented in 1884, about which time it was used by the Anglo American Brush Corporation.

1882 Thomas Edison commissioned his *Pearl Street* power station in New York on 4 September—it had six "Jumbo" generators. A few weeks later the USA's first hydro-electric plant started up in Appleton, Wis.

1882 Electrical Exhibition at the Crystal Palace provided the *first public demonstration of large-scale electric incandescent lighting* by Edison, Swan, Maxim etc.

1882 Siemens introduced the names *'watt'* and *'joule'* with their modern meanings and Preece sponsored their introduction to Britain.

1882 *Ferranti*'s new form of *armature* meant that his alternator could light 12·4 incandescent lamps per hp compared with eight for the Siemens machine.

1882 *"Brush bubble"*—over £7M raised by electricity undertakings, largely on the initiative of the Brush Co. Success of the boom depended on electric lighting being as cheap as gas—which was not achieved and the market for electricity collapsed in 1883.

1882 *First rules relating to electrical risks* published by Phoenix Fire Office in February. IEE's first rules for the prevention of fire risks published on 21 June (*q.v.*).

1882 *A railway carriage propelled by electromagnetism* was tried out on the Edinburgh to Glasgow line by Robert Davidson. Two batteries at the front of the carriage powered four large electromagnets, two on either side of a large cylinder through which passed the front axle, with a smaller arrangement for the rear axle. The magnets attracted in turn large masses of iron grooved into the cylinders. Batteries were pairs of iron plates with zinc plates interposed. The 16 ft. × 6 ft. carriage weighed more than 5 tons and moved at 4 mph.

1882 *Clock meter* patented by Professors Ayrton and Perry but not put into production.

1882 First application of *electricity underground*, at the Trafalgar Colliery, Forest of Dean, to drive a small pumping set.

1882 *Wiring Regulations*—"Rules and regulations for the prevention of fire risks arising from electric lighting" issued by the Society of Telegraph Engineers and Electricians. (This constituted the first edition of what became known as the I.E.E. "Regulations for the Electrical Equipment of Buildings", now in its 15th Edition.)

1882 By year end over 400 lighting installations had been completed in Britain.

1883 Dr John Hopkinson expounded the *principle of the two-part tariff* method of charging for the supply of electricity, incorporating a fixed or service charge in addition to the charge for the quantity of energy consumed.

1883 *Private electric lighting installations* were being installed throughout the country. The motive power for country houses was usually a semi-portable steam engine and, in town, engines usually worked from the town gas supply.

1883 *Portable storage batteries* of sufficient capacity to supply temporary installations for balls and parties were available—charged at the makers' works.

1883 *Grosvenor Gallery Station*—a number of Government Commissioners visited the 1882 Paris Exhibition, including the Earl of Crawford who, on his return, advised Sir Coutts Lindsay to install electric lighting in his Grosvenor Gallery, Bond Street. Two Marshall's semi-portable engines belted to two separately excited Siemens alternators, generating single-phase at 2,000 V, were installed in a yard behind the gallery. The supply was successful and soon became overloaded when it was extended to meet requests from neighbouring premises. Sir Coutts Lindsay, Lord Crawford and Lord Wantage formed the Sir Coutts Lindsay Co. Ltd. to construct a new Grosvenor power station of 1,000 kW capacity in 1885 (*q.v.*).

1883 A & S *Gatti Brothers* installed in the basement of their Adelaide Restaurant in the Strand two vertical multi-tubular Field boilers steaming two Armington and Sims engines each driving two 150-light Edison dynamos to supply 330 incandescent lamps in the restaurant. In 1885 they laid a cable in the ground (without authority) to supply the Adelphi Theatre and in 1888 built a station at Bull-in-Court between *Maiden Lane* and the Strand with three Babcock and Wilcox boilers working at 140 lb/sq. in. pressure and steaming four compound Willans engines directly coupled to Edison-Hopkinson dynamos—two of 84 kW capacity at 425 rpm and two at 50 kW at 475 rpm generating DC at 105 V. In 1889 the *Electric Supply Corporation* took over the Maiden Lane station and changed its name to the *Charing Cross and Strand Electricity Supply Corpn. Limited.*

1883 *First electric traction*—in June electric trams were running on Kew Bridge on the Acton Tramway line driven by 50 Fauré-Sellon-Volckmar cells and a Siemens dynamo, capable of carrying 46 people for seven hours.
—on 3 August a quarter-mile length of electric railway was opened for traffic at *Brighton* by Magnus Volk. Current was taken from a third rail at 140 V DC.
—on 28 September the Traill Bros' electric railway covering the six miles from *Portrush* (the terminus of the Belfast and Northern Counties Railway) to *Bushmills* in the Bush Valley opened. Generation was from two 45 hp American turbines at a salmon leap on the River Bush, with a head of 24 feet, a mile from Bushmills. The Railway was later extended to Derrock, near the Giants Causeway, providing a total length of eight miles. A separate conductor was placed at the side of the railway to carry the current, the return circuit being completed through the rails themselves. The operating voltage was 550 V DC. Board of Trade Regulations restricted the working speed to 10 mph.

1883 The *first significant alternating current transformer installation* was in London's *Metropolitan underground railway* (reported in "Engineering" XXVI, 1883, p. 480). Seven miles were lighted from a central power station at Edgware Road by the National Company for the Distribution of Electricity by Secondary Generators. The Gaulard and Gibbs system was used whereby an AC current "induces at each reversal of its direction a momentary current in wires lying beside the one it is traversing . . . the apparatus will . . . give current of any desired quality . . .". A supply of 10 A at 2,000 V was provided from a Siemens alternator, 15 miles of No. 8 BWG copper strand provided the primary circuit, carried on insulators fixed to the brickwork of the tunnel. Four stations—Aldgate, Gower Street, Edgware Road and Notting Hill Gate were lighted by about 100 Swan filament and six arc lamps. A secondary generator at each station consisted of 16 vertical columns, each comprising an iron core wound with a cable formed of a central wire of No. 8 BWG, surrounded by 48 fine wires, each separately insulated, and all connected together at their ends. The columns were grouped together according to requirement, e.g. a group of four arranged in series might feed a number of Jablochkoff candles also arranged in series or, arranged in parallel, drive a powerful arc lamp or, in compound parallel groups of two, supply high resistance filament lamps.

1884 On 23 April the *Hon. C. A. (later Sir Charles) Parsons* filed two patents on the *steam turbine.* In the same year he built, at the works of Clarke, Chapman, Parsons and Co. the *first turbo-generator in the world*—a DC unit capable of developing about 7·5 kW at 100 V and at a speed of 18,000 rpm. The turbine could utilise higher steam temperatures and pressures than reciprocating steam engines and operate at high speeds like the new internal combustion engines working on the four-stroke 'Otto cycle'.

1884 Dr John Hopkinson showed mathematically that, contrary to general opinion, *alternators* could be *run in parallel.* Later that year this prediction was verified in experiments carried out by Prof. W. Grylls Adams at the South Foreland lighthouse.

1884 First successful *commercial clock meter* was by *Hermann Aron.* A permanent magnet was used for the pendulum weights and was swung above a solenoid carrying the electric current so that there was an electromagnetic force acting on the pendulum as well as the gravitational force. The additional force changed the rate of oscillation of the pendulum which was proportional to the current, and the time lost or gained by the clock was proportional to the quantity of electricity—ampere hours. By using a solenoid connected across the electricity supply for the pendulum weight instead of the permanent magnet the meter could measure kilowatt hours on either AC or DC circuits. Crompton's pupil Miller turned the Aron meter into a very successful instrument.

1884 Hammond Electric Light Company introduced *electrolytic house meters* in Brighton and charged 1s per kWh.

1884 *Price of electricity*—South Eastern Brush Electric Light Co. charged ½d per lamp hour.

1885 *Mercury meter* by Ferranti developed to a satisfactory state. The current flowed first through the coils of an electromagnet and then radially through a shallow bath of mercury placed between the poles of the magnet. The current caused the mercury to rotate and a small fan in the mercury rotated with it. The fan was geared to a counter and measured ampere hours.

1885 *Electric traction*—Trials of electric tramway on Blackpool Esplanade—2¾ miles opened in 1886.
—*Bessbrook and Newry* Tramway opened—3¼ miles.
—*"Application of Electricity to Propulsion of Elevated Railroads"* presented by Frank J. Sprague to Society of Arts, Boston, recommended the electrification of overhead railways in Boston and New York to provide rapid transit for expanding systems. With numerous stops and starts, requirement was for more rapid acceleration and smoother running to reduce track wear.

1885–98 *Tariffs examples* (before suitable meters were available central power stations had a fixed price system—a fixed amount per lamp per year)—Brighton Electric Light Co. introduced a tariff of ½d per hour per lamp (or if consumption was less than three hours per day in a quarter 1d per lamp per hour); modified later in 1885 to 1s per kWh consumed if more than 10 kWh were consumed per lamp, or 1s 4d if less than 10 kWh were used.
—1886 London Electric Supply Corporation charged £1 per year for each 10 cp lamp and £2 for each 20 cp lamp for supplies from Grosvenor Gallery.
—1887 Supplies from Crompton's Kensington Court Electric Light Co. cost 8d per kWh.
—1888 Metropolitan Electric Supply Co. charged 30s pa for each 8 cp lamp supplied from their Whitehall Court Station.
—1891 St Pancras undertaking charged 6d per kWh.
—1893—Brighton Corporation charged from 1 January 1893 7d per kWh for the first two hours per day the demand had been used (as shown by the yearly consumption) and half-price thereafter; demand to be determined by installing near the meter in every house a thermal type of maximum recording ammeter to be read once a month in the two winter quarters. The mean of the six readings was taken as the 'demand' from which the number of hours per day the lamps had been used was calculated. In 1892 Brighton Corporation's expenditure amounted to 7d per kWh sold of which only 2d per kWh was the cost of production and 5d per kWh the cost of having the plant in readiness to supply. On 30 June 1898 Brighton Corporation reduced its tariffs after the first hour's consumption from 1½d to 1d per kWh.

1885 A new permanent generating station on the *Grosvenor Gallery* site, constructed on a considerably larger scale by the Sir Coutts Lindsay Co. Ltd., commissioned towards the end of the year. The plant, of capacity 1,000 kW, was installed under the Gallery and provided a supply at a pressure of 1,200 V, alternating current. *Each consumer had a transformer installed in his house* and the primaries of all the transformers on a circuit were connected in series with the mains, in accordance with the Gaulard and Gibbs system of distribution. The high-voltage current was carried by rubber-insulated cables strung upon poles and roof-top insulators and the system increased until it covered an area extending from Regents Park in the north, to the River Thames in the south, and from Knightsbridge in the west to the High Courts of Justice in the east. Two Siemens single-phase alternators were driven by belts from a countershaft to which three horizontal Marshall engines were clutched. There were about 30,000 lamps connected to the system. The distribution system caused so much trouble that Sebastian Ziani de Ferranti was called in for advice in 1885 and he joined the company in January 1886 becoming Chief Engineer at the age of 21. Within a few months he completely changed the distribution system, installing transformers for working in parallel across the mains, the form of distribution which is universal today. Five separate circuits

were used which, by special switches, could be connected in groups or separately to any generator. The generators were not run in synchronism. Ferranti installed two generators of his own design in place of the Siemens machines. One was belt driven by the three Marshall engines, each of which could be coupled up to the generator by a clutch as the load increased, so that all three engines were driving on to the one generator at full load time. Two of the engines had a capacity of 250 hp and the third was rated at 400 hp. The second generator was rope driven by a 750 hp Corliss engine made by Hick Hargreaves of Bolton. These were the largest generators then in use, with a total capacity of about 800 kW, but they could provide as much as 1,400 kW if necessary. Their armatures were 8 ft. 6 ins. in diameter; they ran at a speed of 250 rpm, and generated single phase current at 2,500 V and 83⅓ Hz (cycles per second). Four Babcock and Wilcox 550 gallon/h boilers provided steam at 130 lb/sq. in. As the engines were non-condensing, the exhaust steam was taken to the boiler chimney via a tank. In winter coal consumption was about 23 tons per day. Five outgoing overhead circuits used braided vulcanised india rubber cables manufactured by the India Rubber and Gutta-Percha Co. of Silvertown, dimensioned for 2,400 V working. Service lines entered consumers' premises through the brickwork in earthenware tubes, cemented into the brickwork, and thence to the transformer fuses. The overhead distribution cables were invisible except where they entered the transformers, which were located in places inaccessible to the occupier. Two 'house wires' were taken from the transformer at 100 V to the meter. The first Ferranti meters (mercury meter) were installed in September 1885; Ferranti/Wright and Frager meters were also used.

1885 *Paddington Works* constructed by the Telegraphic Construction and Maintenance Co. for the Great Western Railway—Manager J. E. H. Gordon. Three 350 kW alternators, among the largest yet built, were driven directly by J. & G. Rennie vertical engines developing 600 hp at 146 rpm working non-condensing at 160 lb/sq. in. The Gordon alternators had stationary armatures and rotating fields producing an axial flux through the armature coils by means of 28 horizontal electromagnets arranged in a circle on each side. Thus, there were 56 armature coils—twice the number of magnetic poles—so the machines were really two-phase. They were excited by three 25 kW Crompton dynamos driven directly by Willans engines. Nine large locomotive boilers supplied a steam range. The station was in commission for 20 years.

1885–87 Introduction by Siemens Bros. of *lead-sheathed armoured cables,* insulated with rubber or gutta-percha.

1886 Beginnings of the *General Electric Co. Ltd.* when Mr Hugo Hirst (later to become Lord Hirst of Witton) joined Mr Gustav Byng, in the proprietary of an electrical warehouse in the City of London called "The General Electric Apparatus Co."

1886 Lord Rayleigh and Lord Bury, two members of the Society of Telegraph Engineers, introduced *Bills amending the Electric Lighting Act, 1882.* Although the Bills did not become law, the pressure exerted was to a large extent responsible for the passing of the 1888 Act—*q.v.*

1886 Sir Oliver Lodge installed the world's first *electrostatic precipitator* in a lead smelter, but development was impeded by lack of high-voltage facilities.

1886 *Incandescent gas mantle*—Carl Auer Von Welsbach developed an incandescent mantle which fitted around a bunsen flame. Cotton fibre formed the support for chemical substances which became incandescent when heated. Rare earth elements (a little oxide of cerium mixed with oxide of thorium) were used. The development of the mantle enabled gas lighting to continue along with electric lighting for several more decades, and opened up new areas of chemical discovery.

1886 *J. Hopkinson* and *E. Hopkinson* read *"Dynamo-Electric Machinery"* before the Royal Society (Phil. Trans. 177, 1886, pp. 331–358). The paper considered the relationship between the magnetic field properties of a dynamo and the magnetising force to produce that field i.e. the electromotive force of the machine at a stated speed and the current around the magnets.

1886 *Westinghouse Electric Co.* established in U.S.A. to build and promote *AC systems.* George Westinghouse and William Stanley commissioned the first commercial U.S. AC system at Buffalo, N.Y.

1886–1887 "The self-induction of wires"—a series of papers by Oliver Heaviside postulated that a rise of voltage would take place when an alternator was switched on to an unloaded feeder having considerable capacitance. Ferranti had discovered this while laying mains in 1890 and had to dispense with step-up transformers at the generating station. The phenomenon became known as the *'Ferranti Effect'* and Tesla wrote about it to "The Electrician" of 6 March 1891. In that year J. A. Fleming set out the problem in a paper to the I.E.E. on 7 May. On his advice compensating condensers and fuses were fitted as a solution.

c. **1886–1900** The so-called *"battle of the systems"* to be used for distribution; with Col. R. E. B. Crompton, Dr John Hopkinson, Lord Kelvin, Thomas Edison and others fighting a rearguard action on behalf of direct current against progressive Sebastian Z. de Ferranti, W. M. Morley, Prof. Sylvanus Thompson and George Westinghouse pressing the claims of alternating current. On 12 April 1888 Crompton gave his classic paper to the Society of Telegraph Engineers and Electricians, "Central Station Lighting: Transformers v Accumulators". High voltage AC transmission had much to commend it because of reduced mains losses and at that time DC machines could not be built for high voltage working. Moreover where the demand was so scattered that it did not pay to put down the heavy feeders and distribution mains required on the DC system, its economical radius of supply being only about 1½ miles, attention was drawn to AC possibilities. On the other hand DC used in conjunction with batteries increased the operating efficiency of stations under light load conditions. AC eventually came out on top, largely because of the ease with which it could be transformed to differing voltages thereby greatly aiding transmission and distribution.

1887 *Battle of the systems*—French copper syndicate cornered much of the world's copper supplies forcing prices up—thereby enhancing attraction of AC compared with DC; moreover Shallenberger's AC ampere-hour meter and Tesla's AC motor were introduced in 1888. Edison's DC interests could no longer attack AC on technical grounds and attacked instead on grounds of safety.

1887 *F. J. Sprague* contracted to electrify the twelve-mile *streetcar* system of Richmond, Virginia, using an overhead wire supply.

1887 Albert Michelson and Edward Morley demonstrated that the *velocity of light is independent of the speed of its source* (see Einstein's Special Theory).

1887 Publication of the *first electrical catalogue* by Hugo Hirst for the General Electric Apparatus Co.

1887 *Kensington Court* power station, owned by the Kensington Court Electric Light Co. and designed by Messrs R. E. B. Crompton & Co. opened in January—*one of the very earliest plants to be working in the London area*, providing a DC supply. The plant was located in a basement and generated at 220 V from steam engines coupled to 35 kW Crompton dynamos; and by 1890 the total capacity was 550 kW. The supply to the consumer was from a secondary battery of 53 cells. The scheme was so successful that it was extended beyond Kensington Court in 1888 and a new company, Kensington and Knightsbridge Electric Lighting Co., was formed to run the undertaking. A second station was

established in *Cheval Place* in 1890 and by 1892 its plant capacity had reached 410 kW compared with 645 kW then at Kensington Court. By 1898 further plant was needed, and it was recognised that amenity considerations prevented any further extension in residential areas. The neighbouring *Notting Hill Electric Lighting Co.* ran a similar system and had the same problems and the two companies therefore decided to build a joint station at *Wood Lane*, near Shepherd's Bush, in October 1900 (*q.v.*).

1887–89 *The Deptford station*—demand on the Grosvenor Gallery station of Sir Coutts Lindsay Co. was still rapidly increasing so that the undertaking had once more to be expanded. A new company, *the London Electric Supply Corporation Ltd.*, was formed in 1887 with a capital of £1M and it embarked on a project to build a large generating station outside London on a site at Deptford which had ample water supplies for condensing purposes, seaborne coal that could be obtained at low prices, and space for expansion. Because the station was seven miles from Central London it was necessary to introduce extra high tension transmission, and 10,000 V was the voltage level selected. To provide a supply from Grosvenor Gallery to light the construction site, Ferranti experimented with two types of cable insulant, then regarded as essential for HV operation—rubber and jute. Rubber cables were unsuitable because of rubber's high permittivity, the charging current was excessive, and rubber, anyway, was very expensive. For most of the insulation he chose jute, impregnated with petroleum residue, using concentric type cable made by Fowler-Waring Co. (later STC). The main was laid along the parapet walls of the railway but was readily ignited by sparks and flying cinders from passing trains. Ferranti decided therefore to design his own cable for his 10,000 V system—using paper impregnated with Ozokerite wax, a byproduct from the manufacture of candles, to insulate from each other two concentric tubes forming the conductors. A drawback was the rigid construction which meant that the cable was laid in short lengths of 20 ft., the length that could be accommodated by a horse and cart, and the overall length of 30 miles needed 7,000 joints—yet over a service life exceeding 40 years there were only 15 joint failures. The network successfully commissioned in 1889. Deptford initially operated on plant transferred from Grosvenor Gallery with the generation voltage stepped up from 2,500 V to 10,000 V for transmission. Grosvenor Gallery became a transforming station (substation). On 15 November 1890 a fire destroyed its transformers and the supply was interrupted for three months. During this period the overhead system radiating from the substation was replaced by underground cables.

At Deptford two 1,500 hp (600 kW) generators were installed in 1889 powered by Hick Hargreaves engines—they were easily the world's largest. They did not commission until 1891 because it was decided to rewire them to generate at 10,000 V.

Even larger units of 10,000 hp each were put in hand. The shafts were 36 in. in diameter, the armatures about 46 ft. in diameter, the speed was 60 rpm and the weight of the generator alone was about 500 tons. They were never completed because the area of supply turned out to be much less than originally expected, the Board of Trade having granted Provisional Orders to rival companies in the area. There were so many competing applicants for Provisional Orders in 1889 relating to London that the Board of Trade held an inquiry presided over by Major (afterwards Sir Francis) Marindin. One of the recommendations was that where a local authority agreed to allow competing companies within its area the number should be restricted to two, but both should not supply alternating current because of its unsuitability for the electric motor then available. At that time, on engineering grounds, AC distribution generally found little favour. Deptford dwarfed the average station which had no more than about eight 100 kW dynamos or alternators.

1887 *Electric welding* introduced by Elihu Thomson, of the U.S.A. (cf. carbon-arc welding 1880–85).

1887–88 *Nikola Tesla*, a Serbian who emigrated to the U.S.A. where he did most of his

work, and Professor Galileo Ferraris of Turin, independently produced *rotating magnetic fields* by two-phase currents. *Tesla* went on to invent the *induction motor* and to establish the fundamentals of the *polyphase system,* which underlies electrical power transmission as we know it today. By applying the principle of the rotating magnetic field to his induction motor in 1888, Tesla was able to satisfy the requirement for an alternating current motor that could be used satisfactorily on the distribution networks employing alternating currents that were now being established, and the motors could be very small, just a fraction of a horsepower, suitable for the electrical appliances that were to follow. His *"A New System of Alternate Current Motors and Transformers"* presented to the American Institute of Electrical Engineers put forward his system of electricity distribution based on two-phase AC generation and AC motors synchronised with system frequency in the same way as an alternator which could be as small as 0·5 hp and still operate at 50 per cent efficiency. The system was exhibited at the Columbian Exposition held in Chicago in 1893 and used by Westinghouse in the hydro-electric power system at Niagara Falls in 1895.

1888 Four 75 kW Parsons *single-phase turbo-alternators* ordered for the Newcastle and District Electric Lighting Co. Ltd. registered on 14 January 1889. The first two sets were commissioned in January 1890 (*q.v.*).

1888 *Institution of Electrical Engineers ("I.E.E.")*—formed from the Society of Telegraph Engineers and Electricians.

1888 *Electric Lighting Act 1888.* This Act *extended the period prior to the exercise of the reversionary purchase right of local authorities* to forty-two years, with further optional stages of ten years, and favourably amended the reversionary purchase price. As a concession to local authorities, their consent was now required for Provisional Orders, but their refusal could be overruled by the Board of Trade.
A clause was inserted in the Act to make it clear that the granting of supply rights to any body did not constitute exclusive rights within any area. The extreme case of *London,* however, presented special complications owing to the need to overlap local authority boundaries.
The Act *gave a new impetus to the establishment of electricity supply undertakings.* In the following ten years 316 Provisional Orders were granted of which 274 were exercised, but of 25 Licences granted only 3 were exercised. In London there were so many competing applications for Provisional Orders that in the following year (1889) the *Board of Trade* decided to hold an *Inquiry, presided over by Major (afterwards Sir Francis) Marindin—see* below.

1888 "The Solution of *Municipal Rapid Transit"* presented by Frank J. Sprague to the American Institute of Electrical Engineers gave details of the successful Richmond railroad and suggested how a similar system might meet the needs of New York.

1888 *"Central station lighting; transformers v accumulators"*—by R. E. B. Crompton to the Society of Telegraph Engineers & Electricians (Proc. vol. 77, p. 349) made the case for DC on grounds of low running costs and reliability.

1889 Oliver B. Shallenberger, Westinghouse's Chief Engineer, designed a *single phase induction motor ampere hour meter.* Its armature was an iron ring mounted on a light metal disc. The armature was surrounded by closed copper bands placed within, and at an angle to, coils carrying the electric current. This current induced secondary currents in the copper bands, and the interaction of the two currents on the iron ring caused the armature to rotate. The necessary braking force was provided by air resistance on four light vanes attached to the armature shaft. It came into widespread use after about 1892.

1889 *Marindin Report* laid down the *general principles which were afterwards adopted as the basis of Provisional Orders granted to electricity supply undertakings in the London area.*
This Inquiry was the first of many attempts that were to be made to settle the electricity supply of London on regional lines.
The point round which the greatest controversy raged was whether it was better to adopt *direct or alternating current* for distribution; there was also contention regarding whether or not supplies to large areas should be dependent on one station. On engineering grounds, AC distribution generally found little favour. Major Marindin expressed himself as being wholeheartedly in favour of encouraging any experiment that was likely to be for the public benefit; and he equally emphatically *upheld the proposal to supply large areas from one power station.*
Where a local authority agreed to allow *competing companies* within its area, the number should be restricted to two, but both should not supply AC because of its unsuitability for the electric motors then available—i.e. *one supply should be DC.*
Electricity should be available to all, even despite local authority objection, and all overhead lines should be removed within two years of a Provisional Order being granted.

1889 *C. A. Parsons & Co.* established. (Previously the firm was Clarke, Chapman, Parsons and Co.)

1889 Foundation of the *Electrical Trades Union ("E.T.U.").*

1889 *Electric fan,* powered by a *one-sixth hp AC motor,* introduced by Nikola Tesla and the Westinghouse Co. of the U.S.A.—probably the *first of the commercial small power units employed in the home.*

1889 *Professor George Forbes'* paper on 23 January to the Society of Arts said "... for extremely concentrated areas a direct supply with continuous-current dynamos, sometimes assisted by secondary batteries, and working on the three-wire system, is the most successful and the most remunerative. . . . But for extensive areas the use of high tension alternating current in our mains, reduced in the house by means of induction apparatus, is the most economical and flexible. In London, while we prefer HV AC for a company which is prepared to supply the whole of London, for a concentrated area bounded by Pall Mall, Green Park, Piccadilly, and Haymarket the LV three-wire DC system is far the best."

1889 *Ferranti's pioneering 10 kV cable* comprised two concentric braised copper tubes of equal cross section separated by paper impregnated with ozokerite (earth-wax), carrying 250A and were constructed in 20 ft. lengths. The outer tube was wound with waxed paper and slipped into an iron tube with wax filling the space between the paper and the outer tube.

1889 In the U.S.A., the *Westinghouse Co.* alone had *150 AC stations* cf. only 14 in all the U.K.

1889 *First experiments in electrocution*—Thomas Edison, supreme advocate of DC, allowed the New York Commission considering execution by electrocution to use his West Orange Laboratory for research with animals, recommending the "Westinghouse Current" of his arch rival in order to illustrate the deadliness of AC. A convicted murderer, William Kemmler, was selected as the first victim.

1889 *First parallel running of alternators*—load sometimes exceeded the capacity of a single alternator and if duplicate feeders were not available the additional set had to be run in parallel i.e. switched into phase and frequency synchronised. This was done when the cranks of engines were in the same rotational position using markers and the stroboscopic effects of the station's lighting, or by using a transformer and a lamp, or removing the caps to the valves of the HP cylin-

ders and adjusting the running so that the release of steam at each cycle coincided.

1889 Inauguration of the Bradford Corporation's electricity supply system on 20 September—the *first municipal power station in the country.* Designed by J. N. Shoolbred and vetted by Dr John Hopkinson the supply was 115 V DC two-wire from 3X100 kW Siemen's shunt-hound dynamos—two directly coupled to two-crank Willans engines of 150 hp and one by a Marshall engine—steamed by three Lancashire boilers working at 120 lb/sq. in.

1889 *General Electric Co. Ltd* incorporated (previously, the General Electric Apparatus Co.).

1890 The *number of lamps in London* reached one million.

1890 In January the *Forth Banks* power station of the Newcastle and District Electric Lighting Co. Ltd. went into commission with an initial equipment of two 75 kW Parsons parallel-flow turbo-alternators constructed by Clarke, Chapman, Parsons and Co. of Gateshead—*the earliest instance of the use of the steam turbine in any public power station.* The single-phase alternators supplied current at 1,000 V and 80 Hz: the speed of the sets was 4,800 rpm. Three Lancashire boilers built by Messrs Hawthorne, Leslie and Co. Ltd., provided saturated steam to the turbines at 140 lb/sq. in. that exhausted at atmospheric pressure.

1890 *Oil-impregnated paper-insulated cables*—the newly formed British Insulated Wire Co. of Prescot acquired from the Norwich Wire Co. of New Jersey the rights of the Co.'s tape lapping process, enabling them to manufacture paper/lead cable. By the end of the following year, the manufacture of both low and high voltage cables had been commenced at Prescot.

1890 *Domestic electrical appliances*—the General Electric Co. by now were selling electric *flat irons, fans, immersion water heaters,* and an *"electric rapid cooking apparatus, which boiled a pint of water in twelve minutes".*

1890 *Electric cooking*—first practical experiments in this country.

1890 City and South London Railway began operating from King William St. to Stockwell—the *first electrically-operated underground railway* in the world.

1890 *First Scottish public supply*—from Fort Augustus, comprising an 18 kW oil engine and a similar size water wheel.

1890 *First legal electrocution*—William Kemmler on 6 August at Auburn Prison, New York.

1890 Establishment of *"The Electrical Standardising, Testing and Training Institution",* later to become the *Faraday House Electrical Engineering College.* Founded by Robert Hammond of Hammond Electric Light Co., the Institution was opened to be responsible to the Board of Trade for inspecting plant, apparatus, meters etc. in electricity undertakings. Faraday House was the pioneer training school for electrical engineers. It closed down in 1967.

c **1890** *First overhead transmission lines* erected in this country.

1891 *Electric street tramway* installed by Leeds Corporation.

1891 James Swinburne introduced his open-core type of transformer with bristles of iron which he called the *"hedgehog" transformer* and sparked off a 'battle' of transformer design—'closed' v 'open' magnetic circuits—*see* plate 8.

1891 Electrical Exhibition at Frankfurt-on-the-Main—an important *demonstration of electrical transmission by three-phase* AC over 110 miles from Lauffen to Frankfurt. At Lauffen some 300 hp of hydro power was used to drive two three-phase alternators made by the Oerlikon Co. in Switzerland. They generated three currents of 1,400 A at 55 V at a frequency of 40 'periods' per second. The voltage was raised by transformers to 8,500 V. The transmission line was three copper wires 4 mm. in diameter, on porcelain insulators on 3,000 telegraph posts. At Frankfurt the voltage was reduced by transformers to 65 V for lighting incandescent lamps and driving motors. It gave an impetus to the Niagara Falls two-phase scheme.

1891 C. A. Parsons & Co. supplied their *first* 100 kW *radial-flow turbo-alternator* sets—to the *Cambridge Electric Lighting Co.* (system 2 kV AC with house transformers)—*the first to operate in conjuction with a condenser* to improve the efficiency of the turbine. The station was located at Thompson's Lane on the banks of the Cam. Two Lancashire boilers provided steam at 140 lb/sq. in. to three 100 kW sets operating at 4,800 rpm.
The new turbines were powered by the velocity of steam rather than its static pressure. Their basic principle was that efficiency depended on the temperature of their hottest and coldest parts. Instead of exhausting steam at atmospheric pressure, the steam in the Cambridge turbines was condensed at the low pressure end and expanded down to the lowest pressures—to a vacuum. Motive power was produced by "dropping" heat from the higher temperature of the boiler to the lower temperature of the condenser. At Cambridge, the *superheating of steam* was also introduced but abandoned after a few months. A *Green's economiser heated the feed water.*
As a result of these advances coal consumption was reduced from eleven to eight pounds per kWh generated and turbines were now as efficient as the best reciprocating engines. By about 1900 *cooling towers* were employed at power stations to provide cooling water for the condenser when natural supplies were not available.

1891 The periodical "Lightning"—now *"The Electrical Times"*—began publication.

1891 *Electric cooking*—brought into the limelight by the Electrical Exhibition at the Crystal Palace.

1891 *Speed control of DC motors*—introduction by Ward-Leonard of the U.S.A. of a system of control making possible numerous applications of electric drive not so far contemplated, as in colliery winding gear.

1891 Crompton coined the term *'load factor'.*

1892 *Oil-immersed circuit breaker*—invented by G. W. Partridge, Chief Engineer and Managing Director of the London Electric Supply Corporation Ltd. for use in the Deptford power station. It was needed to overcome the problem of the switching arcs caused by the heavier currents resulting from load growth.

1892 George Hookham of *Chamberlain and Hookham* patented a *quantity meter* that used a disc in mercury. The mercury provided a sliding contact to the disc and the electromagnetic forces on the radial current in the disc provided the driving force. The necessary retardation was produced by an eddy current brake.
The easiest meters to manufacture measured the quantity (ampere-hours) of electricity passing through an installation—multiplied by the nominal supply voltage and divided by 1,000 gave the Board of Trade Units (kWh) for which the consumers were charged. Later meters measured energy (kWh) directly. Hookham introduced an *energy meter* consisting of an induction motor working against an eddy current brake in 1895.

1892 *First electric heating*—a practical demonstration at the Crystal Palace Exhibition.

1892 *Northern Ireland's first public supply*—at Larne by J. E. H. Gordon & Co. with 2 × 35 kW Mordey Victoria Brush alternators rope-driven from Combe Barbour steam engines generating 2 kV, 100 Hz. Pole-mounted transformers reduced the voltage to 110 V. Supply began with a load of 14 × 500 W arc lamps for public lighting and 100 × 16 cp carbon lamps in private houses. Consumers were supplied by contract at a rate per lamp pa and generation was only from dusk to midnight.

1892 *"On the Law of Hysteresis"*, paper by Charles Proteus *Steinmetz* to American Institute of Electrical Engineers enlarged on his article in the "Electrical Engineer" of 17 December 1890 "Note on the Law of Hysteresis" in which he indicated that hysteretic loss (consumption of energy) varied as the 1·6th power of the magnetic flux density.

1893 *Superheated steam*—W. H. Patchell, Engineer to the Charing Cross and Strand Electricity Supply Corporation, began the *first* serious application of *superheating of steam* in power station boilers, achieving five per cent better efficiency. Ordinarily steam, as evaporated, contains water vapour in suspension and there is some condensation when it comes into contact with the cold surfaces of turbines. If the steam is heated to a temperature beyond that of its pressure a higher proportion of useful heat can be obtained, it is dry and condensation does not take place.

1893 First section of the Liverpool Overhead Railway (in Liverpool Docks) was opened for traffic this year. Electrically equipped from the beginning it was the *first example of an elevated electric railway* in the world.

1893 *First generation of electricity from town refuse* was demonstrated at Halifax—a refuse-fired Livet steam generator powered a Parsons turbo-alternator of 25,000 candlepower capacity. At Cheltenham in 1895 a new electricity station was built adjacent to the town's refuse destructor taking from it 60–70 hp equivalent of steam. New refuse-fired generation projects opened at Shoreditch in 1897 and at Shipley, Stepney, Beckenham, Accrington, Fulham and Nelson in 1900. By 1905 there were over 40 of them.

1893 *First electric kitchen* displayed at the Columbian Exposition, Chicago. Each appliance was connected to an individual outlet.

1893 *AC polyphase system* invented by Nikola Tesla successfully demonstrated by Westinghouse at Columbian Exposition, Chicago—the first application was a three-phase 4·5 kV line at Hartford, Connecticut.

1893 *Electric spectacles* sold by quack oculists to cure defects in vision pronounced by the profession as hopeless.

1893 *What is electricity?* "The Electrical Review" of 22 December stated that—Maxwell's theory of light presented light and heat as particular cases of the theory of electricity; Lodge suggested that electricity had the nature of a material fluid whose locomotion, rotation or vibration produced electric current, magnetism or light; Poynting thought that electric energy did not flow along a wire, but took short-cuts to it through the dielectric; the elastic solid theory of the ether had failed and Kelvin's labile or froth ether was suggested as a substitute yet the stresses in the ether were not those given by Maxwells theory; Kelvin had given gyrostatic molecule and vortex sponge theories of the ether which in some respects gave a better explanation.

1894 *Electric cooking*—cookers were used for a promotional "all-electric" banquet, organised by the City of London Electric Lighting Co. Ltd. This was the first public dinner cooked by electricity—six large ovens with hot-plates etc. serving 120 guests.

1894 *Time-of-day* tariff proposed by A. H. Gibbing, Electrical Engineer to Hull Corporation.

1894 The *Worcester Electricity Works* opened 11 October with an installed capacity of 400 kW. A unique feature was that two of the three Brush compound vertical engines operated side-by-side with two "Cylinder gate" Victor water turbines of 54 in. producing 211 hp from a head of 12 ft.; also similar turbines of 48 in. and 30 in. for use at times of low water on full power could obtain 125 kW from the alternator. The engines and the water turbines drove four Mordey-Victoria alternators. Worcester Corporation charged 5d per kWh for lighting and 3½d for motive power. A three per cent discount was allowed for an annual bill of £25–£50, five per cent for £50–£100 and 10 per cent for £100 and above. Connection charges were 3s 6d per yard of service line to supply 16 cp 60 W lamps up to 15 lamps for a distance of 50 yards etc. The meter and service switch were supplied on hire at rents ranging from 4s 6d per quarter for 15 lamps to 12s per quarter for 300 lamps.

1894 Forerunner of the *oil-filled pipe type cable* was installed by Johnson & Phillips in Worcester. This type had been developed by David Brooks of Philadelphia from about 1875.

1895 Inauguration of the *Niagara Falls hydro-electric project,* primarily for the production of aluminum by the Hall process. Power generation was at 5,000 V on a two-phase 25 Hz system based on Tesla's polyphase AC concept. In the following year, 1896, three-phase transmission at 11,000 V was initiated from Niagara Falls to Buffalo, 22 miles.

1896 *First geared Parsons turbo-alternator* erected at the Forth Banks power station of the Newcastle and District Electric Lighting Co.—capacity 150 kW, 9,600/4,800 rpm.

1896 A hydro-electric power station commissioned at Foyers in Invernesshire, Scotland, for the British Aluminium Co. Ltd. 5,000 kW of DC generating plant was installed for aluminium production—the *first large scale hydro-electric development in Scotland.*

1896 *First Board of Table regulations* for securing the safety of the public and a proper and sufficient supply of electrical energy included a provision that the variation of pressure at any consumer's terminals from the declared constant pressure should not exceed four per cent. Regulations made in 1905 restricted also the variation from the declared frequency in the case of an AC supply to not more than two-and-a-half per cent. The same limits were included in regulations made by the Board of Trade in 1909. Regulations made by the Commissioners in 1934 altered the permissible variation from the declared voltage to up to six per cent, and in 1937 altered the permissible variation from the delcared frequency to up to one per cent.

1896 On March 1st Henri *Becquerel discovered radioactivity*—with lamellas of potassium uranyl disulphate (prepared 15 years earlier) laid above a photographic plate in two sheets of very thick black paper and put in a dark cupboard the plate darkened strongly and an image (a copper cross) shone out white against black background.
The following year Marie Curie described the phenomenon as radioactivity.

1896 *Incorporated Municipal Electrical Association ("I.M.E.A.")*—the first annual convention held in Brighton, in June.

1896 First issue of the *"Manual of Electrical Undertakings"* compiled by Emil Garcke (*"Garcke's Manual"*). This annual publication ceased with the 1959/60 edition.

1897 *The existence of the electron,* the first of the fundamental particles to be discovered, was *confirmed* by J. J. Thomson in a paper to the Royal Institution on 30 April after 40 years of investigations by physicists into the nature of cath-

ode rays. Thomson showed that cathode rays gave negative charge to a shielded electrode when they were magnetically deflected into it. He calculated the charge-to-mass ratio of his "corpuscles" at about 10^{11} C/kg, confirming Schuster's measurements of 1890, representing a particle a thousand times lighter than a hydrogen atom. The term electron was soon adopted; its value was measured with greater accuracy by Millikan but its spin and magnetic moment were not discovered until a quarter of a century later.

1898 Report of the *"Cross Committee"*—a Joint Select Committee of both Houses of Parliament under the chairmanship of Viscount Cross—which recommended compulsory powers of acquisition of sites for generating stations, even though these were not within the areas of supply; that powers might be given for an electricity supply over an area including districts of numerous local authorities and involving plant of exceptional dimensions and high voltage; and that reversionary purchase rights of local authorities should not apply in the case of bulk supplies. (The *recommendations* were not the subject of legislation until the Electric Lighting Act, 1909—*q.v.*—but they *were used by Parliament in the consideration of Private Bills promoted by "Power Companies"*).

1898 *First "Power Bills"* were promoted for the generation of electricity on a large scale and its transmission at high pressure over wide areas—a feature was perpetual tenure, i.e. no reversionary purchase rights.

1898–1920 *Discovery of the proton*—since the atom has no charge, the negative electron identified by J. J. Thomson in 1897 (*q.v.*) appeared to be neutralised by some positive charge. Positive particles were identified by W. Wein in 1898 and Thomson in 1910 and were found to be equal to the mass of the hydrogen atom stripped of its electron. In 1919 Rutherford bombarded a nitrogen atom with high speed alpha-particles (helium nucleus of two protons and two neutrons) and obtained nuclei of oxygen and of what appeared to be hydrogen (*q.v.*). A year later he accepted this hydrogen nucleus as a fundamental particle, naming it proton, thereby confirming the work of Wein and Thomson. (NB. From c. 1960 scientific research indicated that the proton, as well as the neutron, could no longer be regarded as fundamental particles).

1899 *First lady Member of The Institution of Electrical Engineers* elected on Lady Day—Mrs W. E. Ayrton—notable for her research on the electric arc.

1899 *Electric Lighting (Clauses) Act,* laid down common principles to be incorporated in all Provisional Orders *other than those for within the London area.* The Act also expressly prohibited any amalgamation or association of electricity undertakers, or the supply of electricity outside the prescribed area and made the construction of overhead lines subject to Board of Trade as well as local authority consent.

1899 *Cable Manufacturers' Association ("C.M.A.")* formed.

1900 Several special Acts of Parliament were passed, under which *"Power Companies"* were set up with rights in perpetuity to supply electricity to authorised undertakings and for industrial and manufacturing purposes over wide areas, and to give general supplies in the parts of the areas not already covered by distribution rights. The conditions under which the power company may give a supply are contained in what was known as the *"Kitson Clause"*—which resulted from the deliberations of a Committee of the House of Commons presided over by Sir James Kitson in the Session of 1900, when the first of the Power Bills were being considered. The clause safeguarded the privileges of existing company and local authority undertakers.

1900 *First 1,000 kW turbo-alternators,* with the first tandem turbine arrangement, supplied by Parsons to the City of Elberfeld in Germany. Single-phase current was generated at 4,000 V and 50 Hz.

1900 Rutherford discovered that emanation from thorium lost half its activity in about a minute—*the half-life parameter.* With Planck's discovery of his quantum theory later that year (energy of a quantum = Planck's Constant ($6{\cdot}6 \times 10^{-34}$Js) × frequency) the era of classical physics came to an end.

1900 *First substation attendants*—Early transmission systems from the Wood Lane Station and the Bow Station (1902 *q.v.*) of the Charing Cross and Strand Co., provided HV AC that needed to be converted for customers who preferred DC. Substation attendants supervised conversion by motor generators constantly since there was no automatic voltage control.

1900 Cooper Hewitt *mercury discharge lamp* introduced in the U.S.A. An arc was drawn between electrodes by switching on and then tilting the lamp slowly.

1900 *First three-phase turbo-alternator* in the U.K. and, as far as is known, in the world, built by Parsons for the Ackton Hall Colliery, Featherstone, Yorks—output 150 kW, frequency 40 Hz. The machine was to provide power for coal cutting.

1900 *First public supply of three-phase current:* A supply at 6,600 V and 40 Hz was provided from the *Neptune Bank power station,* built by Charles Merz, and officially opened by Lord Kelvin in 1901. In his speech he said "I don't know what electricity is, and cannot define it—I have spent my life on it. I do not know the limit of electricity but it will go beyond anything we conceive of today". This station, originally owned by the Walker and Wallsend Union Gas Co., was later taken over by the Newcastle-upon-Tyne Electric Supply Co., which *pioneered electric power for industry* in the north east coast heavy engineering area, including some of the leading shipyards. The station, equipped with three reciprocating steam engines each of 800 kW provided the *first example of bulk supply.* In a three-phase system each phase differs by one-third of a cycle i.e. 120° as determined by the arrangements of the windings of the generator (the generator's output is divided into three tranches). As the consumers were supplied AC it was possible to provide a higher voltage to industrial motors and a lower voltage to domestic consumers.
Wood Lane power station, constructed as a joint enterprise by the Kensington Court and Notting Hill companies, started a three-phase supply at 5,000 V—raised after forty years to 6,600 V in accordance with other systems. High tension three-phase AC was transmitted to the company's substations where it was converted to low tension DC by means of motor generators.

1901 Formation of the firm of *Merz and McLellan,* consulting engineers, from a partnership of Charles Merz and William McLellan (late of Siemens).

1901 Formation of the *Engineering Standards Committee* (to become in 1918 the British Engineering Standards Association and in 1929 the *British Standards Institution*).

1901 Stalybridge, Hyde, Mossley and Dukinfeld Tramways and Electricity Board Act. At this time many municipalities were aware of the need for larger areas of supply and this was the *first Private Bill for joint municipal action* to be promoted and passed. (Joint Committees or Joint Boards of two or more local authorities were authorised by the Electric Lighting Act 1909—*q.v.*)

1901 *First prepayment meter* (Long Schattner) approved—for direct current. The first AC prepayment meter approved in 1908 (Aron).

1901 Bradford Corporation, by means of a Private Act, obtained *powers to sell or hire electric fittings or apparatus*—the first undertaking to obtain such powers.

1901 Formation of the *Electrical Contractors' Association ("E.C.A.").*

1902 National Electrical Manufacturers' Association formed—to become, in 1911, the *British Electrical & Allied Manufacturers' Association (Incorporated).*

1902 Parsons supplied for the Neptune Bank power station Newcastle-upon-Tyne a *1·5 MW three-phase alternator* of the revolving armature type, generating at 6,600 V 40 Hz. This machine—the largest size yet manufactured—gave trouble and was replaced by one with a rotating field, a radical change which has never been abandoned.

1902 *Bow station* commissioned to the design of W. H. Patchell, Chief Engineer of the Charing Cross Co. It generated 10 kV AC three phase at 50 Hz without step-down transformers. First plant were 2 × 800 kW and 2 × 1600 kW sets. Bellis & Morcom high speed vertical engines powered the 800 kW sets and horizontal slow speed engines by Sulzer Bros. of Winterthur the 1600 MW machines. A pair of 4 MW generators were added in 1904 and 1905, the largest in the country, each driven by a Sulzer vertical three-cylinder compound engine with an HP cylinder in the centre and a LP on each side, and representing the ultimate in reciprocating engine design. The circulating water was cooled in steel circular towers. Lahmeyer supplied the generators. Boilers were by Richard Hornsby of Grantham, superheaters by McPhail & Simpson. A pair of Hornsby "Upright" type boilers with superheaters were added in 1904 and operated as one unit at a rate of 100,000 lb/h and pressure 160 lb/sq. in. to steam a 4 MW set—the largest boiler in existence. The station fed four substations which provided a DC supply, each with 8·4 MW of motor generators by Lahmeyer and battery plant of 1·6 MW on a four-hour rating. The motors drove 350 kW synchronous generators wound for 400–440 V across the outer wires, and 175 kW induction generators wound for 200–220 V as balancers on the three-wire system. Supply eventually was 2 × 200 V on the three-wire system—*see* plate 11.

1903 *Supply of Electricity Bill* introduced by the Board of Trade. The object was to remove some of the restrictive features of the general Electric Lighting Acts, but the Bill, though re-introduced several times in subsequent years, was not proceeded with in its original form.

1903 *First alternator with a rotating field*—rating 2 MW, 6,000 V, three-phase 40 Hz, installed by Parsons at the Neptune Bank power station. Tesla's rotating magnetic field was to become standard practice in power stations—mechanical energy from steam, internal combustion engines or water power rotated an electromagnet inside coils of wire held in a stationary frame. As the magnet revolved, pulses of electric current were generated in the coils. An electric motor used the same kind of equipment to convert electrical into mechanical energy. By applying a current to a motor's windings two magnetic fields were produced, one in association with the stationary frame and the other with the moving part. The interaction between the two fields caused the moving part to rotate.

1903 Experiments with *pulverised fuel firing* began at the Willesden power station of the Metropolitan Electric Supply Co.—later to become the Acton Lane "A" station. PF firing has advantages of better combustion and higher boiler efficiencies due to the more intimate mixing of fuel and air. Coal is ground in ball mills to a fineness of which some 75 per cent will pass through a 200 mesh sieve (the consistency of face powder) before being introduced to the furnace.

1904 *Carville "A" power station* of the Newcastle-upon-Tyne Electric Supply Co. commissioned. This station, designed by Charles Merz and equipped entirely with turbo-alternators, was *world-famous as the first large generating station of the modern type.* The initial plant comprised 2 × 3·5 MW and 2 × 1·5 MW units, the 3·5 MW units being nearly double the capacity of any turbine which had been made up to that time. This was the first power station to have a *control room.*

1904 Sir Ambrose Fleming patented the *rectifying valve.*

1904 Development of the *Merz Price system of protection* and other methods which led to the safe operation of large *interconnected networks,* the first example being the Newcastle-upon-Tyne Electric Supply Co's system on the North East coast.

1904 The Engineering Standards Committee's "British Standards for Electrical Machinery" resolved inter alia that the *standard frequency for AC* work be 50 periods per second. Standard voltages were also recommended for DC and AC distribution and for tramways.

1904 *First steam railway conversion to electric traction*—first section of Tyneside electrification scheme started on 29 March. Merz and McLellan described it in their 1904 BA paper.

1904 *Dispelling fog by electricity*—Sir Oliver Lodge fed an insulated wire from his laboratory at Birmingham University to a flagstaff on the roof terminating in fine points as widely separated as possible. The base of the wire was connected to the positive pole of a high tension generator and the opposite pole was earthed. It cleared a dense fog of 2 ft. visibility in the immediate vicinity of the points.

1904 Completion of the *electrification of the Liverpool–Southport section of the former Lancashire and Yorkshire Railway,* comprising 83 single-track miles—the first example in the U.K. of main line electrification.

1904 *Geothermal energy*—Prince Ginori Conti installed a reciprocating engine driven by the earth's steam which, coupled to a DC generator, supplied lighting in the Italian town of Larderello, Tuscany.

1905 Start-up of the *Lots Road Power Station,* Chelsea—to supply London's underground electric railways. When built it was the largest in Europe and third largest in the world with 64 Babcock & Wilcox boilers and 8 Westinghouse turbines direct-coupled to three-phase 5·5 MW alternators (33 Hz).

1905 *First turbo-alternators to generate at 11 kV* were supplied by Parsons to the Kent Electric Power Co. for their Frindsbury Station.

1905 *Tantalum lamp* introduced (patented 1901 and 1902).

1905 *Metaclad* compound-filled draw-out type *switchgear* designed by H. W. Clothier and B. Price of A. Reyrolle Ltd.

1905 Formation of the *Incorporated Association of Electric Power Companies* ("I.A.E.P.C.").

1905 Formation of the *London Electricity Supply Association* ("L.E.S.A.").

1905 *London Electric Supply Corpn.* was able to pay its *first dividend.*

c. **1905** A new spinning mill at Pendlebury had 75,000 *electrically driven spindles.*

1905 *Einstein's Special Theory of Relativity.* As long as particles were thought to interact with each other across empty space, according to Newtonian principles, the idea of 'absolute' time was never doubted. This changed with the work of Oersted, Faraday and Maxwell. Electrically charged bodies and magnets were shown to affect each other not directly over a large distance, but by way of the so-called electromagnetic field, a state of tension spreading through space at a finite rate of 300,000 km/s, known to be the speed of light

(c). Maxwell therefore hypothesised that light itself was a form of electromagnetic disturbance. He called the carrier of these EM waves, the 'luminiferous ether' but was never able successfully to endow this ether with the properties required to account for the known properties of EM waves. The ether hypothesis led Michelson and Morley to attempt to measure the motion of the ether on the surface of the earth, in the laboratory. Contrary to expected results the experiments showed that the speed of light measured was the same in all directions. These experimental observations provided the clue for Einstein's theory.

Two physicists, FitzGerald and Lorentz, were able to show, independently, that the Michelson/Morley results could still be reconciled with the idea of the earth travelling through the ether, if one considered that any body travelling through the ether is foreshortened in the direction of travel by a ratio that increases with speed (i.e. acceleration decreases as the body approaches the speed of light). These ideas did not provide a completely satisfactory explanation of the concepts—this came with Einstein's theory. Einstein was able to show that the concept of simultaneity of events being constant, regardless of the frame of reference of different observers, did not hold. This led to reinterpretation of the work of FitzGerald and Lorentz, and discounting of Maxwell's theory of the ether.

The consequences of these findings meant that the relative speed of one frame of reference to another cannot exceed the speed of light, c, if light and other EM phenomena are to travel at the speed c in all directions, in both frames of reference.

The Special Theory of Relativity also leads to the conclusion that the mass of a moving body (m) is related to the mass it would have at rest by a ratio determined by the body velocity and c. This leads to the hypothesis $E = mc^2$ (where E is the kinetic energy) and the idea that energy and mass are equivalent physical concepts and interconvertible.

1906 *Tungsten filament lamps* introduced—based on squirted filaments (Just and Hannaman's process). For the same amount of light it used two-thirds less electricity than the carbon filament. The price of electric lighting had fallen to the price of gas for lighting by about 1886, when the introduction of the incandescent gas mantle substantially reduced the cost of gas lighting. Electricity regained its price advantage with the drawn tungsten lamps available from 1909.

1906 Foundation, in London, of the *International Electrotechnical Commission ("I.E.C.").*

1906 Newcastle-upon-Tyne Electric Supply Co. raised their *mains transmission to 20 kV*—the highest in the country.

1906 London County Council (General Powers) Act, 1906. A clause of this Private Act *empowered Metropolitan Borough Councils to supply electric fittings etc.*

1906 Start-up of the *Greenwich power station* of the London County Council, with four 3,500 kW units to power London's electric tramway system. These were the *last large reciprocating engines* to be installed in Britain. Reciprocating engines were limited to about 500 rpm and although engineers tried to improve their design to achieve a faster speed appropriate for direct coupling to generators, they could not match the new turbines.

1906 Formation of the *Batti-Wallah's Society*—society of electrical engineers, the term Batti-Wallah being the Hindustani for "lamp-man", applied in the early days to sea-going electrical engineers with the P. & O. Line.

1906 Commissioning of the *Cwm Dyli hydro-electric station* of the North Wales Power Co., capacity 2,000 kW, erected to supply nearby slate quarries with three-phase 50 Hz.

1906 *London, Brighton and South Coast Railway* electrified their suburban lines to points 10 miles out of London using 25 Hz AC at 6·6 kV supplied by London Power

Co's Deptford power station. When co's merged to form the Southern Railway the system was converted to DC on 22 September 1929 to enable interrunning.

1906–8 Municipal undertakings brought pressure to bear—unsuccessfully—to include in the Supply of Electricity Bill, originally introduced in 1903, *provision for the sale and hire of apparatus and installation wiring* (Many municipalities already had such powers through Private Acts).

1907 *Dolgarrog hydro-electric* station, North Wales, capacity 5,200 kW opened by the Aluminium Corporation to supply power to its *aluminium works:* taken over by the North Wales Power Co. in 1920.

1907 Lee de Forest of the U.S.A. invented the *triode valve.*

1907 *Electric washing machines* introduced in the U.S.A.

1908 Electricity (Factories Act) Special *Regulations* 1908.

1908 Midland Railway equipped its Lancaster Morecambe and Heysham line to operate at 6,600 V AC 25 Hz single phase—the *first AC railway line* in the country.

1908 *Vacuum cleaners* introduced in the U.S.A. under the title "electric suction sweepers".

1908 *"Regulations for the generation, transformation, distribution and use of electrical energy in premises"* under the Factory and Workshop Acts, 1901 and 1907, S. R. & O., No. 1312.

1909 *Electric Lighting Act, 1909,* which took the place of the Supply of Electricity Bill (promoted in 1903), accepted the need for reorganisation of supply to take account of technical development in generation and transmission. It gave effect to some of the essential recommendations of the Cross Committee of 1898, including *authorising local authorities and companies,* as distinct from "power companies" *to supply electricity in bulk,* and the formation of joint committees or joint boards by two or more local authorities. The Act required the *consent of the Board of Trade for the erection of generating stations.* (This consent is still required as amended by the Electricity Acts 1947 and 1957.)
A clause enabling local authorities to provide electrical appliances was included in the Bill but was dropped because of an amendment in the House of Lords to the effect that local authorities might do this work "through a contractor but not otherwise".
The Act authorised the Board of Trade to make *"fringe" Orders,* that did not require confirmation by Parliament, for the supply by an undertaking to specific premises situated outside their defined area of supply. It prohibited unauthorised undertakers from competing with statutory undertakers. S.23 prohibited unauthorised supply of electricity except where such a supply was not the main business of the company or person providing the supply.

1909 *Improved tungsten filament lamps*—Coolidge in the U.S.A. produced tungsten in a ductile form, by sintering and swaging, enabling it to be drawn into strong tough wire suitable for incandescent lamps.

1909 *Fixed Price Light Co.* formed to supply electricity to working people in parts of London at a fixed price per lamp, depending on wattage, through a load limiter. If a consumer exceeded his agreed load all his lights would flash on and off until he reduced load. Lamps had to be purchased from the company.

1910 *Ferranti's Presidential Address to the I.E.E.* advocated full-scale national electrification to conserve coal, which would be economic if generation achieved 25 per cent thermal efficiency at 60 per cent load factor. Generation would be from 100 stations, each of 250 MW capacity with 10 × 25 MW sets, located close to mines where cooling water was available. Capital costs would be £7/kW for generation, and £13/kW for transmission and distribution. Generating costs would comprise capital 0·0776d/kWh and works costs 0·036d/kWh.

Coal cost of 10s/ton would be reduced by proceeds from the sale of chemical by-products and fertilisers. Electricity prices would be so low that other fuels would not be competitive.

1910 *Steam turbines* now the general form of prime mover.

1911 P. V. Hunter invented the split conductor *protective gear.*

1911 Formation of the *British Electrical and Allied Manufacturers' Association (Incorporated) ("B.E.A.M.A.")* to succeed the National Electrical Manufacturers' Association.

1911 Lord Rutherford formulated his *nuclear atomic theory.* The atom was pictured as consisting of a central positively-charged nucleus, around which negatively-charged electrons revolved.

1911 *First commercial trolley buses,* at Leeds and Bradford.

1911 *Superconductivity*—discovery by Kamerlingh Onnes in Holland of that property of a metal apparently offering no resistance to electric current at temperatures near to absolute zero. It was not until 50 years later, however, that materials could be found that could be employed to operate under conditions required in practice for electrical engineering equipment. The temperature of the conductor determines whether the flow of electrons that constitutes the electric current is relatively chaotic and wasteful or ordered and efficient. Electrons travel randomly at normal temperatures and are very likely to collide with the molecular lattices of the conductor which are also in movement, thus producing friction and heat. This phenomenon, symptomatic of electrons lost, reduces the current transmitted and, therefore, the efficiency of the conductor. If the temperature of the conductor is lowered to near absolute zero the flow of current becomes ordered and efficient. The electrons now move in pairs and can pass easily through the very cold and comparatively immobile molecular lattices of the conductor material, avoiding collisions and heat production. This superconductivity is particularly successful with niobium-titanium alloy.

1912 On 12 December, the Institution of Electrical Engineers appointed a *Research Committee* whose objects would be two-fold—(i) to co-ordinate research and (ii) to originate research.
The Committee's first work (1914) was in connection with magnet steels, the heating of buried cables and the properties of insulating oils.

1912 Parsons installed a *25 MW turbo-alternator* set running at 750 rpm at the Fisk Street power station of the Commonwealth Edison Co. in Chicago. Its steam conditions were normal for the time and it had no revolutionary features beyond its size—the largest yet built in Great Britain.

1912 *Electric refrigerators* introduced in the U.S.A.

1912 *First cross-compound turbo-alternator*—a 6 MW machine built by C. A. Parsons for the Ensenada power station of the River Plate Electricity Co.

1913 *Gas-filled incandescent lamps* introduced by Irving Langmuir of the U.S.A., using inert gas (argon) and having a coiled filament.

1913 Formation of the *Electrical Power Engineers' Association ("E.P.E.A.").*

1913 *Neon lamps* used at a West End, London, cinema.

1914 Foundation of the *Association of Supervising Electrical Engineers ("A.S.E.E.")*, which registered as a trade society in 1918.

1914 *Carville "B" power station* designed by Merz & McLellan commissioned by the Newcastle-upon-Tyne Electric Supply Co. This station, a *great advance in*

design, was laid out for five 11 MW units—the largest it was possible to build at the time for the maximum speed of 2,400 rpm permitted by the 40 Hz supply. The rotors were water-cooled. Steam conditions were 250 lb/sq. in. and 650°F. The station was superior both technically and thermodynamically to anything that had preceded it, and for many years held the record for thermal efficiency.

1915 White Paper *"Scheme for the Organisation and Development of Scientific and Industrial Research"*, Cd. 8005.

1915 The Engineering Standard Committee Report No. 72—*"British Standardisation Rules for Electrical Machinery"* recommended in Clause 14 that the standard frequency for AC machines should be 50 periods per second. (Clause 23 of 1917 edition).

1916 Government established the *Department of Scientific and Industrial Research ("D.S.I.R.")* to deal with proposals for instituting specific researches, proposals for establishing research establishments and the establishment of research fellowships.

1916 *Charles Merz,* in his paper on "Electric Power Distribution" presented at the meeting of the British Association for the Advancement of Science in Newcastle, stated: "What is fundamentally and immediately necessary is the establishment of a *national electric trunk mains distribution system*".

1916 Introduction of *regenerative feed heating*—in the 3 MW Parsons turbine installed at the Blaydon Burn waste heat power station of the Priestman Power Co. To improve further the efficiency of generation boiler feed water was progressively heated by partially expanded steam from the turbine. In addition to the increase of the efficiency by utilising the latent heat of the steam it also reduced the volume of the steam which had to pass through the low-pressure blading, and diminished the work of the condenser.

1916 Joint Committee of the I.M.E.A. and I.A.E.P.C. urged that *generation should be considered as a major national problem* irrespective of the separate issue relating to the area of distribution undertakings.

1916 *Coal Conservation Sub-Committee* (Chairman: *Viscount Haldane*) appointed a *Sub-Committee to investigate the question of electric power supply.* The report (issued in 1918) recommended the re-organisation of generation and main transmission on a regional basis under the central supervision of a *"Board of Electricity Commissioners".*

1916 The Engineering Standards Committee Report No. 77—*"British Standard Electrical Pressures for New Systems and Installations"* recommended for DC 240 V at the consumers' terminals with 480 V across the outer conductors of a three-wire system; and for AC three-phase at the consumers' terminals 415 V between phase and for a four-wire system 240 V between neutral and each phase conductor.

1916 *Electrical Trades' Committee* appointed by the Board of Trade under the chairmanship of *Sir Charles Parsons.* Their report, published in 1918, stated that past electricity legislation had restricted the proper expansion of the supply industry, resulting in electricity areas too parochial and entirely unrelated to the economic area of electrical supply, and hence in the growth of small uneconomical stations. The report recommended that the development of electricity supply should be in the hands of a new and independent *Board of Commissioners* free from political control and *untrammelled by past traditions.*

1916 *National Electrical Contractors Trading Association ("N.E.C.T.A.")* formed to deal with commercial matters affecting electrical contracting. (Ceased to exist in 1970.)

1916 *National Federated Electrical Association ("N.F.E.A.")* formed to deal with industrial relations in electrical contracting industry and to negotiate with the E.T.U. wages and working conditions in that industry. (Ceased to exist in 1970.)

1916 Victor *Kaplan* introduced his *water turbine*—providing cheaper and more efficient generation from lower heads than the Francis turbines.

1917 D.S.I.R. appointed an *Electrical Research Committee* consisting of members nominated by the I.E.E. and B.E.A.M.A. to control the research grants made by the Department.

1917 Board of Trade set up an *Electric Power Supply Committee* under the chairmanship of *Sir Archibald Williamson* to consider what steps should be taken to "ensure that there should be an adequate and economical supply of electric power available for all classes of consumer, particularly industries which depended upon cheap supplies of power for their development". The committee's report, published in 1918, led to the Electricity (Supply) Act 1919—*q.v.* The committee concluded that *concentration of larger generating units in fewer power stations* was urgently required, and that one central authority should be created to regulate generation and distribution of electricity to be known as *"The Electricity Commissioners"*. Generating stations and main transmission lines should be *publicly owned*, the ownership being transferred to District Electricity Boards.

1917 Inauguration of the *Provincial Electrical Supply Association ("P.E.S.A.").*

c. **1917** *Electric washing machines* introduced (U.S.A. in 1907).

1918 *Electric refrigerators* introduced (U.S.A. in 1912).

1918 Formation of the *English Electric Co.*

1918 Reports of the *"Haldane"* Coal Conservation Sub-Committee 1916, the *"Parsons"* Electrical Trades' Committee 1916, and the *"Williamson"* Electric Power Supply Committee 1917—See under years mentioned.

1919 *Negotiating machinery* for agreements on wages and salaries and working conditions in the electricity supply industry—formation of the *National Joint Industrial Council* to cover manual grades, and of the *National Joint Board of Employers and Members of staff* to cover the technical staff.

1919 Ministry of Reconstruction, Advisory Council—*Report of the Committee of Chairmen* on Electric Power Supply* appointed in 1918 under the Chairmanship of *Sir Henry Birchenough.* The committee were asked to submit general comments or suggestions on the broad administrative and commercial issues arising out of the Williamson Report. They recommended that generation and transmission should be a *single unified system with a state regulation and finance.* Means should be found for including distribution as well.

* Haldane, Williamson and Parsons.

1919 *Electricity (Supply) Act, 1919,* based essentially on the Williamson and Birchenough reports, introduced *central co-ordination* by establishing the *Electricity Commissioners,* an official body responsible for securing reorganisation on a regional basis. The Commissioners, whose first Chairman was Sir John Snell, delineated *Electricity Districts* and investigated a number of regional schemes

for centralising generation in a relatively small number of large generating stations owned by Joint Electricity Authorities. But in general this method of dealing comprehensively with the problem was handicapped by the lack of compulsory power.
The Act granted powers to undertakings to hire—but *not* to sell—electrical appliances.

1919 *First large pulverised-fuel fired boilers*—three units at the Hammersmith Borough Council's power station, using the bin-feed system.

1919 *Hydraulic coal delivery* introduced at the Hammersmith Borough Council's power station.

1919 The *first district heating scheme* in the U.K. was completed at Gorton and Blackley, Manchester, but it failed as a result of pipeline corrosion.

1919 *British Electrical Development Association ("E.D.A.")* formed.

1919 Lord Rutherford's experiments on radioactive transformations—he bombarded a nitrogen atom (atomic number 7) with high speed alpha-particles (helium nuclei, atomic number 2) naturally emitted by radium-C (an isotope of bismuth) and obtained nuclei of two other elements—oxygen (atomic number 8) and hydrogen (atomic number 1)—*the first "smashing of the atom"*. In 1932 Cockcroft and Walton were the first to split the atom by artificial means (*q.v.*). Since only about one in every million of the bombarding helium nuclei ever hit the target, the rest passed through the relatively immense space between the target nuclei and its associated electrons. According to Einstein it was "rather like trying to shoot birds in the dark in a country where there were not many birds in the sky".

1919 *First totally-enclosed air-cooling system for alternators*, at Blaydon Burn power station.

1919 *Unified field theory*—of gravitation and electromagnetism suggested by Theodor Kaluza using a 5-dimensional continuum based on geodisic mathematical abstraction adapted to match experimental physical dimensions.

Early 1920's Fritz Winkler developed the first *fluidised bed combustion* system—he obtained a U.S. patent in 1921.

1920 *Screened (Hochstadter or "H"-type) three-core cable* introduced in the U.S.A., where it was patented in 1916.

1920 *Electrification of Railways Advisory Committee* appointed by the Ministry of Transport, with *Sir Alexander Kennedy* as Chairman, recommended that regulations be made on standardisation of methods and equipment.

1920 Incorporation of the British Electrical and Allied Industries Research Association—commonly known as the *Electrical Research Association ("E.R.A.").*

1920 *Regulations relating to extra high voltage.* Under the electricity supply acts 1882–1919 the Electricity Commissioners issued Regulations (Ref. ELC. 13) as to extra high pressure—(a) for securing the safety of the public and (b) for ensuring a proper and sufficient supply of electrical energy. They issued their *first Special Orders* to authorise a supply.

1920 *Oil-filled cable* designed to operate at 80 kV developed by Luigi *Emanueli of Pirelli Co.* The use of oil (or inert gas in the 1930's) under mechanical pressure ironed out voids and permitted higher electrical stress in the dielectric.

1921 Commissioning of the *North Tees power station* of the Newcastle-upon-Tyne Electric Supply Co., engineered by Merz & McLellan, notable as the first to use really *high steam conditions*, i.e. 450lb/sq. in. and 650°F at the turbine stop valve; multi-stage reheat and feed heating, using Ferranti's patents of 1902 and 1906 (Ferranti's outstanding contribution to steam power engineering was the carnotising of the steam cycle by the introduction of step-by-step regenerative feed heating and by the adoption of multiple reheating.)
Reheat enabled higher efficiencies to be obtained without raising steam pressure and temperature, especially in stations operating at high load factors. After expanding part way through a turbine, the steam is again heated to a temperature approaching that at the turbine stop valve. The thermal efficiency of the cycle is improved mainly because of the increase in the average temperature of the total heat input. Single-stage reheat increased station efficiency by 4–5% and reduced exhaust wetness by 50% giving corresponding reductions in turbine blade erosion, condensate pumping power and condenser cooling water requirements. Multi-stage boiler feedwater heating was incorporated and the heat from the flue gases which normally would have been used for heating the feedwater in economisers was used in an air heater to heat the incoming air to the furnace. (Feed heating was already common practice in Lancashire cotton industry boilers). Frequency was 40 Hz for which the highest practicable speed was 2,400 rpm and the largest turbine then mechanically possible at that speed was 20 MW and two were installed each driving 2 × 10 MW sets in tandem. The boilers were similar to the original marine-type water-tube, but the tubes were smaller and the drums of smaller diameter and made of thicker plate. The station consumed less than 2lbs of coal per kWh compared with nearly 4½lbs at Carville (1903). Generation was at 11.5 kV. Design thermal efficiency was 21 per cent. The sets were by Metropolitan Vickers and the ten 37.5klb/h chain-grate boilers by Babcock and Wilcox.

1921 British Engineering Standards Association Report No. 77—*"British Standard Electrical Pressures for New Systems and Installations"* recommended stadard voltages for DC supplies—consumer's terminal 220 V or 440 V and power station or substation terminal 242 V or 484 V respectively. For AC 240 V between neutral and phase and 416 V (sic) between phases with corresponding station pressures of 264 V and 457 V.
Recommended standard high and extra high pressures were—delivered pressures 3 kV, 6 kV, 10 kV, 30 kV, 60 kV, 100 kV, 120 kV and the corresponding station pressures were 3.3 kV, 6.6 kV, 11 kV, 33 kV, 66 kV, 110 kV and 132 kV.

1921 *Water Power Resources Committee* appointed by the Board of Trade in 1918 with *Sir John Snell* as chairman, reported that it was vital that natural resources in Great Britain should be developed, and they proposed schemes providing potential water power of some 270 MW, of which four-fifths related to Scotland.

1921 *Lochaber Water Power Act*, sanctioning the construction of hydro-electric works to be carried out by the Lochaber Water Power Co., a subsidiary of the British Aluminium Co Ltd. It included a Section concerning the *preservation of visual amenity.* The plant was commissioned in 1929—*q.v.*

1921 Inauguration in Paris of the *Conférence Internationale des Grands Réseaux Electrique á Haute Tension—"C.I.G.R.E."*

1921 The first *underground hydro-electric power station*, in Norway.

1922 British *turbine* manufacturers began to adopt *two-cylinder designs* for machines of increasing output at speeds of both 1,500 rpm and 3,000 rpm.

1922 *Grampian Electricity Supply Co.* obtained Parliamentary powers for the construction of important hydro-electric works in Northern Scotland, but these schemes were not immediately proceeded with. (*See under* 1930)

1922 *Electricity (Supply) Act, 1922.* This cleared the financial position of *Joint Electricity Authorities* to enable them to take effective action where they were set up, as regional schemes were agreed. But it restricted their right to give a supply of electricity within the area of a power company.

1923 Electricity supply undertakings brought into membership of the E.R.A. when the Associate Member class was introduced.

1923 *National Register of Electrical Installation Contractors ("N.R.E.I.C.")* incorporated. Superseded by the National Inspection Council in 1956—*q.v.*

1923 *First 220 kV transmission* in the USA.

1924 Electricity Commissioners published their first *Overhead Line Regulations* ELC. 39, based on the recommendations of a committee set up by the I.E.E.

1924 *Lanarkshire Hydro-electric Power Act,* providing for the harnessing of the water power of the Falls of Clyde—i.e. the Lanark hydro stations, commissioned in 1927–1928—*see under* that date.

1924 Women's Electrical Association formed (in 1925 name changed to the *Electrical Association for Women*)—as a result of a paper presented by the Women's Engineering Society at a meeting held in the London home of Sir Charles and Lady Parsons. Caroline Haslett, the Secretary of WES, was the first Director.

1924 First meeting of the *World Power Conference* (from 1968 the World Energy Conference).

1924 Appointment in March of an unofficial *Committee on Coal and Power,* under the chairmanship of *Lloyd George.* The Committee's aim was to make proposals for resolving the difficulties of the interlinked questions of coal and electricity. Their proposals, made in a report on "Coal and Power" issued in July, were the *basis of Government policy,* announced the same month, which included promising the introduction of a Bill to give additional powers to the Electricity Commissioners.

1925 *Severn Barrage Committee*—on 25 October, the Prime Minister appointed a Sub-Committee, under the Chairmanship of Lt. Col. J. T. C. Moore-Brabazon, of the Committee of Civil Research, with the following terms of reference: "To enquire into, and report upon the praticability of a Severn Barrage". (The Committee reported in 1933—*q.v.*

1925 *Electricity supply regulations*—Under the electricity supply acts 1882–1919 the Electricity Commissioners issued Regulations (Ref. ELC.38) (a) for securing the safety of the public and (b) for ensuring a proper and sufficient supply of electrical energy.

1925 Commissioning of the *Barking "A"* power station of the County of London Electricity Supply Co., comprising 4×20 MW and 4×40 MW turbo-alternator sets. The 40 MW size were cross-compound units, one of which was the first Parsons set with reheat. There were to be two other stations—"B" and "C"—on the Barking site; *see under* 1933.

1925 Foundation in Paris of the Union Internationale des Producteurs et Distributeurs d'Energie Electrique (*U.N.I.P.E.D.E.*).

1925 Appointment by the Minister of Transport of the *"Committee to review the national problem of the supply of electrical energy"*, under the chairmanship of Lord Weir. The recommendations of the Weir Committee published in 1926, were embodied in the Electricity (Supply) Act of that year.

1925 London Electricity (No. 2) Act formed the *London Power Company* to purchase the Willesden and Amberley Road power stations and some transmission lines of the Metropolitan Electric Supply Co. and to purchase or lease the stations and main transmission lines of Brompton & Kensington, Charing Cross, Chelsea, London, Metropolitan, Kensington and Knightsbridge, Notting Hill, St James and Pall Mall, Westminster and Central Electricity Supply Cos. With the No. 1 Act it delayed the transfer of ownership of London cos. to the London and Home Counties Joint Electricity Authority until 1971.

1925 First *hyperbolic ferro-concrete cooling tower*—at Lister Drive Station (Liverpool) by Henshaw, capacity 523,000 gals/h.

1925 *Standardisation of supply*—Electricity Commissioners approved a system with three-phase AC of 6.6 kV (or 11 kV, 33 kV, 49.5 kV or 66 kV). Lower voltages could be either AC or DC. Frequency should be 50Hz ± 2.5% ("The London Gazette" 8 May).

1925 The existence of a third particle (in addition to electron and proton), the *light quantum*, experimentally confirmed. Proposed by Einstein in 1905 as a parcel of energy it later become clear it was also endowed with momentum and obeyed the conservation laws. In 1926 it was named *the photon.*

1925 Oliver Heaviside proposed a *unified field theory* in which electromagnetism was correlated with the properties of mass and gravitation for vol. 4 of his "Electromagnetic Theory"; which was never published.

1926 *Unified Field theory*—Oskar Klein expressed Kaluza's (*q.v.*) five-dimensional theory in terms of Hamilton-Jacobi equation. In the 1970's physicists interpreted the Kaluza-Klein theories in up to about seven extra dimensions (metrics).

1926 *Electricity (Supply) Act 1926*, introducing the *first effective national co-ordination.* It provided for the creation of a public corporation, the *Central Electricity Board*, to concentrate the generation of electricity in a limited number of "Selected" stations, and to interconnect these stations, linking up the existing regional system into a national *"Grid"*, by the erection of a high-tension main transmission system. The Act also required the Board to standardise the frequency of alternating current throughout the country, so that effective interconnection could be established; and to supply, either directly or indirectly, local undertakings which required electricity for distribution, and for this purpose to purchase the output of the Selected Stations and sell it to the local undertakings.
A clause conferred full trading powers on those undertakings who did not already possess them.
The "Grid" system, which operated at 132,000 V, was largely completed by the end of 1935. By 1938 the proportion of spare generating plant had been reduced from 80 per cent to about 15 per cent and the resulting capital saving amounted to 75 per cent of the cost of building the "Grid"; and generation costs fell by 24 per cent.

1926 Hochstadter patented the application of gas pressure through a flexible diaphragm, leading to the *compression cable* in 1931—*q.v.*

1926 *First oil-filled cable at 132 kV*—some 36 miles of single-core cable ordered by the New York Edison Co. (First use in the U.K., 1931.)

1926 Invention of the *air-blast circuit-breaker* by W. B. Whitney and E. B. Wedmore. Developed experimentally by the E.R.A. this design was first produced commercially in Germany and Switzerland.

1926 First experimental *hydrogen-cooled alternators* put into service in the U.S.A.

1927 *Railway Electrification Committee* appointed by the Minister of Transport with *Sir John Pringle* as Chairman, endorsed the recommendations of the Kennedy Committee of 1920. As a result of its recommendations the Minister made the Standardisation of Electrification Order 1932—*q.v.*

1927 Foundation at Arnhem of the *N.V. tot Keuring van Electrotechnische Materialen ("K.E.M.A.")*, the Dutch national research and testing laboratories for electrical equipment and appliances.

1927 *"The Design of City Distribution Systems and the Problems of Standardisation"* by J. R. Beard and T. G. N. Haldane, JIEE, Vol. 65. Recommended standard LV distribution by AC three-phase four-wire system, 400 V between phases and 230 V between phase and neutral, based on 11 kV primary distribution.

1927 Appointment by the Minister of Transport in March of the first members of the *Central Electricity Board ("C.E.B.")*, under the chairmanship of *Sir Andrew Duncan.*

1927 *Grid Scheme Areas*—for the purposes of the Grid construction programme, England, Wales and South of Scotland were divided into nine Scheme Areas adopted by the C.E.B. during the years 1927–1930. These Schemes were so designed that they would connect into each other to complete the national plan. The *first* to be adopted was for *Central Scotland* in June 1927. The designs and specifications were by consultants Merz & McLellan, Kennedy & Donkin, and Highfield & Roger Smith.

1927 Sir Archibald Page's Presidential Address to the I.E.E. on 20 October reviewing the development of electricity supply up to 1927 and the main features of the *Grid system.* Published in the "I.E.E. Journal", December 1927.

1927 Electricity Commission—*Report of the Advisory Committee on Domestic Supplies of Electricity and Methods of Charge* appointed by the Electricity Commissioners in 1925.
The committee were to consider what methods of charge for domestic supplies could be authorised as standard methods in place of flat rates. They were unable to recommend exclusive adoption of any of the forms of two-part tariff considered.

1927 Single core *132 kV paper-insulated cable* in commercial use in the U.S.A.

1927 *Electricity Supply Board, Ireland* established by statute to generate, distribute and sell electricity.

1927–28 Commissioning of the *Lanark hydro-stations* on the Falls of Clyde: Bonnington, capacity 9.84 MW, and Stonebyres, 5.68 MW—owned by the Lanarkshire Hydro-electric Power Co.

1928 First *oil-filled cable in the U.K.*—a single-core cable at 66 kV.

1928 *Maentwrog hydro-electric* station of the North Wales Power Co, capacity 24 MW, commissioned.

1928 *First Grid tower* erected near Edinburgh on 14 July.

1928 *Energy storage* by steam storage at the Berlin–Charlottenburg 40 MW/70 MWh power station.

1928 *International X-Ray and Radium Protection Commission* established as a result of consultations between radiologists from various countries—name changed to *International Commission on Radiological Protection* in 1950.

1928 Electricity Commission—*Report of Proceedings of Conference on Electricity Supply in Rural Areas*, convened by the Electricity Commissioners in November 1927.
The Conference appointed two Sub-Committees to report on (i) the nature and extent of the potential demand for electricity in rural areas and (ii) the bearing and general effect upon rural development of the price of supply and the cost of electrical equipment. The reports of the two sub-committees were generally adopted by the Conference.

1928 Electricity Commissioners, after consultation with the I.E.E. and the electricity supply industry, published a new Code of *Overhead Line Regulations*, as ELC 53.

1928 First turbo-alternator to *generate direct at 33 kV*—a Parsons 25 MW unit at the *Brimsdown "B"* station of the North Metropolitan Power Station Co. designed by Captain J. M. Donaldson.

c. **1928** Martin Hochstadter introduced *metallised paper sheaths* over individual cores in 3.3 kV and higher voltage cables to eliminate ionization of air pockets in the dielectric by turning tangential into radial electric stresses.

1929 Commissioning of the *Hams Hall "A" power station* of the Birmingham Corporation planned by Frank Forrest and F. W. Lawton. The installed capacity was 249 MW based on main generating sets of 30 MW and 50 MW with steam conditions 350 lb/sq. in. and 700°F. There were to be two other stations on this site, the "B" station, 321 MW, commissioned in 1942—*q.v.*; and "C", 360 MW commissioned in 1956.

1929 *Galloway Water Power Act*, for developing water power on the River Dee and its tributaries in the Stewartry of Kirkcudbright—the Galloway scheme, which came into operation in 1935—see under that year.

1929 Commissioning of the *Deptford West* power station—adjacent to the historic Deptford East station—being the first major construction undertaken by the London Power Company, based on sets of 50 MW and 35 MW with steam conditions of 350 lb/sq. in. and 780°F.

1929 A. Reyrolle & Co. installed the country's *first short-circuit testing station* at Hebburn-on-Tyne—designed by H. W Clothier.

1929 Commissioning of the *Ardnacrusha hydro plant* on the River Shannon, capacity 100 MW from four generating units, constituting the *Shannon Scheme* of the Electricity Supply Board of Ireland.

1929 *First electrostatic precipitators* to be installed in a power station in the U.K.—at Taylor's Lane, Willesden, owned by the North Metropolitan Electric Power Supply Co. Dust and grit in chimney gas were given a positive charge by means of an electrostatic field and were deposited on a negatively charged screen of wires or other electrodes.

1929 *Lochaber hydro-electric scheme* of the Lochaber Power Co., a subsidiary of the British Aluminium Co. Ltd.—completion in December of the first stage comprising 36.4 MW of plant. Of ultimate capacity 85.75 MW, this was the *first*

large scale water power development in the country to be planned on comprehensive lines.

1929 Formation of *Associated Electrical Industries Ltd. ("A.E.I.").*

1929 Johnstone Wright and C. W. Marshall presented to the I.E.E. on 24 January a paper on *"The construction of the 'Grid' transmission system in Great Britain".* Published in the "I.E.E. Journal", June 1929, this paper gave an outline of the chief constructional features of the high voltage (132 kV) lines of the Grid.

1929 *Heat Pump.* I.E.E. Paper "The heat pump—an economical method of producing low-grade heat from electricity" by T. G. N. Haldane, read before the Institution on 19 December. Included a description of an experimental plant installed in the author's home in Scotland, used for operating the central heating system and for the production of a supply of hot water for domestic purposes.

1929 Four per cent of *rural households* had a supply of electricity.

1920's Two new basic physical forces discovered in addition to gravitational and electromagnetic forces—the *strong force* which binds protons and neutrons together and the *weak force* which is manifested in radioactive or particle-decay processes.

1930 First use of *mercury arc rectifiers* for railway traction in this country.

1930 Electricity Commission—*Report on Assisted Wiring and the Hiring and Hire-purchase of Electrical Apparatus* by a Committee appointed by the Electricity Commissioners in March 1929.
Among their recommendations was that all undertakings who had not hitherto done so should be urged to put into force their powers to provide and sell complete wiring installations on a deferred payment system and provide electrical apparatus to consumers on hire and/or hire-purchase terms.

1930 *Solar sea power*—The French engineer Georges Claude attempted to build a 40 kW ocean—heated engine off Cuba to produce electricity through a "boiler" operating in the warm ocean surface layer and a "condenser" in the colder lower layers—described in "Mechanical Engineer", vol. 52, p 1039.

1930 Inauguration of first Grid scheme—the Central Scotland Electricity Scheme—on 30 April. Herbert Morrison, the Minister of Transport, closed a switch to energise a 132 kV line from Portobello power station.

1930 *Research* by the electricity supply industry—the beginnings on a *national basis,* with the establishment by the C.E.B. of laboratories at Croydon and Waddon to investigate *HV transmission problems.*

1930 Electricity Commission—*Report on Uniformity of Electricity Charges and Tariffs* by a Committee appointed by the Electricity Commissioners on the 16 March 1929.
Committee recommended legislation to make it compulsory for undertakings to offer *two-part tariffs* as an alternative to flat rates with variations based on size-of-house.

1930 *Oil-circuit breakers*—invention of the side-blast baffle arc-control pot, generally known for short as the *baffle switch,* by W. B. Whitney and E. B. Wedmore. Developed experimentally by the *E.R.A.,* this formed the basis of most modern designs of high-voltage oil circuit breakers.

1930 Electricity Commission—*Rural Electrification.* Description of *Bedford Demonstration Scheme.*

1930–33 Commissioning by the Grampian Electricity Supply Co. of the Loch Rannoch (48 MW) and *Tummel Bridge* (34 MW) *hydro-electric stations.*

1930's *Germany—Honnef planned gigantic wind generators* with towers several hundred metres high and an electrical output of 20 MW—but none was realised.

1931 Completion of the construction of the *first Grid Scheme.*

1931 Electricity Commission—*Rural Electrification.* Description of *Norwich Demonstration Scheme.*

1931 Electricity Commission—*Statement by Minister of Transport at Conferences with Electricity Undertakers, 1931.*
As part of the Government's efforts to stimulate economic development and employment, the Minister addressed a series of conferences at each of which he made the following appeal:
"I would like strongly to endorse the views which have been expressed by the Commissioners that undertakers who have not yet done so *should institute schemes of assisted wiring* and of hiring or *hire-purchase* of apparatus, establish *showrooms* and adopt an active publicity campaign."

1931 *Oil-filled cable*—runs of 132 kV single core and 66 kV three-core installed by the C.E.B. By the following year, the latter cables were being extensively used.

1931 Ministry of Transport—*Report of the Committee on Main Line Electrification.* Appointed in 1929 under the chairmanship of *Lord Weir,* the Committee reported in favour of large-scale electrification and estimated that a return of about 7 per cent could be shown on a capital expenditure of some £261 M on the necessary track equipment, traction etc.

1931 *Faraday Centenary Exhibition* in London.

1931 English Electric Co. installed the first *"topping turbine"* at the Valley Road, Bradford, power station—a unit of 2·5 MW, 6,000 rpm, steam conditions 1,100 lb/sq. in. and 800°F exhausting to the existing steam mains at 205 lb/sq. in.

1931 *Electricity Board for Northern Ireland* formed to co-ordinate generation and transmission and to advance development throughout Northern Ireland.

1932 Sir John Cockcroft and Dr E. T. S. Walton achieved the *first artificial splitting of the atom.* They used protons to bombard lithium, resulting in the formation of helium. This inaugurated the era of "atom smashing".

1932 *The neutron* identified by James Chadwick—by bombarding beryllium with alpha particles he obtained an unknown radiation that was able to penetrate the nuclei of various substances, causing protons to be ejected from them. For this to be possible the unknown particles had to be neutral otherwise they would have been deflected by the electric forces in the atom. The particle was called the neutron at the suggestion of Lord Rutherford—he described it as "like an invisible man passing through Piccadilly Circus: his path can be traced only by the people he has pushed aside". The neutron was found to be a most valuable missile for bombarding nuclei to produce transmutation of elements. Heisenberg's Uncertainty Principle (1927) meant that the presence of the electron in the nucleus seemed unlikely – with the small volume of the nucleus the indeterminacy lay in the momentum of the electron which could be far too energetic to remain in the nucleus for more than a fraction of a second. The discovery of the neutron meant that the electron could be assumed to be outside the nucleus and that quantum mechanics provided a plausible description of the nucleus. The electron, proton and neutron provided a simple model

of the world until other sub-atomic particles were discovered from 1945 using particle accelerators.

1932 World's first pipe line *compression cable*—a 2½ mile length of three-core nitrogen-filled 66 kV cable between Hackney and Walthamstow, London—based on the Hochstadter patent 1926, for the application of gas pressure through a flexible diaphragm.

1932 *"An Analysis of the Costs of Electricity Supply, and its Application in Relation to Various Types of Consumers"* by E. H. E. Woodward and W. A. Carne was presented to the I.E.E. on 14 April. At a discussion at the North Midland Centre, Leeds on 6 December, J. N. Waite, City Electrical Engineer of Hull, produced a table of data collected around 1928 which related to domestic electrification of an estate of 500 working class houses each equipped with one coal fire and boiler, electric cooker, washboiler and lighting with a total connected load of 8·6 kW. The data showed that the maximum demand on generation peak was 0·2 kW per house, corresponding to a diversity of 43 and that an average annual consumption of 1,140 kWh per house corresponded to a generation peak load factor of 65·25 per cent. Waite concluded that the data showed that domestic electrification for a smaller house was a practical and economic proposition and that there could be no doubt that a low tariff was justified for domestic electrification. This perpetuated a myth that on grounds of diversity cheap electricity could be justified for domestic consumers. However, the results were based on a biased sample because each house had a coal fire and back boiler which might be a combination cooking range so that the electric cooker would not be used in the winter. Utilisation research by the Electrical Research Association and the B.E.A and C.E.A. pioneered by *P. Schiller* indicated that the peak demand of domestic consumers rose proportionally to their consumption and that it was sensible to increase kWh charges so that they contributed to financing the new plant which increasing sales required. A major problem was domestic space heating, the economics of which was presented in the report on the "Characteristics of the Space Heating Load" presented by an Electricity Council Working Party in February 1964 (*q.v.*).

1932 *Metalclad principle first applied to 132 kV working*—C.E.B.'s two-switch 132 kV substation at Tongland, Kirkudbrightshire.

1932 *The Labour Party* issued a *Policy Report* outlining their proposals for the *nationalisation* of the electricity supply industry, i.e. bringing the industry under full public control by means of a National Electricity Board advised by a National Consultative Council of consumers, local authorities and labour. Another argument for nationalisation was published (by "G.H.") under the auspices of the New Fabian Research Bureau.

1932 *Thames 132 kV grid crossing* between Dagenham and Woolwich completed. The towers, of height 487 ft., were the highest on the grid; the span between towers was 3,060 ft.

1932 *Railway electrification.* Standardisation of Electrification Order 1932 permitting only the 1,500 V DC system with overhead current collection and a lower voltage system of 750 V DC with conductor rail, as general standards for main line operation.

c. **1932** *Lighting*—high pressure mercury and low-pressure sodium lamps introduced for street lighting.

1933 Commissioning of the *Barking "B"* power station. With the completion of this station in 1940, with 4 × 75 MW turbo-alternator sets, the total capacity on the site reached 540 MW—the highest in Europe. A third station—"C"-comprising 3 × 75 MW units was commissioned in 1952.

1933 *Report of the Severn Barrage Committee* of the Economic Advisory Council set up by the Prime Minister in 1925 under the chairmanship of Lieut. Col. J. T. C. Moore-Brabazon. The committee's investigations of the technical possibilities and merits of a barrage indicated there was a balance of advantage in such a scheme. (The conclusions of the committee were reviewed in a report dated 1945—*q.v.*)

1933 Commissioning of *Battersea power station*, built by the London Power Co. to the design of *Sir Leonard Pearce* for the main purpose of supplying the central and western areas of London. The architectural features were to the design of *Sir Giles Gilbert Scott* and the station was popularly referred to as a *"cathedral of power"*. "Battersea" was planned as two separate stations "A" and "B". The steam conditions of the "A" station were 600 lb/sq. in. and 830°F, the plant comprising two turbo-alternator units each of 69 MW and a third of *105 MW—the largest set then operating in Europe.* Smoke proved a major problem and the London Power Co. were obliged to install costly gas washing plant so that, despite its high efficiency, it was one of the more expensive stations supplying the "Grid".
The "B" station commissioned in 1944 (*q.v.*).

1933 Commissioning of *Dunston "B"* power station of the North Eastern Electric Supply Co. (formerly the Newcastle-upon-Tyne Electric Supply Co.). Designed for six 50 MW turbo-alternator sets working on the re-heat principle with initial steam conditions of 600 lb/sq. in. and 800°F, this station ranked consistently *among the leading stations in the country* both in respect of thermal efficiency and cost per unit.

1933 A watershed area covering parts of seven States in the U.S.A. was put under a Federal-controlled authority—the *Tennessee Valley Authority (T.V.A.).*

1933 The *last* of the original 132 kV *'Grid' towers* was erected at Fordingbridge, Hants. on 5 September.

1933 *C.E.B. commenced normal trading* in the Central Scotland and Mid-East England Areas. The *"Grid" tariff* embodied a service charge in respect of the second and each additional point of supply, a charge per kW of maximum demand progressively reduced as maximum demand increased beyond "basic demand", and adjusted according to power factor and changes in local authority rates, and a running charge per kWh sold that varied with the price of coal.

1933 *"E.L.M.A."* developed out of the Electric Lamp Manufacturers' Association of Great Britain Ltd.

1933 C.W. Marshall presented to the I.E.E. on 9 November a paper on *"The lower voltage sections of the British grid system"*, published in the "I.E.E. Journal" February 1934. The paper dealt with the main constructional features of the 66 kV and 33 kV lines.

1933 The *hertz (Hz)* as a replacement for cycles per second approved by the International Electrotechnical Commission—it was accepted by the Bureau International des Poids et Mèsures in 1960.

1933 *30 per cent of households were connected* according to Kennedy and Noakes.

1934 *Production of coiled-coil filament lamps* began—for small domestic lamps they were 20 per cent more efficient.

1934 Borough of Fulham Electricity Department promoted *free all-electric kitchens* offering a cooker, wash boiler or water heater and an electric iron installed, fixed, wired and maintained free of charge.

1934 *Completion of the* construction of the initial *Grid* system at 132 kV.

1934 *Moderation of neutron velocity*—by 1934 radioactivity could be induced by neutron bombardment and it was discovered that the effect could be increased by reducing the velocity of the neutrons. Enrico Fermi put a neutron source and target element down on a table and the disintegration rate went up—fast neutrons had been slowed by collisions with hydrogen atoms in the wood of the table and were more efficiently captured by the target atoms. He also found that when uranium was bombarded by neutrons several subatomic particles were formed. Fermi thought that these products were artificial elements similar to uranium.

1934 *Power blackout*—on Sunday 29 July, when some Grid lines were out of service for maintenance, a 69 MW set at Battersea and two 35 MW sets at Deptford West tripped out. Thirteen other stations on the 132 kV rings took up 90 MW for 15 minutes until a third set at Deptford switched out. This overloaded the lines out at Barking. The Sunday disposition of generating plant had not allowed for the loss of two major stations and the consequent cascade tripping resulted in the disruption of supplies in a large part of the South East England Grid Area for up to two hours.

1934 *Van de Graaf electrostatic generator* capable of developing 10 MV completed at the Round Hill Research Station of Massachussetts Institute of Technology.

1935 *First fluorescent lamps* demonstrated in the U.S.A.

1935 *Galloway hydro-electric scheme,* based on the River Dee and its tributaries in the Stewartry of Kirkcudbright, in commercial operation. The total installed capacity planned was 103·25 MW from five stations—Tongland, Glenlee, Earlstoun, Carsford and Kendoon.

1935 *Electricity (Supply) Act 1935* empowering the C.E.B. to enter into *arrangements with owners of non-selected stations* concerning their operation under directions of the Board for peak load and standby purposes.
Another clause gave effect (in part) to a recommendation of the Weir Committee on Main Line Electrification by empowering the C.E.B. to give *supplies direct* to any railway company *for traction purposes.*

1935 *Grid in full commercial operation* from 1 January throughout the country with the exception of North-East England, and South Scotland—and of the North of Scotland, for which no Grid scheme was contemplated.

1935 Formation of *London Associated Electricity Undertakings Ltd.* as a merger of six companies.

1935 *Electroslag refining process* for melting metals—invented by R. K. Hopkins in the U.S.A.; but industrial development was delayed for over twenty years.

1936 *Fulham* power station commissioned. Engineered by W. C. Parker, the total installed capacity was 360 MW from six 60 MW turbo-alternator sets, steam conditions 600 lb/sq. in. and 800°F, this station returned the *highest thermal efficiency of any power station in the country in 1948.* At these steam conditions one pound of steam occupies just over one cubic foot of space at the inlet of the turbine, but at the exhaust end, after expansion through the turbines, the same weight occupies some 650 cubic feet.

1936 *Report of the Committee on Electricity Distribution,* appointed by the Ministry of Transport, under the chairmanship of *Sir Harry (later Lord) McGowan.*
Committee *recommended legislation to give adequate compulsory powers for reorganisation* based on the absorption by the larger and more efficient undertakings of the smaller and less efficient. Whilst they considered that there were not adequate grounds for immediate regional reorganisation

under public control, they suggested that provision should be made in the *new schemes to be prepared for the possibility of ultimate public ownership of all undertakings*, including those not then subject to purchase by local authorities. In developing this approach they envisaged consolidation of undertakings under existing power companies and ultimate purchase, after not more than fifty years, by some form of public authority. To set such a reorganisation in motion they suggested the setting up of Advisory Committees representing the undertakings in each area, under a District Commissioner who would have the duty of preparing the schemes for submission to the Electricity Commissioners.

1936 Eugene Paul Wigner's theory of neutron absorption—in a crystal lattice atoms are displaced when bombarded with neutrons and its shape and dimensions change. Some of the energy lost by the neutrons is stored in the lattice e.g. graphite in a reactor—known as *Wigner energy*.

1936 World's first commercial installation of *220 kV underground cable*—in Paris, comprising 11 miles of three single-core oil-filled cables in concrete troughs.

1936 *Electricity Supply (Meters) Act*, which started as a Private Member's Bill introduced by a supply association, made better provision for the *certifying and examination of electricity meters* by competent and impartial Meter Examiners appointed by the Electricity Commissioners. Meters had to be constructed to a pattern approved by the Commissioners. They would not approve commutator ampère-hour and watthour meters, single-phase meters with two current windings for single-phase three-wire circuits, single-phase meters with two current windings for three-phase three-wire circuits, double circuit or "power and light" meters, and two element three-phase four-wire meters. In 1937 the Commissioners prescribed limits of error not exceeding 2½ per cent plus or 3½ per cent minus at any load.

1936 P.E.P. (Political and Economic Planning) issued a report on *"The Supply of Electricity in Great Britain"*, putting forward proposals for the re-organisation of distribution largely coinciding with those of the McGowan Committee.

1936 *Boulder Dam* hydro-electric scheme in the U.S.A. commissioned—designed for ultimate capacity 1,217 MW, based on 115,000 hp turbines.

1936 During a day in November *six Grid Areas were run in parallel to form a single interconnected system*—maximum demand 4,218 MW supplied by 112 power stations controlled directly by C.E.B. control rooms. In addition 45 other stations, outside C.E.B. control, were linked to the Grid—the largest number of stations ever operated in parallel. There was no difficulty in synchronisation.

1937 Electricity Commission issued two papers relating to the *Electricity Supply (Meters) Act 1936*, viz:

(i) *Explanatory Memorandum* concerning the testing of electricity meters; the apparatus approved for use in Meter Testing Stations; and the procedure contemplated by the Electricity Commissioners in connection with the certification of meters.

(ii) *Approved Apparatus for Testing Stations.*

1937 *Minister of Transport* announced that the Government had decided to adopt in principle the main recommendations of the McGowan Committee, subject to certain modifications in detail, and a memorandum on *"Electricity Distribution—Outline of Proposals"* was issued, as a basis of discussion with representative associations.

One of its proposals was that the Electricity Commissioners should themselves review each District and prepare schemes for consolidation into groups, instead of delegating that duty to District Commissioners, as envisaged in the McGowan Report. Provisional groups of undertakings in the sug-

gested Distribution Districts were set out. The recommendations were not, however, implemented before the war.

1937 *Hydrogen-cooling* of alternators coming into general use in the U.S.A. (The first hydrogen-cooled alternator in Great Britain was a 60 MW set installed in the Littlebrook "B" power station in August 1949.)

1937 Electricity Commission issued their *"Electricity Supply Regulations 1937*, for securing the safety of the public and for ensuring a proper and sufficient supply of electrical energy"—also *"Explanatory notes on the Electricity Supply Regulations 1937"*.

1937 *Gas-filled cable* system developed by C. J. Beaver and E. L. Davey of W. T. Glover & Co.—first commercial use at 33 kV and field trials by C.E.B. at 132 kV.

1937 *All Areas of the Grid first coupled together as a single unit* on 29 October for several hours. Previously, limited use of inter-Area tie lines between pairs or trios of Areas had been made for small-scale power transfers e.g. excess hydro from Scotland to N W England or for mutual assistance during temporary generation or transmission shortages. From the beginning of March 1939 inter-Area operation became normal practice.

1937 *"Electrical Thermal Storage"* by F. I. Campbell and W. C. Parker, presented to I.M.E.A Convention, suggested that off-peak storage by means of electrode-boilers could compete with cheap coal for central heating. For a typical undertaking the load factor would improve from 51 per cent to about 55 per cent.

1938 *Nuclear fission* discovered by the German chemist Otto Hahn and radiochemist Fritz Strassmann by bombarding uranium (atomic number 92) with neutrons. They were able to show that one of the products was a radioactive form of the much lighter element barium (atomic number 56), indicating that the uranium had split into two lighter atoms. The Austrian physicist Lise Meitner and her nephew Otto Frisch formulated a plausible explanation of the process which they called "nuclear fission".

1938 *Association of Short-Circuit Testing Authorities ("A.S.T.A.")* formed—a co-operative association of short-circuit testing stations.

1938 E.R.A. were asked to prepare a specification for *"light rural lines"* with a view to submitting the proposal to the British Standards Institution, so that a complete specification could be prepared. (This resulted in B.S. 1320–1946 "High voltage overhead lines on wood poles for line voltages up to and including 11 kV".)

1938 Commissioning in December of *pioneer high pressure plant at Brimsdown "A"* power station of the Northmet Co., operating at steam conditions of 1,900 lb/sq. in. and 930°F on a reheat cycle. The two boilers were of the Loeffler forced-circulation type, capacity 210,000 lb/h continuous maximum rating.

1938 Arrangements were perfected by the C.E.B. for establishing a *National Control* organisation at the Bankside control room in London and during the latter part of the year the Grid in all the nine areas was *normally operated as one interconnected system.* From the beginning of the war it has been continuously operated as a single unit.

1939 *Nuclear power*—work by Joliot in France, and by Fermi and Szilard in America, indicated that it was almost certain that a *nuclear chain reaction* in a large mass of uranium could be achieved in the near future.

1939 In January the decision was taken to establish a *national reserve* of switchgear, transformers and ancillary equipment as a *precaution against war*

risks. The cost was estimated at £3M—the Government to undertake half of this liability, the C.E.B. being authorised to borrow the remaining half.

1939 Early in the war, a *Joint Committee of Electricity Supply Undertakings* was set up, representing both company and municipal undertakings. The immediate object was to enable undertakings to keep in touch with one another in *dealing with common problems resulting from the war.*

1939 Presidential Address to the I.E.E. by Johnstone Wright, on 26 October, dealing with the *construction and operation of the Grid,* published in "I.E.E. Journal", January 1940.

1939–1941 *Fuel Efficiency Committees:*
Government appointed, in succession, three Committees to report on measures for effecting economies in fuel under war conditions, but the reports were unpublished, viz:

Home Produced Fuels, Chairman *Sir William Bragg,* appointed September 1939

Efficient Use of Fuel, Chairman *Sir Clement Hindley,* appointed February 1940

Efficient Use of Fuel—Second Committee, Chairman *Dr E. S. Grumell* appointed September 1941, "to review the recommendations of the 1940 Committee . . ."

The two latter Committees led to the setting up of twelve *Regional Fuel Efficiency Committees* and the recruitment, on a part-time basis, of voluntary engineers from industry to give specialist advice to factories on plant maintenance and operation.

1940 Twenty-sixth Thomas Hawkesly Lecture by *Sir Leonard Pearce* on *"A Review of Forty Years' Development in Mechanical Engineering Plant for Power Stations"*, presented to the Institution of Mechanical Engineers on 10 January. Published in "I. Mech. E. Proceeding" Vol. 142, 1939.

1940 *First gas turbine* for public electricity supply commissioned at Neuchatel, Switzerland.

1940 *Electricity Commissioners,* in July in agreement with the *C.E.B.* recommended an *emergency programme of new generating capacity, to minimise war risks* and to deal with the rapid growth of load in the North West England and North Wales and the South West England and South Wales Grid Areas consequent upon the concentration of new munitions factories in those areas.
The programme provided for the installation of about 180 MW of plant divided between four existing selected stations and two new selected stations—Earley and Castle Meads, referred to under 1942—so as to spread the risks due to possible war damage.

1940 *Merz-Price* discriminative balanced *protective gear* introduced on the Grid system.

c. **1940/42** *Fulham power station produced war equipment* on its machine tools outside maintenance periods. Employees of Borough of Fulham Electricity Department were assisted by women taken on and trained for the work.

1940-43 *Kleinheuz designed wind turbines* in collaboration with Maschinenfabrik Augsburg—Nurenburg (M.A.N.) but the war prevented its realisation.

1941 U.S.A.—*Palmer C. Putnam* built a *1250 kW wind turbine* which supplied electricity to the public network from 1942–1945.

1941 Government's war-time Production Executive, in March, took the view that *C.E.B.'s programmes for new generating plant* to commission in 1943 and

1944 were not necessary to the war effort and *withdrew the priorites* formerly granted.

1941 *"Use of Uranium as a Source of Power"* and *"Use of Uranium for a Bomb"* were reports submitted in July to the Ministry of Aircraft Production by the Maud Committee (Maud was a code name), a sub-committee of the Committee for the Scientific Survey of Air Warfare, set up in April 1941 with Professor Sir George Thompson as Chairman. They reported that the large-scale separation of uranium isotopes by gaseous diffusion seemed feasible based on research by Professor Simon at Oxford and Professors Peierls and Haworth at Birmingham. The project was taken over by Directorate of Tube Alloys in 1942.

1941 Functions of the *Ministry of War Transport* in relation to *electricity* were transferred in September to the *Board of Trade*, which had administered the various statutory electricity provisions prior to the Electricity (Supply) Act 1919.

1941 *Battersea "B"* power station—commissioning of the low-pressure unit of 84 MW of the 100 MW cross-compound turbo-alternator set—see under 1944.

1942 *Ministry of Fuel and Power* formed in June, taking over the responsibilities of the Board of Trade in relation to the control of electricity, along with that of gas, coal and other fuels.

1942 Commissioning of *Hams Hall "B" power station* of the Birmingham Corporation, designed for an installed capacity of 321 MW, based on main generating sets of 50 MW, with steam conditions 650 lb/sq. in. and 825°F. This station returned the *highest thermal efficiency for the country in 1947.*
With the completion of the "B" station, the two stations on the site represented the *greatest concentration of generating plant in Europe.* A third station on the site, Hams Hall "C", 360 MW commissioned in 1956.

1942 The *Committee on Land Utilisation in Rural Areas* reported (Cmd. 6378) (Chairman Rt. Hon. Lord Justice Scott). Recommended inter alia the reorganisation of electricity distribution so that a parity of cost between town and country could be achieved without increasing the burden on the town; standardisation of supplies, fittings and regulations; the rationalisation of supply areas; and extensive rural electrification.

1942 Commissioning of the two *"war emergency" power stations* in December, viz:
Earley near Reading, *owned by the C.E.B.* and operated by Edmundson's Electricity Corporation. This station, the only one owned by the C.E.B., comprised 2 × 40 MW turbo-alternators, the first of which had originally been ordered for an undertaking in South Africa. "Earley" was in *commercial operation in 22 months* after the start of the work on site.
Castle Meads, owned by the Gloucester Corporation, comprising 2 × 20 MW turbo-alternator sets. Sanctioned in 1940, the first set went on load almost exactly two years after the start of the work on site.

1942 Report of the Committee on *Hydro-Electric Development in Scotland*—Chairman, *Lord Cooper*—presented to Parliament in December and published as Cmd. 6406, 1943.
The main recommendations were that a North of Scotland Hydro-Electric Board should be created to be responsible for initiating and developing all future generation of electricity in the northern area for public supply and its transmission and supply in bulk to the existing undertakers. It should further be responsible for generation, transmission and distribution in all areas outside the limits of existing undertakers.

1942 Joint Committee of Electricity Supply Organisations were asked by the Minister of Fuel and Power to make recommendations on the *future constitution, control and management of electricity supply.*

1942 The realisation that all matter consisted of energy meant that all massive particles might be broken down into particles of energy. When the structure of the atom became clear it was found that the mass of the nucleus was always less than the sum of the masses of its constituent particles, and this difference was called the *'mass defect'*. According to Einstein, mass and energy are related by the equation $E = mc^2$, where E is energy; c is the velocity of light (3×10^8 metres per second); and m is the mass change. Therefore, because c^2 is a constant, the mass defect observed is equivalent to an energy loss which occurs during the formation of the nucleus. Conversely an amount of energy equal to this energy loss would be required to break up the nucleus into its constituent nucleons, in order to re-establish the higher total mass of the individual nucleons—the energy equivalent of the mass defect is known as the *nuclear binding energy*. If a heavy nucleus is split into two nuclei each has a greater binding energy per nucleon than the original heavy nucleus and their total binding energy is therefore greater than the total binding energy of the original. The total mass of the two nuclei is less than the mass of the original and because mass and energy are equivalent this loss of mass appears as a release of energy, mostly in the form of kinetic energy of the fission products. This kinetic energy is immediately converted into thermal energy by collisions with neighbouring nuclei which can be achieved in a facility in which nuclear fuel is assembled for the purpose of supporting a sustained, controlled chain reaction—known as a *nuclear reactor.* The *world's first nuclear reactor* started up in Chicago on 2 December. Enrico Fermi achieved a controlled chain reaction by striking a target nucleus, uranium–235, with a low energy neutron, emitting two or more neutrons to initiate further fission. Low energy neutrons (about 0·025 eV) are most effective for producing fission in uranium–235, and the energy of each of the fission neutrons, about 2·5 MeV, was reduced ("moderated") to the required level by the use of graphite i.e. slowed down from 12,000 miles per second to four miles per second so that the neutron can spend more time in the vicinity of the nucleus and increase its chances of being absorbed. Like Fermi's reactor, the first British commercial reactors used natural uranium as fuel and graphite as the moderator.

1943 Publication on 20 January of the Hydro-Electric Development (Scotland) Bill leading to the *Hydro-Electric Development (Scotland) Act 1943*, making provision for the establishment of a public corporation called the *North of Scotland Hydro-Electric Board*, as envisaged by the Cooper Report of 1942—*q.v.* The first Chairman of the N.S.H.-E.B. was the Rt. Hon. The Earl of Airlie.

1943 *First three-core 132 kV cable* in the world—a mile and a quarter length of *impregnated gas pressure cable* manufactured by the Callender Co. put into service by the C.E.B. at Burford, Oxon.

1943 *River Liffey Scheme* of the Electricity Supply Board of Ireland—comprising three hydro-electric stations at Pollaphuca (30 MW), Golden Falls (4·24 MW) and Leixlip 4 MW); Golden Falls commissioned at end of 1943 and the whole Scheme was completed in 1949.

1943 *Future development of the grid system*—to reduce to the minimum the delay in putting a new construction programme in hand after the war, the C.E.B. gave preliminary consideration to the future *use of higher voltages* than 132 kV. (The 1946 Annual Report of the C.E.B. indicated that they were then thinking in terms of *264 kV*).

1943–44 *Proposals for the reorganisation of electricity supply*—put forward at the request of the Minister of Fuel and Power by individual undertakings, trade associations, and staff associations, viz.—the London and Home Counties J.E.A., Conference of Joint Electricity Authorities and Joint Boards, the E.P.E.A., the I.A.E.P.C., the I.M.E.A. and the Joint Committee of Electricity Supply Undertakings. For the most part, attempts to secure agreement on a common policy for the industry as a whole broke down owing to *disagreement over the question of ownership.*

—A *London Electricity Board* was proposed by the General Purposes Committee of the *London & Home Counties Joint Electricity Authority* to absorb the 75 undertakings in the London & Home Counties District.
—*Electrical Power Engineers Association* Report 'Post War Planning for the Electricity Supply Industry' proposed a *National Electricity Supply Board* to take over the C.E.B., generating stations and distribution as a public service.
—"The Electricity Supply Industry: Memorandum on the Ownership of Distribution Undertakings, Ownership of Generating Stations and National Bulk Supply Tariff"; by the *Incorporated Municipal Electrical Association* recommended that in distribution *local authority ownership should be extended, power stations should be owned by the C.E.B.* and there should be a national standard B.S.T. with a sliding scale kW charge related to demand and a running charge per kWh with fuel cost variations.

1944 *Geothermal energy.* Italian geothermal capacity reached 136 MW, but equipment destroyed in this year. New developments after the war started up again in 1956 in the Larderello field, Tuscany.

1944 *"Electricity Supply: Distribution and Installation"*—report by the Post War Planning Committee of the I.E.E. recommended system standardisation by means of a four-wire, three-phase, 400/230 V system. It indicated that in 1939, 74 per cent of urban dwellings were on the supply, 50 per cent of rural dwellings and about 35,000 farms.

1944 Electricity Commissioners and Secretary of State for Scotland approved the *North of Scotland Hydro-Electric Board's development scheme*, which listed 102 projects.

1944 Electricity (Factories Act) *Special Regulations* 1944.

1944 First commercial *cyclone-fired boiler*—installed by Babcock and Wilcox at the Calumet power station, Chicago, U.S.A.

1944 Commissioning of the *first section* of the *Battersea "B"* power station, consisting of a *100 MW cross-compound set*—comprising a 16 MW *high pressure unit (1,350 lb/sq. in.) exhausting to a twin-cylinder 84 MW secondary unit.* The second and third sections comprised a 60 MW machine with hydrogen-cooled alternator (1951) and a further cross-compound machine of 100 MW (1953) of similar design to that of the first section.

1944 The *Fuel and Power Advisory Council* (Chmn. Sir Ernest Simon) appointed by the Minister of Fuel and Power to consider and to advise on questions concerning the development and utilisation of national fuel and power resources.

1944 *First large-scale* general purpose electronic *computer* (E.N.I.A.C.) designed at the Moore School of Electrical Engineering, University of Pennsylvania.

1945 *P.E.P.* (Political and Economic Planning) published *"The Market for Household Appliances"* which considered the possibility of employing, after the war, the additional light engineering capacity created by the war to produce domestic appliances expected to be in growing demand.

1945 *Report on Heating and Ventilation of Dwellings*, by the Heating and Ventilation (Reconstruction) Committee of the Building Research Board of the D.S.I.R., under the chairmanship of *Sir Alfred Egerton.* Ministry of Works Post-War Building Studies No. 19.

1945 *Experimental heat pump* put into operation for the heating of administrative buildings in Norwich by J. A. Sumner, City Electrical Engineer. The source of low grade heat was the neighbouring river.

1945 *Report on the Severn Barrage Scheme,* by A. G. Vaughan-Lee, Sir William Halcrow and S. B. Donkin, issued by *Ministry of Fuel and Power.* The panel of engineers, mentioned above, were appointed by the Minister to review the conclusions of the 1933 Committee. The principal conclusion of the present report was that "The Barrage scheme is practicable from the engineering point of view and it *can be economically justified* under the conditions stated".

1946 Foundation on 1 January of the *Atomic Energy Research Establishment,* Harwell, under the aegis of the D.S.I.R.

1946 *Coal Industry Nationalisation Act* under which the coal mines passed into public ownership and which set up the *National Coal Board* in 1947 as a statutory corporation to manage the industry.

1946 Publication of E.R.A. Report Ref. KT116 *"Characteristics of the domestic load".*

1946 Electricity Commissioners, on 17 July, appointed a *Uniformity of Tariffs Committee* under the chairmanship of *Sir John Dalton* to examine the whole range of tariffs for supply of electricity for all purposes, other than bulk supplies to other undertakers. They turned their attention first to domestic tariffs but were only able to make an interim report on this question (see under 1947) before new legislation again changed the outlook.

1946 *International Commission on Rules for the Approval of Electrical Appliances ("C.E.E.")* founded in Amsterdam.

1946 *Report on Domestic Fuel Policy,* by the Fuel and Power Advisory Council (Chmn. Sir Ernest Simon).

1946 Interim Memorandum on *District Heating,* by the District Heating Sub-Committee of the Heating and Ventilation (Reconstruction) Committee of the Building Research Board, set up in October 1942, under the Chairmanship of *Sir Alfred Egerton.* (The final report was published in 1953.)

1946 British Standard for *"light rural lines"*, viz—B.S. 1320–1946 "High voltage overhead lines on wood poles for line voltages up to and including 11 kV". This design formed the basis of the later rural electrification programmes.

1946 Introduction on 20 December of the *Electricity Bill* for the *"nationalisation"* of the supply industry.

1946 *Standardisation of consumers' voltage*—the Minister of Fuel and Power in the House of Commons on 12 February stated that the *Electricity Commissioners* in a report to him had reached the conclusion that "the most practicable and economical method of obtaining complete standardisation of low voltage alternating current supplies at one voltage would be to adopt 240 volts as the standard . . ." This was made mandatory for all new systems from 1 October 1947. It took about 25 years to complete standardisation, involving the conversion of ¾ million DC consumers and 2½ million non-standard AC consumers. The 50 Hz adopted for the "Grid" was the standard frequency.

1946 *Electricité de France* became the French nationalised electricity undertaking, created under legislation of April 1946.

1946 *Atomic Energy Act,* giving statutory form to the transfer of the responsibility for work on atomic energy from the D.S.I.R. to the Ministry of Supply.

1946 Paper by J. Hacking and J. D. Peattie on *"The British Grid in War-time"* presented to the I.E.E. on 6 November and published in the "I.E.E. Journal", October 1947.

1946 In December the first village received a supply under the North of Scotland H.-E.B.'s distribution schemes for remote areas—Finstown, Orkney.

1947 White Paper Cmnd. 7007, of January, gave the *Electricity Supply Areas* envisaged in Part 1 of the Electrcity Bill 1946.

1947 *Isle of Wight connected to the mainland for the first time* by a 33 kV submarine cable from Nursling, near Southampton to Cowes.

1947 Formation in Brussels of the *Organisme de Liaison des Industries Métalliques et Electriques Européennes ("ORGALIME").*

1947 *Report of the Electricity Sub-Committee of the Joint Consultative Committee,* Ministry of Labour and National Service—Chairman: initially *R. M. Gould*; from 1954, *Sir Wilfred Neden.* The Sub-Committee were set up on 4 March "to examine the measures necessary to *reduce peak industrial loads* on the electricity supply system . . ." The report published on 12 May, recommended that the Regional Boards for Industry make arrangements immediately for *"load spreading".*

1947 *First atomic reactor in the U.K.*—the Graphite Low-Energy Experimental Pile *("G.L.E.E.P.")* at the Atomic Energy Research Establishment, Harwell, started up on 15 August.

1947 *Minister of Fuel and Power,* on 13 May, in anticipation of the passing of the Electricity Act, appointed an *"Organising Committee"* for the electricity supply industry under the chairmanship of *Lord Citrine,* who was to be the Chairman of the new Central Authority in due course.

1947 *"Electricity Development in Northern Ireland",* Cmd 250, proposed the establishment of a Joint Electricity Committee to co-ordinate generation in Northern Ireland.

1947 *Interim Report on Domestic Tariffs for Residential Purposes* by a Committee appointed by the *Electricity Commissioners,* 6 June.

1947 *Electricity Bill* received the Royal Assent, 13 August.
Electricity Act 1947 brought the supply industry of England and Wales and Southern Scotland under *public ownership,* and the existing undertakings, which then numbered 560, were integrated into new statutory Electricity Boards appointed by the Minister of Fuel and Power.
Fourteen *Area Electricity Boards,* twelve in England and Wales and two in southern Scotland, shared responsibility for the retail distribution of electricity to consumers.
Generation and main transmission together with central co-ordination and policy direction, were the responsibility of the *British Electricity Authority.*
Electricity Consultative Councils, comprising representatives of consumer and general public interests, were established for the areas of the Area Boards.
The North of Scotland Hydro-Electric Board (q.v.) had already been formed in 1943 to develop the hydro-electric resources of that area, although the existing undertakings maintained their responsibilities for distribution. Under the 1947 Act, the Board absorbed these undertakings and became responsible for all public generation, transmission and distribution throughout the north of Scotland.

1947 *British Electricity Authority ("B.E.A."),* the Central Authority, established on 15 August, under the Chairmanship of *Lord Citrine.*

1947 *Meaford "A"* power station, near Stone, Staffs., owned by the North West Midlands J.E.A.—*first power station to come into operation after the war:* capacity 4 × 30 MW sets.

1947 Control of Turbo-Alternators (No. 1) Order, (S. R. & O. 1947 No. 2386), issued by the Ministry of Supply on 7 November, *standardised the production of steam turbo-alternators* of over 10 MW capacity to two set sizes with prescribed steam conditions—30 MW operating at 600 lb/sq. in. and 850°F, and 60 MW at 900 lb/sq. in. and 900°F; it applied retroactively to all contracts made from 1 November 1946. 30 MW sets with the prescribed steam conditions were already well established; the first to commission after the vesting date on 1 April 1948 was as Ocker Hill in the following month. The first 60 MW set with the standard steam conditions was at Staythorpe "A" (Newark) in March 1950.

1947 The *transistor effect* discovered by John Bardeen, Walter H. Brattain and William B. Shockley while working on electron-conducting properties of semiconductors at Bell Telephone Laboratories, New Jersey. A small piece of germanium was able to amplify a speech signal about 40 times. A semiconductor is a material in which the electrical conductivity lies between that of insulators and of conductors depending on its purity and crystal perfection. Its resistivity decreases with the addition of an impurity atom which provides a ready source of charged carrier for electrical conduction. When an electron in the valency band of a semiconductor, which is densely packed with electrons, is 'excited' so that it is raised to the conduction band which has very few electrons it leaves an unfilled valency state known in physics as a 'hole'. The filling of a 'hole' by another electron creates new 'holes' and thus there is 'hole' conduction, and a 'hole' may therefore be regarded by analogy as a positive electron because it appears to attract electrons. There is, therefore, a 'state' in a semiconductor that acts like a positive charge and has the same mass as an electron, and is mathematically equivalent to a positive electron (positron).

1947 *13 A ringmain plug specification* published—BS 1363. The report on "Electrical Installations" (Post-war Building Studies No. 11) stated—a standard 3-pin domestic socket outlet and plug, intermediate in capacity between the existing 5 A and 15 A standards, should be made available; the recommendation for a ring circuit connected to a single 30 A fuse necessitated arrangements for fusing at each point of outlet; provision should be made in the plug for the accommodation of fuses for 13 A and, alternatively, 3 A; fuses being interchangeable and readily identifiable. These recommendations were considered inter alia by the Electrical Industry Committee of B.S.I. and the final conclusion was that a new type of 'all purpose' 3 kW (13 A at 230 volts) fuse-plug and shuttered socket outlet should be standardised for general domestic purposes.

1948 The fourteen *Area Electricity Boards* established on 1 January.

1948 *Negotiating machinery*—on 31 March, based largely on pre-vesting arrangements, the Central Authority made agreements with the *National Joint Industrial Council*, for the manual workers; with the *National Joint Board*, for the technical engineering staff; and with the newly established *National Joint Council*, for administrative and clerical grades.
An agreement later in the year (23 November) provided for a *National Joint (Building and Civil Engineering) Committee* for building and civil engineering workers.

1948 *Vesting Day, 1 April*—B.E.A. and the fourteen Area Electricity Boards became responsible for the public system of electricity supply throughout Great Britain, except in the north of Scotland.

1948 *E.D.A. Testing House* established in London, to provide testing facilities for the *Joint E.D.A./B.S.I. Advisory Committee on Electrical Appliances and Accessories* which had just been formed (B.E.A.B. from 1960, *q.v.*).

1948 *North of Scotland H.-E.B.* commissioned its *first new stations*—at Morar (600 kW) and Lochalsh (1,000 kW). The former believed to be *Britain's first underground power station.*

1948 B.E.A. introduced an *interim bulk supply tariff* operative from 1 April. The uniform tariff incorporated a fuel cost adjustment with regional effect. But surcharges and discounts were applied to avoid abrupt changes in the cost to Area Boards, compared with pre-vesting.

1948 Report of the *Committee to Study the Electricity Peak Load Problem in Relation to Non-Industrial Consumers* (Chairman: *Sir Andrew Clow*), Cmnd. 7464, published in July. Recommendations included seasonal variations in tariffs. At the request of the Minister of Fuel and Power the Area Boards introduced a surcharge of 0·35d per unit on the domestic running charge in three months of the 1948–49 winter, followed by a rebate of 0·1d per unit in the ensuing nine months. The measure had no appreciable effect on peak loads and was not repeated.

1948 The Electricity (Supply) Act (Northern Ireland) established the *Northern Ireland Joint Electricity Committee* with a general duty of co-ordinating generation by the three undertakings in Ulster, viz the Electricity Board for Northern Ireland, and the undertakings of the Londonderry and Belfast Corporations.

1948 *Power failure*—On 23 May plant overhaul and lower than expected temperatures led to the import of 190 MW into the South East. At 12.25 p.m. the Kings Lynn/Norwich main transmission line developed a fault throwing 90 MW of load on to other circuits that were already overloaded and which tripped, leaving a large section of the South East isolated from the Grid. System frequency and speed of generators fell very rapidly, auxiliaries went out of action and it was necessary to shut down generating plant. Areas particularly affected included Norwich and Yarmouth in the North, Luton down across parts of London to the South East coast including Littlehampton, Worthing, Brighton, Eastbourne, Hastings and Folkestone. To restore supplies it was necessary to isolate into sections and to isolate the sections into small parts which were started off one after the other and ultimately the sections were paralleled togther. All supplies were restored by 3.25 p.m. At 8.45 p.m. a line that had been under maintenance was switched in and immediately tripped. Sequential tripping again occurred over an even more extensive area reaching to the West coast. Load disconnections, sometimes exceeding 25 per cent, were implemented to avoid shutting down power stations again and supplies were restored at 10.38 p.m.

1948 Publication of E.R.A. Report Ref. KT125 *"A large-scale sampling-survey of domestic consumers"*. (An abridged version was published as Ref. KT125A.)

1948 *Gas Act 1948* received the Royal Assent on 30 July. The vesting date set for nationalisation of the gas industry was 1 May 1949.

1948 Commissioning in October of the first of four 30 MW sets at the *Kingston "B"* power station—the *first new post-vesting station.*

1949 A *220 kV impregnated pressure-type cable* designed for continuous 200 MVA duty was manufactured by B.I.C.C., installed in the grounds of the Clamart Laboratories of Electricité de France and connected to the 220 kV grid for field testing.

1949 *Report on a visit to the United States and Canada* of a delegation from the B.E.A. led by *Sir John Hacking.* Reported in particular on the latest practices adopted by U.S. electric utility companies in the design, construction, maintenance and operation of generating plant, transmission developments, costs of production and tariffs.

1949 An inter-departmental committee of the B.E.A. recommended a substantial increase in grid interconnection capacity by means of a higher voltage system additional to the existing 132 kV system. B.E.A. decided that *planning of a*

275 kV system capable of meeting requirements for at least twenty years should begin immediately.

1949 Publication of E.R.A. Report Supp. to Ref. KT125 and 125A, *"A large-scale sampling-survey of domestic consumers. A condensed repeat survey for 1948".*

1949 *"Top-hat" kiln*—an electrically-fired horizontal intermittent pottery kiln, designed by Midlands E. B. in conjunction with manufacturers.

1949 *National Joint Advisory Council* for the electricity supply industry held its inaugural meeting on 27 January.

1949 *Nationalisation of gas industry.* On 1 May 1949, 1,037 gas undertakings in Great Britain vested in twelve Gas Boards.

1949 *Electricity Supply Research Council* established by the B.E.A. in July (Chairman: *Sir Harold Hartley*) to review research matters and advise the Central Authority. Membership included eminent academic authorities as well as supply industry engineers.

1949 Commissioning in August of the *first hydrogen-cooled alternator* in the UK—a 60 MW unit at the Littlebrook "B" station. Better cooling reduces the size of set for a given output, resulting in lower capital costs and easier transportation.

1949 Statement of principles governing the conduct of *electrical contracting and retailing* agreed in August by the B.E.A., Area Boards, Electrical Contractors' Association and the Electrical Contractors' Association of Scotland.

1949 *Liverpool Street to Shenield railway electrification scheme* inaugurated on 26 September. The 1,500 V *DC overhead conductor system* was introduced over 25 route miles of the densest steam-operated train services in the world.

1949 First large-scale application in Britain of the *unit boiler* arrangement *with reheat steam cycle* was commissioned at the *Dunston "B" II station.* This was the first of two 50 MW sets, with a unit boiler of 410,000 lb/h capacity and steam conditions 600 lb/sq. in. 849/849°F. One of the earliest unit boilers was at Stockport HP in 1943, when a 30 MW set was installed steamed from a single 300,000 lb/h boiler.

1940's late *Linear induction motors.* Professor E. R. Laithwaite began his long-term research and development work.

c. **1950** *Storage radiators*—Eastern E.B. developed a prototype storage radiator; and models became available in the U.K. market for commercial and industrial premises. The new radiators were intended for use with off-peak tariffs. Electric storage heaters were in use as early as 1904—some of the most successful used soapstone as the storage medium.

1950's early Introduction of *plastic insulated mains cables.*

1950 O.E.E.C. published *"Interconnected Power Systems in the U.S.A. and Western Europe"* the report of the *"Tecaid" Mission* of European engineers to U.S. utilities to study methods of co-ordinating the use of generating plant and network interconnection. A consequence of the "Tecaid" Mission was the creation of the Union for the Co-ordination of Production and Transmission of Electricity (U.C.P.T.E.) in 1951.

1950 *Ireland's first peat-fired station commissioned.* Portarlington station had two 12·5 MW sets, consuming 120,000 tons of peat a year.

1950 *Public Utilities Street Works Act* to ensure uniform provisions for regulating work done by those who have statutory rights to break open streets and lay apparatus there.

1950 The Retail Tariffs Committee of the B.E.A. and Area Boards recommended general principles on which *uniform tariffs* for domestic, commerical, farm and industrial supplies should be based. They were approved by the Minister of Fuel and Power in February 1951. By 1 April 1956 all Boards had standardised their domestic tarriffs and the standardisation of other tariffs was completed by about 1958–59.

1950 The grid's *National Control Centre* and the *Control Centre for South East and East England* moved from premises in the lift shaft of the former Post Office station of the underground railway system at King Edward Street, EC4, which they had occupied since 1941, to new temporary buildings in Paternoster Square, EC4. At the same time the South East and East England Control Area was divided into new grid control areas named Thames North and Thames South.

1950 Commissioning of the *first standard 60 MW unit,* at the Staythorpe "A" station—the *first of the new Trent Valley stations* using East Midlands coal. Its building design gained an R.I.B.A. Bronze Medal.

1950 Start-up of a 32·5 MW set at the Sloy station of the Loch Sloy scheme—the *first of the North of Scotland H.-E.B.'s schemes* to come into service. By the end of the year the Clunie and Pitlochry stations of the Tummel-Garry scheme and the Grudie Bridge station of the Fannich scheme were also in commission.

1950 *Cross-Channel cable link.* Joint E.D.F./B.E.A. Cross Channel Interconnection Study Committee held its first meeting on 23 March. Interim report issued in May 1952 recommended that the construction of a 132 kV cable was practicable and economic. Cable-laying trials were carried out in 1953. In 1956 the C.E.A. approved in principle the construction of a DC link, and approval of the Ministry of Power was obtained in September 1957. The cross-Channel cable was commissioned on 8 December 1961—*q.v.* It was decommissioned on 31 December 1982 on account of poor availability.

1950 Midlands E.B. began an investigation of the use of *auto-reclosing circuit breakers on 11 kV overhead line networks* which led ultimately to their wide-scale use throughout the country. They can clear lightning faults thus avoiding power failures.

1950 B.E.A. introduced on 1 April a *uniform bulk supply tariff* for supplies to Area Boards. Earlier tariffs included a provision to avoid abrupt changes in the cost to Area Boards compared with pre-vesting.

1950 Commissioning of the Stourport "B" LP station. A feature of the single 60 MW unit was its *slag-tap furnace*—the first in Britain.

1950 *"The Economics of Electricity Supply".* Paper by Sir Henry Self to the British Electrical Power Convention, June. Published in "Proceedings B.E.P.C." 1950, pp. 17 etc.

1950 *British Electricity Laboratories* (now the Central Electricity Research Laboratories) at Leatherhead opened by Lord Citrine on 15 July.

1950 Recommendation by an inter-departmental committee of the B.E.A. that *275 kV transmission* lines superimposed on the existing grid should be constructed, was adopted by the Authority in July.

1950 *Control of Turbo-Alternators (No 2) (Revocation) Order* (SI 1950 No 1221) revoked the Control of Turbo-Alternators (No 1) Order (1947) thereby freeing

the production of steam turbo-alternators from control by the Minister of Supply with effect from 1 August 1950.

1950 *Anglo-American Council on Productivity* published in September "Electricity Supply", the *report of a visit to the U.S.A.* in 1949 of productivity teams representing the British electricity supply industry.

1950 *Load controlling devices.* Working Party drawn from B.E.A. and Area Boards to investigate possibilities afforded by load controlling devices, reported in November. Their recommendation that at least two large-scale pilot tests should be mounted was not finally adopted. A Joint Working Party, set up in 1951 to examine the whole subject de novo, reported in 1952—*q.v.*

1951 E.R.A. installed a *heat pump,* drawing its energy from the ground, to heat a laboratory building at the E.R.A. Agricultural Establishment at Shinfield, Reading.

1951 Experimental *heat pump* installation commissioned at the *Royal Festival Hall* under the auspices of the Chief Scientist's Division of the Ministry of Fuel and Power, driven by two Rolls-Royce Merlin aircraft engines converted to run on town gas. The main source of heat was provided by the River Thames. Aim was to compare heating costs with those of the permanent gas-fired boiler installation.

1951 Union pour la Co-ordination de la Production et du Transport de l'Electricité ("U.C.P.T.E."), (Union for the Co-ordination of the Production and Transmission of Electricity), founded in Paris.

1951 *"Electrification of Railways"*—Report of a committee (Chairman: *C. M. Cock)* appointed by the Railway Executive and the London Transport Executive, published in March. Its principal recommendation was that the DC system with an overhead line at 1500 V should be adopted as standard in all future electrification schemes (confirming main conclusions of the 1927 Railway Electrification Committee (the Pringle Report).

1951 *"Problems of Decentralization in a Large Scale Undertaking. The Organisation of the Central Authority and Area Boards of the Electricity Supply Industry".* Paper by Sir Henry Self at the British Institute of Management, Winter Proceedings, 6 March, published by B.I.M. in May.

1951 *European Coal and Steel Community (E.C.S.C.)* established by the Treaty of Paris 18 April.

1951 Working Party on *District Heating* in Relation to Public Water Supplies (Chairman: *G. S. Wells*). Set up by the Ministry of Health in 1948, an interim report was published in June 1951. Recommended that district heating schemes should be designed with distribution by the 2-pipe or 3-pipe system, and if practicable with a separate calorifier or indirect cylinder in each dwelling.

1951 An experimental breeder reactor (EBR I), *the world's first FBR to produce electricity,* began operating in Idaho.

1951 *Pimlico District Heating* Scheme officially opened in July. Steam was taken from the main boiler-house range at Battersea "A" power station, passed through 2 × 1·35 MW back-pressure turbines to a heat exchanger from which heated water was pumped through a tunnel under the Thames to a large thermal storage tank providing space heating for adjacent blocks of flats.

1951 *Fuel Efficiency Advisory Committee* established to advise the Minister of Fuel and Power on aspects of fuel efficiency, on the setting up of committees for special problems, and on the reports of such committees. It replaced the former Fuel Efficiency Committee.

1951 *Negotiating Machinery.* An agreement establishing the *National Joint Managerial and Higher Executive Grades Committee* was signed by the Central Authority and Area Boards and N.A.L.G.O., E.P.E.A. and A.M.E.E. on 1 August.

1951 *Monopolies and Restrictive Practices Commission* report on the *supply of electric lamps* published in October.

1951 A Parsons *100 MW generator* commissioned at Richard L. Hearn station of the Hydro-Electric Power Commission of Ontario—at the time probably the largest two-cylinder tandem set yet built in Britain.

1952 *Electricity Supply in Great Britain: Its development and organisation* by Sir Henry Self and Elizabeth M. Watson, published by Allen and Unwin.

1952 *Manchester-Sheffield-Wath railway electrification.* The first stage of the trans-Pennine scheme, Wath to Dunford Bridge, opened to traffic in February. It employed a catenary system operating at 1,500 V DC.

1952 *Ownership of transmission lines.* A large proportion of the B.E.A.'s 66 kV and lower voltage lines was transferred to Area Boards.

1952 *North Wales Hydro-Electric Power Act 1952.* Provided for the extension of the Maentwrog and Dolgarrog catchment areas and a 10 MW extension at the latter station. Proposals for a scheme at Ffestiniog were superseded by new proposals in a 1955 Act—*q.v.*

1952 Eastern E.B. introduced standard *day/night tariffs* for domestic, commercial and farm consumers. Cheap night rates served to flattern the load curve thereby improving the use made of the system.

1952 Commissioning in April of the first of six 60 MW units at the Keadby station. The 550,000 lb/h boiler was the largest so far commissioned in the U.K.

1952 *Monopolies and Restrictive Practices Commission* Report on the *supply of insulated electric wires and cables* published in April.

1952 *"275 kV Developments on the British Grid System",* by D. P. Sayers, J. S. Forrest and F. J. Lane. I.E.E. paper read before the Supply Section on 21 May, reporting progress made by the B.E.A. on the new 275 kV system.

1952 A 15 MW open compound cycle *gas-turbine* set was put on load in August at the Trafford power station, Manchester. It did not enter commercial operation until 1957.

1952 *Report of the Committee on National Policy for the Use of Fuel and Power Resources* (Chairman: *Viscount Ridley*), Cmd. 8647, urged greater efficiency in the use of fuel, research into total gasification of coal, and a move away from coal on the railways. It expected the NCB to be able to expand coal production in the medium-term to meet an increasing demand for coal at prices which would remain competitive with oil.

1952 *Load controlling devices.* Joint Working Party drawn from Ministry of Fuel and Power, B.E.A. and Area Boards examined the question of load controlling devices and reported in October. Majority view was that automatic and centrally-controlled load limiters offered no prospect of a clear-cut margin of national advantage as would warrant their adoption.

1952 A 500 kW *experimental gas turbine* at Clydebank completed in November an endurance test of 1000 hours' running on pulverised peat.

1952 Commissioning of the first 60 MW set at Bankside "B" LP the *first large public supply station to be specially designed for oil-firing.* The station building was

designed by Sir Giles Gilbert Scott to harmonise with surrounding buildings. Bankside and Battersea were the only stations in Britain with *full-scale gas washing plant.*

1953 *Union Internationale d'Electrothermie ("U.I.E."),* (International Union of Electroheat), founded in Paris.

1953 *Nuclear power,* B.E.A. established a nuclear power branch in their Chief Engineer's Department to study, plan, design and eventually arrange for the construction of nuclear stations.

1953 *National Industrial Fuel Efficiency Service ("N.I.F.E.S.")* established, following a recommendation of the Committee on National Policy for the use of Fuel and Power Resources (Ridley Committee), to assist industrial and commercial fuel users in improving their fuel efficiency. It replaced the Fuel Efficiency Service provided by the Ministry of Fuel and Power. In 1972 Government financial assistance ended and it became a private commercial concern.

1953 *Pithead power station*—Bold "A" (St Helens), 4 × 30 MW sets, started up. Had *belt conveyor link with colliery.*

1953 *Association Internationale des Entreprises d'Equipment Electrique ("A.I.E.")* (International Association of Electrical Contractors) founded in Paris. Electrical Contractors' Association was a founder member.

1953 *A 100 kW wind generator* at Costa Head in Orkney under development by North of Scotland H.-E.B. ran at full output for the first time. The experiments were taken over by the E.R.A. in 1956. In 1955 an experimental 100 kW Andreau wind generator developed by Enfield Cables Ltd. was commissioned by the B.E.A. at a temporary site near St Albans. The plant was sold to a foreign undertaking in 1956.

1953 *British Productivity Council* published in April "The British Electricity System", the *report of a productivity team from the U.S. electric utility industry on the B.E.A. system.*

1953 *Rural electrification:* On 19 June the House of Commons resolved that steps should be taken to develop the supply of electricity in rural areas as much and as fast as possible. The Minister of Fuel and Power relaxed restrictions on capital expenditure and the supply industry announced a *rural electrification programme* with a target of 85 per cent of farms connected by 1963. The target was achieved eighteen months ahead of schedule.

1953 First section of the *275 kV grid*—41 miles of single-circuit line between Staythorpe (Newark) and West Melton (Sheffield)—commissioned on 15 July. This was a trial section orginally designed for 264 kV and already under construction when the 275 kV schemes was adopted in 1950.

1953 The Low-Separation *Gaseous Diffusion Plant* at Capenhurst began full operation. It provided two-fold enrichment of uranium fuel (i.e. double the U-235 content) to provide fuel suitable for use in reactors requiring enrichment. The later high-separation plant provided military levels of enrichment.

1953 *Railway electrification*—experiments with alternating current. In August the *Lancaster-Morecambe-Heysham line,* some 15 route km in length, *began electric operation on the single-phase 50 Hz AC* system, using 6·6 kV from an overhead contact wire. Powered coaches were fitted with mercury-arc rectifiers and DC traction motors. *Germanium and silicon rectifiers were tried out for the first time* anywhere in the world.

1953 *District Heating:* Report by the Heating and Ventilation (Reconstruction) Committee of the Building Research Board of the Department of Scientific and

Industrial Research (Chairman: *Sir Alfred Egerton*) (Ref. Post-War Building Studies Nos. 31 and 32, Ministry of Works) dealt with possible district heating developments in Britain, practice abroad, and heat pumps. Principal conclusion was that the national case for district heating rested generally on fuel savings obtainable through linking the service with electricity generation.

1953 *Report of the Committee of Enquiry into Economy in the Construction of Power Stations* (Chairman: *Sir Hugh Beaver*) published in October. Established in August 1952 to consider possible savings of materials or manpower in power station construction in regard to scarcity of materials at that time. Recommendations included introduction of larger units in stations of at least 400 MW capacity, use of uncovered or semi-clad plant where practicable, and greater simplification and standardisation in finish and design of plant and buildings, with use of lighter cladding.

1953 *Nuclear energy. "Future Organisation of the United Kingdom Atomic Energy Project"* (Cmnd. 8986). This White Paper, issued in November, accepted the recommendations of the Waverley Committee (reported unpublished) and dealt with the *transfer of responsibility for nuclear energy from the Ministry of Supply to a non-departmental authority.* An Order in Council, operative from *1 January 1954,* made the *Lord President of the Council* the Minister *responsible for nuclear energy.* A Bill was introduced providing for the establishment of the United Kingdom Atomic Energy Authority which received the Royal Assent on 4 June 1954 (Atomic Energy Authority Act 1954.) *The U.K.A.E.A.* came into being on 19 July 1954. During the period 1 January to 18 July 1954 responsibility for nuclear affairs was exercised by a Department of Atomic Energy reporting to the Lord President.

c. **1954** *Installation practice.* Moulded-case circuit-breakers (*"m.c.c.b.'s."*) seriously introduced to the British market as an alternative to the conventional fused switch.

1954 *Oil burning programme.* As part of the Government's fuel policy to meet a likely coal shortage, plans were put in hand to burn oil at 17 power stations representing an annual oil consumption of 5⅔ million tons by 1960–61, equivalent to 9 million tons of coal. Improved supplies of coal and uncertainty about future oil supplies led to a modification of the programme in 1957, reducing the number of stations to 14 and the oil burn to 4½ million tons a year. Marchwood station, Southampton Water, with 8 × 60 MW units, which commissioned in 1955, was included in the programme, suppled by the near-by Esso refinery. Other oil-fired stations sited near developing refineries, were later commissioned—including Fawley in 1969, Pembroke and Kingsnorth in 1970. From about 1965 relative fuel prices provided a case for a increased oil burn, but until 1970, conversions to oil were largely prevented by the Government's support for coal policy. After 1973 oil became expensive relative to coal.

1954 *Submarine cable link,* capacity 20 MW at 100 kV DC between Swedish mainland and Island of Gotland (63 miles) commissioned.

1954 *Highest transmission line in Great Britain* completed—over the Corrieyairack Pass in Inverness-shire, some 2,500 ft. above sea level at summit.

1954 *Electric floor heating.* South East Scotland E.B.'s experiment in conjunction with Kirkcaldy Corporation in a prototype eight-storey block of flats.

1954 *Pottery manufacture—intermittent electric kiln for biscuit firing of china* designed by Shelley Potteries in conjunction with Midlands E.B.

1954 *Arc furnaces*—start-up by Samuel Fox & Co. Ltd. of a 60-ton unit for the melting of alloy and special steels and believed to be the largest electric furnace in Europe.

1954 *Report of the Scottish Peat Committee* published. Appointed 1949 under the chairmanship of *Sir Edward Appleton*, to advise the Secretary of State for Scotland upon a survey of Scottish peat deposits; a programme of research into peat-burning gas turbines; and the commercial exploitation of Scottish peat deposits generally. Proposed that the North of Scotland H.-E.B. should bring into operation two peat-fuelled gas turbo-alternators. The Board should be invited to order a 2,000 kW closed-cycle gas turbine and install it at Altnabreac Moss, Caithness.

1954 *Diesel plant*—start-up of the *Ashford "B"* power station. With 5 ×2 MW sets, this was the largest diesel station operated by the C.E.G.B.

1954 *Domestic heat pumps.* Development of a refrigerator/hot water system, called the Duo-Therm, by G. O. McLean, Chief Engineer, South Western E.B. and in production by Brentford Transformers Ltd.

1954 *"Nuclear Reactors and Power Production"* by *Sir Christopher Hinton.* James Clayton Lecture to the Institution of Mechanical Engineers on 26 February, published in "Proceedings I.Mech.E", 1954, Vol. 168, pp. 55 etc.

1954 *Testing of 275 kV cables* began at a new cable testing station, near Staythorpe power station, inaugurated on 25 March. Test lengths submitted by manufacturers were connected to Staythorpe/West Melton 275 kV grid line.

1954 *Electricity Reorganisation (Scotland) Act 1954,* provided for the transfer to the Secretary of State for Scotland of practically all the functions of the Minister of Power in relation to electricity supply in Scotland, and for the setting up of a new public authority, the *South of Scotland Electricity Board,* to be responsible, from 1 April 1955, for the generation and supply of electricity in the part of Scotland outside the area of the North of Scotland H.-E.B. Also provided for the title of the British Electricity Authority to be changed to *Central Electricity Authority* ("C.E.A.") from the same date.

1954 *Atomic Energy Authority Act* authorised discharge of radioactive wastes only in accordance with authorisations given by Minister of Housing and Local Government and Minister of Agriculture, Fisheries and Food—or Secretary of State for Scotland.

1954 *Enlarged generation division*—inauguration on 1 April of the North West Merseyside & North Wales Division, a *merger* of the Merseyside and North Wales and North Western Divisions of the B.E.A.

1954 *Organisation of the supply industry in England and Wales*—appointment by the Minister of Fuel and Power in July of a committee of inquiry under the chairmanship of *Sir Edwin Herbert.* The committee reported in January 1956—see under that year.

1954 *"Report on the Design of Underground Distribution Systems* for New Housing Estates" prepared by the C.E.A. and Area Boards—published July 1955.

1954 *United Kingdom Atomic Energy Authority (U.K.A.E.A.) established on 19 July.*

1954 *Obninsk* 5 MW nuclear power station commissioned in Russia. This water-cooled, graphite-moderated, pressure-tube station, using uranium enriched to 5 per cent U–235 content, was *claimed to be the world's first commercial nuclear station.* It is believed that it did not enter into regular service until 1965.

1954 A Treasury working party (Chairman Burke St John Trend) reported on the economic feasibility of a civil *nuclear power programme.* They recommended some 1,700 MW of nuclear capacity by 1965 from 12 reactors. Despite the great difficulty in estimating nuclear costs accurately, and the fact that a nuclear programme might only become economic in its later stages, the coal

shortage justified taking calculated technical and economic risks. The Government adopted a nuclear power programme in 1955 (*q.v.*).

1954 Commissioning of *Stourport "B" HP.* The 60 MW unit had the *most advanced steam conditions* on the public supply system—1500 lb/sq. in. 1050°F at the turbine stop valve.

1954 *Report of the Committee on Air Pollution,* Chairman: *Sir Hugh Beaver;* Cmnd. 9322, November. Looked into the causes and effects of air pollution and the efficacy of preventative measures. Its recommendations were embodied in the Clean Air Act 1956.

1954 Commissioning of the *Ince "A"* station—the first British station with the *semi-outdoor design of boiler plant.*

1955 *Railway electrification*—publication of the British Transport Commission's Plan for the modernisation and re-equipment of British Railways, to be started within five years and completed within fifteen. Provision made for the electrification of certain main lines and other routes.

1955 *Overhead line crossing*—completion of the crossing of the Messina Straits from Sicily to the mainland of Italy, said to be the longest overhead link in the world, comprising a double circuit 220 kV line, 11,950 ft. total length with two towers of height 735 ft.

1955 *Sulphur hexafluoride (SF_6) circuit breaker rating* 115 kV 1,000 MVA put into service in the U.S.A.—one of the earliest in the world. Westinghouse Electric Corpn. had been installing lower power SF_6 load-break isolator switches since 1953.

1955 *Domestic heat pumps*—announcement of the "Fridge-heater", for water heating and larder cooling, developed by Basil Z de Ferranti, for marketing by Ferranti Ltd.

1955 *Oil-filled cables*—Henleys develop three-core 132 kV cable.

1955 *British Nuclear Energy Conference* inaugurated—sponsored by the Institutions of Chemical, Civil, Mechanical and Electrical Engineers, and the Institute of Physics.

1955 *Research*—Extension to Central Electricity Research Laboratories (C.E.R.L.) Leatherhead, officially opened.

1955 *Joint Meter Reading.* Reports on the joint reading of electricity and gas meters prepared by a firm of industrial consultants for the C.E.A. and the Gas Council were submitted between August 1954 and September 1955. The reports were summarised in the Weir Committee report of 1959—*q.v.*

1955 *North Wales Hydro-Electric Power Act 1955.* Conferred powers upon the C.E.A. for the construction of hydro-electric projects at Ffestiniog and Rheidol.

1955 *"A Programme of Nuclear Power",* Cmnd. 9389, February, announcing a ten-year programme for the United Kingdom comprising about 1,500 to 2,000 MW of gas-cooled graphite-moderated stations, using natural uranium canned in magnesium alloy ("Magnox").
This *first nuclear power programme* was expanded in 1957 with the further technical progress in nuclear design and because of the Suez crisis which drew attention to the security aspects of oil supplies. The programme was subsequently re-phased because of the easing of the fuel situation, restrictions on capital expenditure, and a number of factors which affected its economics—rising interest rates, a reduction in the price of recoverable plutonium, and the rate at which conventional generation costs were falling. In its final form the

programme comprised nine stations with a design output capacity of nearly 5,000 MW. The last reactor commissioned in 1971.

1955 Vesting day 1 April for the *South of Scotland Electricity Board* established under the Electricity Reorganisation (Scotland) Act 1954—*q.v.* There were consequential reductions from 14 to 12 in the number of Area Boards and from 13 to 11 in the number of the C.E.A.'s Generation Divisions.

1955 O.E.E.C. published in June *"Some Aspects of the European Energy Problem" (Armand Report)* its first important energy survey for Western Europe.

1955 A 12 MW *gas turbine* of the "closed cycle" type at the Carolina Port station in Dundee was connected to the system for the first time in July. Trials continued until in 1959 the project was abandoned, as reliable commercial operation seemed unlikely. Experimental 15 MW gas turbines were commissioned by the C.E.A. at Dunston "A" in November 1955 and at the Trafford station in February 1957, but were taken out of service in 1960–61.

1955 United Nations *International Conference on the Peaceful Uses of Atomic Energy* in August, in Geneva. About 80 nations participated.

1955 *Heat Pumps*—"First Interim Report on Heat Pumps" issued by the C.E.A.'s Generating Station Operation—Research Liaison Committee, in December. Dealt with the study of heat pump installations at Meaford and Stourport power stations and other methods of heating similar power station administrative buildings.

1955 At the end of the year the British Transport Commission decided to adopt *50 Hz single-phase 25 kV as standard for railway electrification.*

1956 *National Inspection Council for Electrical Installation Contracting* incorporated, the C.E.A. and Area Boards, and the South of Scotland E.B. being among the member bodies.

1956 *Appliance Testing*—E.D.A. to undertake tests for the British Standards Institution in connection with the "Kite Mark" scheme.

1956 *Wind-power generation*—a 10 kW generator erected for tests at the *E.R.A.* station at Cranfield. Built by Dowsett organisation in conjunction with Ministry of Power.

1956 *Nuclear power stations.* The French Commissariat à l'Energie Atomique commissioned their first reactor, a natural uranium graphite-moderated gas-cooled type, designated GI, capacity 5 MW(e).

1956 *Rural electrification.* South of Scotland E.B. published their plan for completing in a systematic manner, by 1960, the electrical development of those parts of the rural areas not yet on supply.

1956 Commissioning of the first two 30 MW sets at the *Barony station* of the South of Scotland E.B., the *first of its kind* in the U.K. using *colliery washery slurry as a fuel.*

1956 *Clean Air Act 1956,* based on the recommendations of the Beaver Committee on Air Pollution (Cmnd. 9322, November 1954). The Act provided for the establishment by local authorities of smoke control areas in which only authorised fuels might be used.

1956 White Paper *"Report of the Committee of Inquiry into the Electricity Supply Industry"*, Cmnd. 9672, published January. The committee was set up by the Minister of Fuel and Power in July 1954, under the chairmanship of *Sir Edwin Herbert,* "to enquire into the organisation and efficiency of the electricity

supply industry in England and Wales in the light of its working under the Electricity Act 1947". The main recommendation of the report was that the C.E.A. should hand over its responsibility for generation and transmission to a new statutory body with clearly delimited supervisory functions, and Area Boards should be given a greater degree of independence. The Government in a White Paper *"Proposals for the Reorganisation of the Electricity Supply Industry"*, Cmnd. 27, expressed their general agreement with the recommendations, and gave them effect by the Electricy Act 1957 (*q.v.*).

1956 *"The Hazards to Man of Nuclear and Allied Radiations"*, Cmnd. 9780. An independent committee under Sir Harold Himsworth appointed by the Medical Research Council accepted the International Commission on Radiological Protection recommendation that persistent exposure to radiation should not exceed 0·3 rem weekly averaged over any period of 13 consecutive weeks. Lifetime accumulated dose should not exceed 200 rem of "whole body" radiation, in addition to natural background radiation, spread over tens of years—"but every endeavour should be made to keep the levels of exposure as low as possible." An individual should not accumulate more than 50 rem of radiation to the gonads, in addition to natural background radiation, from conception to age 30—this allowance should not apply to more than one-fiftieth of the total population. Any recommended upper limits to the total dose of extra radiation received by the population as a whole should not exceed twice the dose received from natural background radiation.

1956 O.E.E.C. published in May *"Europe's Growing Needs of Energy—How can they be met?"*, the report of a Group of Experts (Chairman *Sir Harold Hartley*). Reviewed energy problems of Western Europe and its recommendations led to the creation of the O.E.E.C.'s Energy Advisory Commission and Energy Committee.

1956 Government took over direct responsibility for financing the long-term borrowing requirements of the nationalised industries under Section 42 of the Finance Act 1956. *Borrowing through stock issue was replaced by Exchequer advances.*

1956 Monopolies and Restrictive Practices Commission *"Report on the supply and exports of electrical and allied machinery and plant"* published in July.

1956 White Paper *"Electricity Supply in Northern Ireland"*, Cmnd. 355—included plans for a 200 MW nuclear station.

1956 *Submarine cable link* between *Vancouver Island* and the mainland of *British Columbia*, Canada, length nearly 19 miles—two circuits, total capacity 250 MW each consisting of a 138 kV AC cable, the first circuit being commissioned in September 1956 and the second in July 1958.

1956 *World's first large-scale nuclear power station*—the U.K.A.E.A.'s *Calder Hall "A"*, in Cumberland, rating 4 × 23 MW generating sets, connected to grid after Royal opening 17 October. Its primary purpose was to produce the fissile fuel plutonium, essentially for military use.

1956 First *cyclone-fired boiler* in Britain commissioned at the Kynoch Works of I.C.I. The 200,000 lb/h Babcock and Wilcox boiler provided heating and process steam at this non-ferrous metals producing works and also steamed a 6·5 MW turbo-alternator at steam conditions 900 lb/sq. in. 900°F.

1956 Commissioning of the *first 100 MW unit*, at Castle Donington station, near Derby. This station, with 6 × 100 MW turbo-alternators and 6 × 830,000 lb/h boilers was the first to break away from the standard 30 MW and 60 MW sets. Its turbines incorporated a double shell high-pressure cylinder and the rigid coupled three bearing rotor, both novel to British practice. Steam conditions were 1,500 lb/sq. in. and 1,050°F. Sets of this size were later commissioned at

the Willington "A", Ferrybridge "B", and Aberthaw "A" stations, the latter two having steam conditions of 1,500 lb/sq. in. and 975°F with reheat to 950°F.

1956 *Electricity Bill* presented to the Minister of Power 27 November provided for the dissolution of the C.E.A. and the establishment of C.E.G.B. and The Electricity Council. (See Electricity Act, 1957.)

1956 *Water cooling of turbo-alternators.* Commissioning of a prototype 30 MW set at the Bold "A" station, the first machine in the world with water flowing through the stator bars.

1957 Electricity Bill received Royal Assent 17 July.
The Electricity Act 1957, based largely on the recommendations of the Herbert Committee report of January 1956 (*q.v.*), established two new statutory bodies, *The Electricity Council*, a central council for the electricity supply industry in England and Wales as a whole, and the *Central Electricity Generating Board* ("C.E.G.B.") to take over from the C.E.A. the duties of generation and transmission. The vesting date for these two new bodies was 1 January 1958. Also, the Act gave *greater financial responsibility* to the Area Boards.

1957 Formation of the *British Lighting Council* (disbanded in 1967).

1957 A 125 MW unit commissioned at the Philo station of the Ohio Power Co. with turbine stop valve *steam conditions of 4,500 lb/sq. in. at 1,050°F with reheat to 1,000°F.*

1957 *World's largest walking drag-line scraper*, designed and built by Ransomes and Rapier Ltd.; weight 1,675 tons; equipped with 282 ft. long tubular jib, capacity of grab 30 tons; electricity taken from mains at 6·6 kV through trailing cable feeding two 1,500 hp motor-generator sets providing DC to the 14 main driving motors each of 225 hp—at work on open-cast ironstone quarry, near Stamford.

1957 *World's largest steam power plant* commissioned at Kingston by the T.V.A.—total rated capacity 1,440 MW (total capability 1,600 MW) from 4 × 135 MW and 5 × 180 MW sets.

1957 The *first commercial pressurised water reactor* (P.W.R.) *nuclear station* commissioned at Shippingport, near Pittsburgh. Owned by the U.S. Atomic Energy Commission, the station had a capacity of 141 MW(e).

1957 *Storage radiators:*
"E.D.A. Recommendations for the Design, Installation and Use of Thermal Storage Block Heaters", published.

1957 Field trials of storage radiators suitable for *dwelling houses.*

1957 *Wind-power generation*—a 200 kW AC generator on trial at Gedser, Denmark.

1957 A working party at the Ministry of Fuel and Power (Chairman M. T. Flett) recommended an *enlarged nuclear power programme.* On 5 March the Government announced that planning was to proceed on the basis of *5,000 to 6,000 MW* of nuclear capacity in operation *by the end of 1965.* This represented a *trebling of the 1955 programme—q.v.*

1957 *European Economic Community ("E.E.C.")* and *European Atomic Energy Community ("Euratom")* set up under the Treaty of Rome, on 25 March.

1957 First *cyclone-fired boiler* on the public supply system commissioned at the Barking "C" station. This 540,000 lb/h Babcock and Wilcox boiler was scrapped in March 1971, having served as a prototype for the 860,000 lb/h cyclone-fired boiler commissioned at the Padiham "B" station in 1962.

1957 *ZETA—(Zero Energy Thermonuclear Assembly).* An experimental apparatus for studying the pinched-ring discharge as a possible method of producing controlled thermonuclear power. The self-magnetic field of the discharged current isolated the plasma from the walls of the discharge tube. The objective was to heat isotopes of hydrogen (usually deuterium) to temperatures in the region of 107°C at which the nuclei fuse to form heavier nuclei, releasing energy in the process ($H^2 + H^2 \rightarrow H^3$ + a proton + 4MeV). Zeta had a bore of 1m and mean diameter of 3m and was linked by the iron core of a large pulse transformer. A current pulse was passed into the primary windings of the transformer from a bank of condensers capable of storing 5×10^5J. This pulse induced a unidirectional pulse of current of up to 23×10^4 A in the plasma. Zeta achieved temperatures of from 1–5 million degrees for periods of up to 3ms. The gas consisted of charged ions and free electrons and in the case of hydrogen they were nuclei without attached electrons. The mixture was so different from a solid, liquid or gas that it was termed 'plasma'. A hot plasma had a high conductivity for heat and electricity. Excessive loss of energy from the gas during the current pulse indicated the need for precise and independent control of the plasma parameters, and of the magnetic field. This was not practical with Zeta in which the magnetic field derived from current carried by the plasma itself and interest switched to the production of precisely engineered magnetic fields produced by current flowing in conductors placed around the plasma or within it.

1957 *SCEPTRE III*—an apparatus for research on *controlled thermonuclear* problems was commissioned by Associated Electrical Industries at their Aldermaston laboratory. *SCEPTRE IV* was commissioned in November 1959, capable of passing current of up to a million amperes. This research complemented ZETA.

1957 *Automatic control in power stations*—commissioning of oil-fired station at *South Denes*, Gt. Yarmouth, notable at the time for the completeness of its automatic control.

1957 Commissioning of the 5 MW generating/pumping set at Sron Mor power station of the North of Scotland Hydro-Electric Board. This part of the Glen Shira scheme was the *first example of pumped storage* on any considerable scale on the British public supply system.

1957 O.E.E.C. published *"Production, Transmission and Distribution of Electricity in Europe"*, the report of a mission of American and European engineers, known as *"Project 350"*, to European electricity undertakings in order to assess progress made since the "Tecaid" Mission of 1949.

1957 On 1 September the Minister of Power appointed *Sir Henry Self* Chairman of The Electricity Council and *Sir Christopher Hinton* Chairman of the Central Electricity Generating Board.

1957 *Rogerstone* power station commissioned—the first of two 60 MW sets entered service after only three years' work on site. It was *the first station to use aluminium cladding.*

1957 *Windscale accident*—during a routine release of Wigner energy which had become stored in the graphite moderator of No. 1 Pile as a result of the normal operations of the pile, heating to release the energy was applied too soon and at too rapid a rate. This created a failure in one or two channels of fuel, whose contents then oxidised slowly, eventually leading to a fire and the overheating of some 150 channels of fuel by the evening of 10 October. After initial unsuccessful attempts to put out the fire, it was finally extinguished at about 09.00 on the morning of 11 October, by flooding the pile with large volumes of water. The resultant uncontrolled release of activity to the atmosphere subsequently dispersed and radionuclides could be detected over England, Wales and parts of Northern Europe.

The 'collective dose equivalent' (overall radiological impact) was estimated at $1{\cdot}2 \times 10^3$ man Sv. The route of exposure which contributed most was the ingestion of contaminated milk. Iodine–131 was the most important radionuclide, contributing nearly all of the collective dose to the thyroid and the largest parts of the collective effective dose. In the longer term the contribution of caesium–137 to the collective dose via external irradiation from ground deposits and the ingestion of contaminated foodstuffs became significant. Restrictions were imposed on the distribution of milk which contained more than 3,700 Bq l^{-1} of I–131 during 11 to 13 October and the area restricted was 520 km^2 covering a rectangular strip of coastline about 15 km wide from 10 km north of Windscale southward to the Barrow Peninsular. Milk distribution was resumed within about 25 days for most of the region, but not until 44 days in the most contaminated area close to Windscale. The radiological impact was assessed by Crick and Linsley in 1982 (*q.v.*).

1957 *"Accident at Windscale No. 1 Pile* on 10 October", 1957, Cmnd. 302—a less technical version of the report of the Committee of Inquiry, including the report of a Special Independent Committee on the Health and Safety Aspects to the Medical Research Council.

1957 *Hydro-electric developments in the U.S.S.R.*—visit by British delegation appointed by the three senior engineering institutions in association with the British Council, October 1956, led by *Sir John Hacking*—report presented 20 May 1957 to a joint meeting of the three Institutions.

1957 *"Report from Select Committee on Nationalised Industries (Reports and Accounts)"* H. C. Paper 304, October. The Committee examined the 1956 Reports and Accounts of the two Scottish boards. In the case of the *North of Scotland H.-E.B.* they also heard evidence on the Board's operations and functions, and on the state of rural electrification in the Highlands. The Committee's criticisms were on comparatively minor points and did not detract from the good opinion they had formed of the Board's achievements. Bearing in mind the satisfactory performance of the *South of Scotland E.B.* throughout its brief existence, the Select Committee decided not to pursue their investigations into the Board's operations at this time.

1957 *European Nuclear Energy Agency* established by O.E.E.C. Council in December to further the development of the production and uses of nuclear energy for peaceful purposes by the participating countries, through co-operation between those countries and a harmonisation of measures taken at national level.

1958 *H.V. aerial cable.* South Western E.B. energised the first 11 kV aerial plastic cable, designed for stringing through wooded areas in the National Parks.

1958 *Railway electrification.* The *first section to operate at 25 kV 50 Hz* was completed—the Styal Line pilot scheme between Wilmslow and Slade Green Junction. The British Transport Commission had adopted in 1955 50 Hz single-phase 25 kV as standard for their railway electrification programmes.

1958 *First 275 kV transmission line in Scotland* brought into use by the South of Scotland E.B. between Clyde's Mill power station and the Harker substation, near Carlisle.

1958 *Grid system*—completion of new standardised system of Area Control Centres.

1958 *Pithead power stations.* Opening of N.C.B.'s Grimethorpe station, 3 × 20 MW sets, which used *high-ash coal.*

1958 *Water cooling of turbo-alternators.* Commissioning at Tilbury "A" power station of set No. 6, 60 MW, which employed a *stator cooled by distilled*

water—a prototype machine used to obtain experience with this cooling system before applying it to the 200 MW sets.

1958 The Electricity Act 1957 came into effect on 1 January, establishing *The Electricity Council* and the *Central Electricity Generating Board* ("C.E.G.B.")—see under 1957.

1958 Appointment in March of the *Committee on Co-operation between Area and Scottish Electricity and Gas Boards*, under the chairmanship of *Sir Cecil Weir*. The Committee reported in 1959—*q.v.*

1958 *Battery train*, comprising two coaches, inaugurated in April on Aberdeen–Ballater branch, Scottish Region, British Railways.

1958 *Gas turbine designed to run on milled peat* at the Olgrinbeg power station, Altnabreac, of the North of Scotland H.-E.B., started up in June. Peat combustion proved difficult to control and the experiment was abandoned on economic grounds in June 1960.

1958 Second United Nations *International Conference on the Peaceful Uses of Atomic Energy*, held August, in Geneva.

1958 *St Lawrence Power Project*, International Rapids Section—official inauguration on 5 September of the adjoining Canadian and United States power stations, having combined capacity of 1,880 MW.

1958 *"Final Report of the Committee appointed by the Prime Minister to make a technical evaluation of information relating to the design and operation of the Windscale piles, and review the factors involved in the controlled release of Wigner energy"* Cmnd. 471, (Chairman Sir Alexander Fleck) recommended certain steps for the release of Wigner energy, and improved instrumentation and filters for Windscale Pile No. 2.

1958 *Radioactive Substances Act* enabled regulations to be made, after consultation with the Radioactive Substances Advisory Committee, for the safe disposal of radioactive wastes.

1958 *Hydrogen cooling of alternators*—direct cooling of all conductors. The No. 2 generator at Willington "A", which commissioned in October, was the first machine to employ internal hydrogen cooling of both stator and rotor conductors. Gas pressure was at 30 lb/sq. in.

1958 *Geothermal power generation* at Wairakei, New Zealand. Start-up of the first generating set, a 6·5 MW back pressure unit, in November. Completion of Stage I, at 69 MW, in March 1960. Stage II, total capacity 123 MW, completed in 1963.

1958 Commissioning of the *first 120 MW units* in the U.K. on 23 December at the Blyth "A" station on the Northumberland coast, and on 28 December at the Kincardine station, South of Scotland E.B., on the north bank of the Firth of Forth. Turbine stop valve steam conditions were 1,500 lb/sq. in. and 1,000°F with reheat to 1,000°F. Altogether 44 of these standard units were installed in 14 stations in Great Britain.

1958 *Re-organisation of the C.E.G.B.*—Two main changes introduced:

(i) to secure more delegation of authority from headquarters to the localities, the Board's territory was divided into five *Regions*, entrusted with the maintenance of the power stations and the transmission system and with their operation to the requirements of the National Grid Control;

(ii) because of the increased size of generating plant and power stations, the design and construction of new power stations and associated sub-

stations were transferred to three *Project Groups* responsible direct to Headquarters.

1958 *Training Research Isotope General Atomic (TRIGA) reactor* at San Diego. The special feature of this 10–100 kW(t) reactor designed by General Atomic was its inherent safety. Core composition had a large prompt negative temperature coefficient of reactivity—any sudden excess reactivity would result in a fuel temperature which would automatically terminate the power excursion before any core damage resulted. It featured a graphite reflector, light-water cooling and a uranium–zirconium hydride fuel clad in aluminium which constituted an integral fuel moderator system. Zirconium hydride and light water were the moderator. The fuel contained 8·5 to 12 per cent of 20 per cent enriched uranium as a fine metallic dispersion in the zirconium hydride matrix. The H/Zr ratio was nominally 1·6.

1958 *Electroslag refining* process for melting metals. U.S.S.R. built first pilot plant and by end of year had two production furnaces in operation.

1958 *Underground gasification of coal.* A 3·75 MW power station, at Newman Spinney, Derbyshire, fired by gas from a National Coal Board underground gasification project, was completed at the end of the year. Intended as a prototype for a 60 MW station, it began operating in April 1959, but the trials ceased in the summer of that year because the results obtained did not warrant further expenditure. The station was demolished in 1960.

1959 *Microwave oven,* based on a continuous wave magnetron, demonstrated at a Catering Exhibition in London for reheating cooked food.

1959 *Water cooling of turbo-alternators*—Electrosila works in Leningrad commissioned a 60 MVA set at the Lenenergo station with *direct water cooling of both stator and rotor.*

1959 Commissioning of the first 100 MW set of the *Kariba hydro-electric project* on the Zambesi River. The first part of the scheme (6 × 100 MW) was completed in March 1962. The total eventual capacity was expected to be at least 1,500 MW.

1959 South Western E.B. start up the 3 MW gas-turbine station at Princetown for operation at time of peak. Powered by Bristol Siddeley Proteus turbines, this was the *first installation of aircraft-type gas turbines on the British system,* and also the *first fully-automatic remote-controlled station* in England.

1959 Introduction in Britain of solid-core plastic insulated aluminium (*"Solidal"*) cable—developed jointly by Aluminium Union Ltd., Northern Aluminium Co., Aluminium Laboratories, of Banbury, and Sterling Cable, and first manufactured for voltages up to 1,100 V. B.I.C.C. also produced some experimental 4-core cables.

1959 Spondon "H" *process steam station,* near Derby, commissioned. Of capacity 3 × 10 MW, it was unique among C.E.G.B.'s power stations in being designed primarily as a steam producing station, to supply a nearby British Celanese plant.

1959 *Automatic control in power stations*—Agecroft "C" started up, capacity 2 × 120 MW sets equipped with automatic control of *turbine output.*

1959 *Meters (Periods of Certification) Order 1959*—providing among other things that in general all meters will need *re-certification* at intervals of fifteen years.

1959 *Electron beam welding*—first commercial equipment available in the United States.

1959 *The grid*—commissioning of the *Severn and Wye 275 kV crossing* of 2¼ mile length from Aust to Beachley, including a one mile span across the Severn and

a 1,000 yard span across the Wye. The two high crossing towers were 488 ft. high.

1959 Start up in February of the U.K.A.E.A.'s *nuclear power station* at *Chapelcross*, Dumfriesshire. Like Calder Hall (1956), this station was based on gas-cooled natural uranium reactors and was designed primarily as a producer of plutonium for military purposes. Final capacity was 8 × 23 MW turbo-alternators operating on a dual-pressure steam cycle.

1959 *Report of the Committee on Co-operation between Area and Scottish Electricity and Gas Boards*, under the chairmanship of *Sir Cecil Weir*, published as Cmnd. 695, in March. The terms of reference aimed at improving the services provided by the two industries through co-operation, as in joint meter reading, but were not concerned with general policy or competition between the industries.
The committee reported that they did not consider that consumers would benefit if certain parts of the boards' activities were combined. They were satisfied that any formal co-operation along the lines they had been considering would not lead to worthwhile savings, even in theory.

1959 *Little Barford* "B" station commissioned. Had *completely remote operation* of the two 60 MW units. Boilers were of fully outdoor construction. The *automatic electronic boiler-control system* used single-analogue on-line computers and three-term process controllers—the *first comprehensive installation of its kind* in the country.

1959 275 kV cables connecting the No. 5 generator transformer at the Drakelow "B" station to the grid were commissioned on 24 April—the *first operational use of 275 kV cables* on the British system.

1959 *Fuel cells.* On 24 August, *F. T. Bacon* demonstrated his "Hydrox" (hydrogen-oxygen) fuel cell on an airfield at Cambridge. Developed over some twenty-seven years of research at the University, this was a prototype unit consisting of forty cells having a total rating of 2½ kW. For short periods the unit could produce 5 kW at 24 V. Claimed to be the most advanced fuel cell in the world, and the *first to become a commercial proposition.*

1959 *Mr C. R. King* (later Sir Robertson) appointed Chairman of the Electricity Council on 1 September 1959 (until 31 December 1961).

1959 *Heat pump* installations at the Meaford and Stourport power stations—C.E.G.B. sub-committee set up to examine the operating conditions and costs of these heat pumps and to compare the results with the costs of alternative forms of heating, reported in October.

1959 Commissioning in October of *Europe's first 200 MW unit* at the High Marnham station on the River Trent, near Retford, Notts., steamed from a 1,400,000 lb/h boiler, with the most advanced steam conditions yet introduced on the British system—2,350 lb/sq. in. at 1,050°F with reheat to 1,000°F at the turbine stop valve. The last of five 200 MW units commissioned in June 1962, units 4 and 5 having more advanced boilers of 1,350,000 lb/h capacity. Standard units of this size were later installed at the West Thurrock, Willington "B" and Kincardine HP stations. High Marnham was Europe's *first one million kilowatt coal-fired station.* It was the *first* to employ the *"merry-go-round" system of automatic discharge of rail coal wagons.*

1959 *Nuclear reactor research*—The *Halden Project* of the O.E.E.C. European Nuclear Energy Agency officially opened in October—the world's *first heavy water moderated boiling water* reactor, power 20 MW (thermal).

1959 *Nuclear reactor research:*
U.K.A.E.A.'s experimental *fast breeder reactor at Dounreay* went "critical" in

November. The aim with this kind of reactor was to produce up to three neutrons for every neutron absorbed, one to carry on the chain reaction, one to transmute a fertile nucleus into a fissile one, leaving one neutron to allow for loss by absorption by the coolant and reactor structure etc. From the outset the main goal of nuclear scientists had been to produce such a breeder reactor. The term 'fast' was used because breeding was more likely to take place when plutonium–239 was fissioned by fast neutrons, that is by neutrons that had not been slowed down by a moderator as in reactors such as Magnox (*q.v.*), A.G.R. (*q.v.*) and P.W.R. (*q.v.*).
Inauguration of the *"Merlin" reactor* of the "swimming pool" type, 5 MW, at the A.E.I. research laboratories at Aldermaston Court, built for fundamental and applied research.

1959 *Nuclear Installations (Licensing and Insurance) Act* gave Minister of Power control over nuclear installations.

1959 *The Control of Radioactive Wastes,* Cmnd. 884—contained the report of the Radioactive Substances Advisory Committee Panel on Disposal of Radioactive Wastes. Indicated that the 1957 average monthly discharge from Windscale was 2,612 Ci of beta-activity (cf. authorised 20,000 Ci) and 4·5 Ci of alpha-activity (authorised 150 Ci). The allowable limits were derived from International Commission on Radiological Protection limits. Recommended that no member of the public should receive from waste disposal more than 0·03 rem weekly and the whole population not more than 1 rem per person over thirty years—and to do what was reasonably practicable to reduce the doses far below these levels.

1959 A team of German and Russian scientists revealed the possibility of a lightweight *gas centrifuge.* Their Dr Zippe designed a machine about ⅓m long with a wall velocity of 350 m/s that could produce about 0·4 kg/year of enriched uranium.

1959 *Road heating*—first major installation, total loading of 900 kW covering about 55,000 sq. ft. of steep roadway, at the Mound, Edinburgh, connected in December by the South of Scotland E.B.

1959 Towards the end of the year the C.E.G.B. began to assemble research teams for work on *magnetohydrodynamic (M.H.D.) generation.* Interest became centred on developing a topping unit for conventional steam stations and ultimately for nuclear stations. Work was started on a 200 MW(t) open-cycle demonstration plant at the Marchwood Engineering Laboratories for commissioning in 1966, with electricity generation due to begin in 1967. By 1968 the plant had not yet been commissioned due to setbacks in experimental equipment, and changes in the long-term economics of power generation meant that the likely economic benefit could not justify the cost of further development. The work was, therefore, discontinued.

1959 *Rural electrification*—the South of Scotland E.B.'s development programme virtually complete at end of year, nine months ahead of schedule, when 93 per cent of all farms were connected or in process of being connected to the supply.

1959 Germany—Professor *Ulrich Hutter* designed a *100 kW test wind turbine,* located at Stotten in the Swabian Mountains by the Wind Power Study Group, which operated until 1968.

1959 China commissioned a 40 kW one-way *tidal power station at Shashan.*

1959 *"The Control of Radioactive Wastes",* Cmnd. 884, discussed the basic principles of radioactive waste arrangements and radiation exposure and laid the framework for the Radioactive Substances Act, 1960.

late 1950's and early 1960's *Underground Residential Distribution (U.R.D.).* In the U.S.A., development of pad-mounted transformers and polyethylene insulated primary cable made possible significant cost reduction in underground distribution, marking the beginning of what was called U.R.D. I.E.E.E. national conference on underground distribution in 1964 stimulated the spread of U.R.D. Principal feature was high voltage single-phase distribution to transformers serving one or a few consumers, typically at 15 kV.

1960 Foundation of the *European Committee for the Co-ordination of Electrical Standards in the Common Market countries,* for short *"CENELCOM"*, with the general aim of harmonising electrical standards in the E.E.C. countries.

1960 Interim Report of the *Committee on Consumer Protection* (Chairman: *J. T. Molony*), Cmnd. 1011. The Committee "found no evidence to suggest the marketing on any widespread scale of consumer goods from which recognised hazards have not been eliminated as far as reasonably practicable". They called for standard plugs and sockets.

1960 *Electrostatic paint spraying*—the Ransburg process introduced in the United States.

1960 *Railway electrification.* Inauguration of the Manchester-Crewe section at *25 kV single-phase AC*—the first main-line section with this system in the country.

1960 First of six 120 MW units commissioned at the *Northfleet power station* in Kent. *Data logging equipment,* the *first* to be installed *in a British power station,* provided a continuous scan of plant conditions.

1960 O.E.E.C. published in January *"Towards a New Energy Pattern in Europe"*, a report by their Energy Advisory Commission (Chairman *Professor Austin Robinson*) on the energy problems of Western Europe, in particular the shortfall between demand and domestic production.

1960 The *first commercial boiling water reactor* (B.W.R.) *nuclear station* commissioned at Dresden, Illinois. The station, owned by the Commonwealth Edison Co., had a capacity of 200 MW(e).

1960 *First supercritical once-through boiler* commissioned at the Margam "B" power station of the Steel Company of Wales. The 240,000 lb/h Benson boiler, designed and constructed by Simon Carves, steamed a 9·5 MW back-pressure set. Steam conditions at the turbine stop value were 3,000 lb/sq. in. 1,050°F.

1960 *Radioactive Substances Act* gave effect to the recommendation of the Panel on Disposal of Radioactive Wastes contained in Cmnd. 884, 1959 (*q.v.*).

1960 *First low thermal mass electric furnace* commissioned at John Thompson (Wilson Boilers) Ltd. Lilybank Works, Glasgow. Designed by the South of Scotland E.B.'s Industrial Advisory Service, the furnace was used for stress relieving of welded structures.

1960 White Paper *"The Nuclear Power Programme"* Cmnd. 1083, published June. Since it appeared that nuclear power would not compete in costs with conventional power as early as had been expected, the Government decided that the period of the programme was to be extended to provide for the construction of about *5,000 MW by 1968.*

1960 *"The Economics of Nuclear Power in Great Britain"* by Sir Christopher Hinton, F. H. S. Brown and L. Rotherham. Paper to 1960 World Power Conference, Madrid. Published in "Proceedings W.P.C.", 1960, Vol. VII, pp. 3887 etc.

1960 *Committee on Natural Resources in Scotland* of the Scottish Council (Development and Industry), Chairman: *L. A. Elgood.*

1960 *British Electrical Approvals Board for Domestic Appliances formed*—since 1971, *British Electrotechnical* Approvals Board for Household Equipment ("B.E.A.B.")—for approving applicances tested to British Standards, and publishing a list of appliances so approved.

1960 *Organisation of Petroleum Exporting Countries* (O.P.E.C.) created in September. Founder members were Iran, Iraq, Kuwait, Saudi Arabia and Venezuela.

1961 Publication of *"Homes for today and tomorrow"*—a Report of the Housing Advisory Committee (Chairman: *Sir Parker Morris*) of the Ministry of Housing and Local Government—covering design and equipment, including electrical socket outlets.

1961 *Electric stress relieving furnace*—believed to be the largest in the world—installed for use in the fabrication of the boilers for Dungeness nuclear power station.

1961 Commissioning of the *Rheidol hydro-electric power station* near a beauty spot, the Devil's Bridge, some ten miles from Aberystwyth. Of capacity 53 MW, this scheme received *several amenity awards.*

1961 Commissioning of the *Ffestiniog pumped-storage* hydro station, N. Wales, capacity 300 MW from 4 × 75 MW turbine/pump units—the *first installation of this type in the U.K.* and among the largest in the world at the time. The plant was later uprated to 4 × 90 MW units. Pumped storage was the only large-scale method of storing electricity, comprising an upper and lower reservoir with water being pumped from the lower reservoir to the upper when low cost electricity was available from the 'Grid' and returned to the lower reservoir through turbines when generation was required. Ffestiniog generated for four hours a day and could be brought on load rapidly, helping to meet sudden fluctuations in load caused, for example, by a loss of a large turbo-alternator or a transmission line, thus reducing the extent of expensive part-loading of steam plant.

1961 *H.V. transmission*—750 kV AC achieved by the U.S. General Electric Co. on their 4·3 mile prototype transmission system.

1961 *Electroslag refining process* for melting metals—serious work first started in the U.K. by British Iron and Steel Research Association (B.I.S.R.A.).

1961 *Factories Act 1961—Memorandum on the Electricity Regulations* Ref. S.H.W. 928.

1961 *Niagara Project* of the Power Authority of New York State, four miles below the Falls, inaugurated—ultimate capacity 2,190 MW, including a 240 MW pumped storage scheme, claimed to be the largest hydro plant in the Western World.

1961 *Domestic storage radiators* now being offered by some manufacturers.

1961 *"The Development of Rural Electrification. A Review of Progress".* Paper to the I.E.E. by G. F. Peirson and published in the "I.E.E. Proceedings", Vol. 108 Part A, No. 38, April 1961.

1961 *Power failure* on 15 May—South East and parts of London were blacked out when a fault cut off supplies from the Midlands and cascade tripping resulted which overloaded the 132 kV system. A protective circuit breaker opened on overload at Wimbledon which led to a surge on the system and interruption of supplies to Chichester. A loss of double-circuit supplies from Deptford West resulted in the complete isolation of the South East area where the power stations became overloaded and tripped. Subsequently, gas turbine sets were installed at new stations to safeguard auxiliary supplies.

1961 *"A Study of the Electrification of Four Farms"*, Utilisation Research Report No. 25, published by The Electricity Council.

1961 *Lighting*—introduction of the tungsten halogen lamp.

1961 *"A Domestic-Heating Survey of England and Wales"*, Utilisation Research Report No. 18, published by The Electricity Council.

1961 Commissioning in January of *Rugeley "A"* power station, the first station to be *built alongside the sinking of a new coal mine*, designed to supply most of the station's requirements.

1961 Appointment in March of a Departmental Committee under the Chairmanship of *Colin H. MacKenzie* to review the arrangements for *electricity supply in Scotland*. The Committee reported in November 1962, (*q.v.*).

1961 *Consumer Protection Act 1961*, based closely on proposals in the Interim Report of the Molony Committee April, 1960 (*q.v.*) permitted the Home Secretary to make regulations on design and construction of goods to reduce injury risk. Later legislation of this kind included the Trade Descriptions Act 1968, the Fair Trading Act 1973, the Restrictive Trade Practices Act 1976 and the Competition Act 1980.

1961 White Paper *"The Financial and Economic Obligations of the Nationalised Industries"*, Cmnd. 1337, April 1961. Laid down that the industries should aim to balance their accounts "taking one year with another" over a period of five years after providing for interest, and depreciation at historic cost. Provision should also be made for the difference between depreciation at historic cost and replacement cost, and allocations to reserve sufficient to make some contribution towards the industries' future capital development programmes. Financial objectives or "targets" were to be determined for each undertaking in the light of its needs and capabilities in relation to these criteria. In practice, targets were normally expressed as a rate of return on the undertaking's assets.

1961 *Fuel Oil.* Duty of 2d per gallon imposed—including oil burnt at generating stations—by the Finance Act 1961. In July this duty was increased to 2·2d per gallon.

1961 *Research*—Opening of the C.E.G.B.'s *Berkeley Nuclear Laboratories* in May, for research directed towards a better understanding of the behaviour and performance of nuclear reactors.

1961 Inauguration on 8 December of the *cross-Channel submarine cable* link between England and France—from Dungeness Point in Kent, to Boulogne, in the Pas de Calais, some 30 miles—operating on direct current at 100 kV above and below earth potential, permitting power exchanges between the two countries of up to 160 MW each way. It connected the British 275 kV system with the Electricité de France 225 kV network. Availability was poor due to fouling by ship's anchors and it was taken out of service in 1980 and decommissioned in 1982. A further HV DC link of 2,000 MW commissioned in 1986 operating at ± 270 kV and buried 1·5 m in the seabed.

1961 *Dry cooling tower* commissioned in December at the Rugeley "A" station. The 3·6M gal/h tower based on the Heller System was associated with a 120 MW set. This experiment for conserving water used water/air heat exchangers and a special condenser.

1962 *Professor R. S. Edwards* (later Sir Ronald) appointed Chairman of the Electricity Council on 1 January 1962 (until 31 October 1968).

1962 *Grid system*—inauguration of the new *National Control Room* at Bankside House, London to co-ordinate the seven Area Control Rooms.

1962 Second report of the *Scottish Peat Committee*, chairman *Sir Edward Appleton*, considered that whilst electricity generation based on Scotland's peat reserves could be undertaken on a substantial scale, the costs would be somewhat higher than the costs in the large new coal-fired stations (the Committee's first report was in 1954—(*q.v.*)).

1962 First International Symposium on *Magnetoplasmadynamic (M.P.D.) electrical power generation* at Newcastle-upon-Tyne, held under the aegis of the I.E.E.'s North Eastern Centre.

1962 *Electric arc furnaces*—first of the six 110-ton furnaces for steel production at the Templeborough melting shop of Steel, Peach and Tozer, Rotherham, went into operation—the "Spear" project.

1962 *First financial targets* announced for electricity boards—for 1962/63 to 1966–67 (House of Commons Official Report 28.3.62)—average gross return as percentage of average net assets of 12·4 per cent for the Industry as a whole.

1962 Demonstration of the *linear motor*, fitted to a rail trolley, for traction purposes by Prof. E. R. Laithwaite, Manchester University.

1962 A Committee to look at the scale of the next *nuclear programme* and the type of reactor to be adopted was set up under Sir Richard Powell, Permanent Secretary at the Board of Trade. Their conclusions were outlined in the 1964 White Paper "The Second Nuclear Power Programme", Cmnd. 2335 (*q.v.*).

1962 *Pumped storage*—commissioning of the 900 MW Vianden scheme in Luxembourg, operated as part of the Rheinisch—Westfalisches Elektrizitatswerk (R.W.E.)—the then largest pumped storage scheme in the world.

1962 *Establishment of the Ente Nazionale per L'Energia Elettrica ("E.N.E.L.")* the Italian National Electricity Board.

1962 *Computers for management information and accounting.* Yorkshire E.B. installed the first central computer for dealing with the needs of an entire Area Board.

1962 London E.B. opened a *Commercial Catering Centre* at Salem Road in Bayswater. Primarily to meet enquiries from London consumers, it assumed almost a national character and was re-named *The Electric Catering Centre* when taken over by The Electricity Council in 1969.

1962 *"The 400 kV grid system in England and Wales"*—paper by E. S. Booth, D. Clark, J. L. Eggington and J. S. Forrest to the I.E.E. on 14 March and published in the "Proceedings I.E.E." Vol 109, Part A, 1962. Paper outlined the plans for the 400 kV system.

1962 *275 kV/400 kV Super-grid crossing.* Commissioning in April of the Thames crossing between Northfleet, Kent and West Thurrock, Essex, designed for 275 kV initially and 400 kV ultimate operation. Tower height 630 ft.—the *highest transmission towers* in the country: crossing span, 4,500 ft.

1962 *Research*—new Central Electricity Research Laboratories *(C.E.R.L.)* at Leatherhead officially opened by the Minister of Power, in May.

1962 *"Planning for expansion in electricity supply"*—paper presented by R. S. Edwards and D. Clark to the British Electrical Power Convention in June, principally concerned with *demand forecasting* and the planning and financing of plant programmes.

1962 *First commercial nuclear power stations commissioned—Berkeley* (Glos.) design output 275 MW in June and *Bradwell* (Essex) design output 300 MW on 1 July. These and later stations of the first nuclear power programme were equipped with gas-cooled graphite-moderated reactors using natural uranium fuel canned in magnesium alloy ("magnox")—they were known as "Magnox" stations.

1962 Final report of the *Committee on Consumer Protection* (Molony Committee), Cmnd. 1781, July. Reviewed merchandising legislation and suggested formation of a *Consumer Council* to ascertain and review problems experienced by the consumer and to devise and advance the methods of resolving them (Interim report published April 1960).

1962 In August The Electricity Council's *Working Party on the Characteristics of the Space Heating Load* reported on the feasibility of applying load limiters to domestic and other small loads. They concluded that even when savings on plant costs could be achieved, they were not sufficient to provide the financial inducement for consumers to accept load limitations.

1962 *Nuclear reactor research*—the advanced gas-cooled reactor *("A.G.R.")* of the U.K.A.E.A. at Windscale operational in August.

1962 *Dounreay Fast Reactor (D.F.R.).* This experimental reactor of the U.K.A.E.A., which produced electricity as a by-product, achieved a power level of 30 MW(t) in August. In November the reactor started exporting surplus electricity to the national grid.

1962 *Electricity in Scotland*—Report of the departmental committee, appointed in March 1961 under the chairmanship of *Colin H. MacKenzie* to review the arrangements for electricity supply in Scotland, published in November. The committee's central recommendation that the two Scottish boards should be merged was rejected by the Government on the grounds that it would be unwelcome to a wide range of interests, although there was to be closer consultation and co-operation between the two boards. This took effect in 1965 when the two Scottish boards established an arrangement which placed the control of generation and the planning of future power stations on an all-Scotland basis.

1962 A Simon Carves 860,000 lb/h *slag-tap boiler* was commissioned at the Padiham "B" station to gain direct operational experience of this kind of boiler—might have an advantage over conventional pulverised-fuel boilers where there were problems of ash disposal.

1962 *15 MW gas turbine* unit went into service at the Hams Hall "A" station, powered by a Bristol Siddeley Olympus *aircraft-type jet engine.* Its purpose was to assess the performance of aircraft gas turbines for meeting peak-load and emergency requirements.

1962 *"The duty and development of modern power station plant"* by F. H. S. Brown. Parsons Memorial Lecture to the Institution of Mechanical Engineers on 12 December, published in the "Proceedings I. Mech, E", Vol. 177, 1963, pp. 1133 etc.

1962 Commissioning of the *first of two 275 MW units* at the Blyth "B" station, Northumberland, in December. They were steamed from 1,900,000 lb/h boilers and were the only units of this size on the system. Turbine stop-valve steam conditions were 2,300 lb/sq. in. at 1,050°F with reheat to 1,050°F.

1963 *Power failure*—on the night of 25–26 January a major disruption to the Grid occurred. Freezing fog forming ice on insulators on top of industrial pollution that had been moistened by a partial thaw, caused flashovers and leakage which operated protective gear. Reclosure was not possible until many insulators at substations had been hand cleaned.

1963 *Domestic storage heaters*—E.D.A. launched their *Unit Plan* campaign; and followed up their earlier (1957) work by publishing *design recommendations*, the major item of which was to make a charge controller compulsory.

1963 First large-scale application in the U.S.A. of the *combined-cycle* commissioned at the Horse-shoe Lake station of the Oklahoma Gas and Electric Co. A 220 MW gas-fired conventional steam unit was combined with a 27 MW gas-fired gas turbine unit, the gas turbine's exhaust providing preheating for the steam unit's boiler.

1963 *400 kV grid*—completion of the first tower, at Thorpe Marsh, near Doncaster.

1963 *Research*—commissioning of the C.E.G.B.'s *Marchwood Engineering Laboratories* near Southampton, mainly concerned with large-scale experimental work involving large rigs and pilot plants.

1963 *Metal painting by electrophoresis*—first commercial application, following development by the Pressed Steel Co., Oxford, in conjunction with I.C.I.

1963 *Diesel plant*—Jersey Electricity Co. commissioned a station designed for a final capacity of 50 MW, making it the largest diesel station in Europe.

1963 *Use of helicopters*—for overhead line maintenance. Faulty insulators replaced on 132 kV line.

1963 *Vacuum circuit breakers*—in full scale production by the U.S. General Electric Co.

1963 *Electron beam welding*—first industrial use, in Germany (in the U.K., under development by the British Welding Research Association).

1963 *Electricity in mining.* The N.C.B. began their experiments in the application of *remote control* to longwall mining operations, at Newstead and Ormonde Collieries. These experiments led to the operational development of *"R.O.L.F."* at the Bevercotes Colliery in 1967—*q.v.*

1963 *"C.A.N.D.U." nuclear reactors.* Nuclear Power Demonstration (N.P.D.) reactor near Rolphton, Ontario commissioned. This 20 MW(e) demonstration plant, a joint project of Atomic Energy of Canada, Ontario Hydro and Canadian General Electric Co. served as a prototype for later Canadian deuterium uranium (C.A.N.D.U.) stations. It uses natural uranium fuel in pressure tubes with heavy water as coolant and moderator. During the war, Canada was assigned the task of developing the heavy-water moderated reactor system as a method of plutonium production.

1963 *District Heating*—scheme at Vastera, Sweden, commissioned with two generating units each of maximum electrical output of 44 MW, together providing heat sufficient for 13,000 flats.

1963 *Nuclear power stations.* EdF commissioned their first commercial station at Chinon 1, a natural uranium graphite-moderated gas-cooled type, capacity 70 MW(e). By 1986, the total nuclear capacity of EdF and the Commissariat à l'Energie Atomique was 47,170 MW(e) from 49 reactors—mainly PWR.

1963 U.K.A.E.A.'s prototype *advanced gas-cooled reactor* (AGR) at Windscale reached design output in January, and was synchronised with the grid in February. It ceased continuous operation and electricity generation in March 1981, having provided a net electrical output of 34 MW at an availability of 82 per cent over 18 years, and producing over 3·5 TWh of electricity. By using ceramic uranium dioxide pellets contained in thin stainless steel cans higher operating temperatures than the Magnox fuel/can combination were achieved. Steam pressure and temperature were about the same as for the best conventional stations. Because stainless steel absorbs neutrons it was necessary to raise the content of the fissile uranium–235 content of natural uranium from 0·7 per cent (the remaining 99·3 per cent is non-fissile uranium–238) to about 2·3 per cent (enrich the fuel) in order to maintain a critical assembly (for a chain reaction to continue).

1963 *The Consumer Council* set up in March by the President of the Board of Trade, following a recommendation of the Molony Committee 1962 (*q.v.*). Its functions were to inform itself about consumers' problems and about matters affecting their interests, and promote action to deal with these. It was closed down at the end of 1970.

1963 *Report of "Ingrid" Mission*—of May 1961, published by the O.E.C.D. Under the leadership of *Sir Robertson King*, the Mission visited the United States primarily to study economic and technical aspects of *interconnected networks* and power system operation.

1963 *Electricity in Scotland*—publication in February by the North of Scotland H.-E.B. of their comments on the MacKenzie Committee Report, of November 1962 (*q.v.*).

1963 The National Economic Development Council's report "The growth of the U.K. economy 1961–1966" published in February. The electricity supply industry accepted a request from Government that it would base its forecasts on the assumption that the N.E.D.C.'s target of a *4 per cent growth rate* would be achieved.

1963 *"Report from the Select Committee on Nationalised Industries—the Electricity Supply Industry"*—Vol. 1 Report and Proceedings, Vol. II Minutes of Evidence, Vol. III Appendices and Index, H.C. Paper 236. The committee's remit was to report on the state of the electricity supply industry in England and Wales and the way in which the industry as a whole was proposing to deal with the problems that faced it—perhaps the most intensive examination of the industry yet undertaken. Among the major points made by the committee was that "the industry's structure appeared sound, and, if it was open to criticism, this should be confined to its performance."

1963 *Dounreay fast reactor (D.F.R.)* first operated at full design output of 60 MW(t) in July. Net electrical output was 12·5 MW (later 14 MW).

1963 First public demonstration of the *electrophoretic painting* process at the Industrial Demonstration Centre of the North Western E.B.

1963 *Thorpe Marsh* station, near Doncaster started up in December. Two *550 MW cross-compound* sets were each steamed from a single 3,750,000 lb/h boiler, Europe's largest units at the time of commissioning. Steam conditions were 2,300 lb/sq. in. at 1,050°F with reheat to 1,050°F.

1963 *400 kV grid*—commissioning of the *experimental 400 kV line.* The 64 mile long double-circuit 275 kV line from High Marnham to Monk Fryston had been re-insulated and then re-energised at 400 kV for the first time.

1963 White Paper *"Domestic Fuel Supplies and Clean Air Policy"*, Cmnd. 2231, published in December, gave the background to the changes being made by the Minister of Housing and Local Government in the arrangements for grants under the Clean Air Act 1956, in an effort to overcome regional difficulties over supplies of suitable fuels and ensure that progress with smoke control was not impeded. *Ministry of Housing and Local Government Circular No. 69/63,* issued to local authorities, giving advice based on the findings of the White Paper, said that householders should be discouraged from installing, with the aid of the Clean Air Grant, all forms of electric space heaters other than storage heaters.

1964 *Computer control of 200 MW unit at West Thurrock* power station. The installation controlled the raising of boiler pressure, the run-up of the turbine to full speed, and the subsequent loading of the generator—the *world's first application to a large coal-fired unit.*

1964 *"The Economics of the Domestic Space Heating Load"* by P. A. Lingard. Paper to Symposium on Electricity and Space Heating, in March, organised by the Power Division of the I.E.E. and the Institution of Heating & Ventilating Engineers. Published in "Electricity and space heating" edited by E. M. Ackery, London: Blackie, 1965.

1964 *"National Power Survey. A Report by the Federal Power Commission 1964"* (U.S. Government Printing Office: 1964 0-735-906). A major undertaking by the F.P.C. projecting U.S. power needs for the 1970s and 1980s and indicating how the supply industry could move towards fully co-ordinated power networks covering broad areas of the U.S.A. A second survey was published in 1971 covering future load growth, with fuller treatment of such aspects as changing power technology, environmental problems, commissioning delays and fuel supply problems. ("The 1970 National Power Survey", U.S. Government Printing Office 0-356-238, 239, 240, 241.)

1964 *Submarine cables*—first 132 kV oil-filled cable in British waters, laid by A.E.I. between mainland and Isle of Wight.

1964 *Electromagnetic forming* of metals introduced by the National Engineering Laboratory.

1964 *Institution of Electrical and Electronics Technician Engineers ("I.E.E.T.E.")* in course of formation, the Council governing its affairs to be appointed initially by the A.S.E.E. Council.

1964 *Nuclear district heating* in Sweden—a 65 MW(t) heavy-water cooled and moderated reactor in operation at Agesta, providing steam for central heating 12,000 flats and 10 MW of electricity.

1964 *Use of helicopters* to transport sections of 400 kV grid towers to sites in Kent.

1964 Introduction of the *integrated-system transformer,* usually 33/11 kV, the design of which was related to a continuous emergency rating for peak-load conditions with forced cooling.

1964 *"The 1961 Sample Survey of Domestic Consumers"*, Utilisation Research Report No. 42, published by The Electricity Council.

1964 The Electricity Council's Working Party on the *Characteristics of the Space Heating Load* reported in February.

1964 *Hunterston "A" nuclear station* near Largs on the north Ayrshire coast, started up in February. Design output was 300 MW from six 60 MW sets.

1964 White Paper *"The Second Nuclear Power Programme"* Cmnd. 2335, published April. Government decided that for planning purposes a programme of 5,000 MW of nuclear capacity should be adopted in England and Wales for commissioning during the six years 1970 to 1975. The programme was intended to be flexible and would be reviewed at regular intervals in the light of later information. The question of a further nuclear station in Scotland would be considered in these reviews. The C.E.G.B., after a most thorough assessment chose a design based on the Advanced Gas Cooled Reactor (A.G.R.) developed by the U.K.A.E.A. In the event the programme comprised five stations with a total design capacity of 6,480 MW—Dungeness "B" in Kent, Hinkley Point "B" near Bridgwater in Somerset, Hartlepool in Cleveland, Heysham in Lancashire, and the South of Scotland Electricity Board's Hunterston "B" station near West Kilbride, Strathclyde. Each station has two reactors with a single 660 MW turbo-alternator per reactor. Hinkley Point "B" and Hunterston "B" commissioned in 1976 and Dungeness "B" in 1985.

1964 On 21 April Sir Alec Douglas-Home announced that part of the plutonium produced in commercial reactors will be used for civil purposes in the UK and part sent to the USA in exchange for U235. It was not envisaged that any of this plutonium would be used for military purposes. (House of Commons Official Report 21 April col.1098)

1964 Russia commissioned the first *V.V.E.R. water-moderated water-cooled pressure vessel reactor at Novo Voronezh*. Fuel was 1·5–2 per cent enriched uranium dioxide clad in zirconium. The site was fully developed by 1980 with a capacity of 2455 MW. This P.W.R. type and the R.B.M.K. channel water-graphite boiling reactor (*q.v.*) formed the mainstay of the Soviet nuclear programme.

1964 The generating *plant margin* over forecast average cold spell simultaneous maximum demand adopted for planning purposes was increased from 14 per cent to 17 per cent following recommendations in the 1963 report of the Select Committee on Nationalised Industries on the Electricity Supply Industry. The security standard satisfied was a risk of disconnection at winter peak of three per century. The increase allowed for higher forecasting uncertainty and increased allowance for severe weather.

1964 *Japan*—new basic legislation passed to control the electricity supply industry—*Electric Utility Industry Act* (later amended by legislation in 1967, 1970 and 1973). Ministry of International Trade and Industry was the responsible ministry.

1964 *Supply industry dispute.* "Report of a Court of Inquiry into the causes and circumstances of a dispute between the parties represented in the National Joint Industrial Council for the Electricity Supply Industry", (Cmnd. 2361) published May, recommended the boards and unions to resume negotiations on a stage by stage approach to a *staff status scheme for manual workers.*

1964 *H.V. transmission research*—inauguration in May of test line at C.E.R.L., which could be operated at the equivalent of *800 kV* system voltage.

1964 *E.D.A. Testing House,* Leatherhead, integrated into The Electricity Council and given its present title, *Appliance Testing Laboratories ("A.T.L.").*

1964 *Magnetohydrodynamic (M.H.D.) generation of Electricity:*
Second International Symposium on M.H.D. held in Paris in July under the aegis of O.E.C.D.'s European Nuclear Energy Agency. (The series was initiated by the Newcastle Symposium on M.P.D., September 1962.)

Electricité de France had an experimental 8 MW M.H.D. generator at their Renardieres Centre.
For the first time in the world—*M.H.D. generation was achieved below 1,800°C* by the International Research and Development Co. Ltd.

1964 *Dragon experimental high temperature reactor (H.T.R.)* at Winfrith, Dorset, first operated at low power in August. Operation at high power began in July 1965. The 20 MW(t) reactor was a joint European project run through the European Nuclear Energy Agency of the O.E.C.D.

1964 *Third United Nations International Nuclear Conference,* held Geneva, 31 August–9 September.

1964 Commissioning of *the first* of two *300 MW units* at West Thurrock station, Essex. The boilers, of outdoor construction, were rated at 2,050,000 lb/h. Steam conditions were 2,300 lb/sq. in. at 1,050°F with reheat to 1,050°F. Four other units of this size were later commissioned at the Cockenzie station of the South of Scotland E.B.

1965 The first of two 120 MW oil-fired units commissioned at the *Carolina Port "B" station* of the North of Scotland H.-E.B. It achieved the *highest thermal efficiency* of any steam station in the U.K. in the years 1966/67, 1967/68 and 1969/70 to 1972/73.

1965 *World's first 1000 MW set* commissioned—a cross-compound American G.E.C. unit at the Ravenswood station of Consolidated Edison Co. of New York, with steam conditions 2,400 lb/sq. in. at 1,000°F and reheat to 1,000°F.

1965 Early in the year, The Electricity Council suggested the desirability of a *ducted warm-air storage system*—to be called *"Electricaire"*. By the end of the year the Council had published an Electricaire Design Manual and an interim test specification had been prepared and was in use.

1965 *Plasma jet furnace* for refining steel now operating at the research laboratories of the English Steel Corporation.

1965 *Sulphur hexafluoride (SF_6) switchgear* in use in mines at voltages of 6·6 kV and 11 kV.

1965 *First radio-isotope generator*—the U.K.A.E.A.'s milliwatt generator, using a radioactive isotope heat source, for operating a marine light.

1965 *Dungeness "B" nuclear station*—Minister of Power announced the choice of an A.G.R. design. Work commenced in 1966, but because of fundamental design faults it did not commission until 1985.

1965 *French Government Order,* Decret No. 55–662, set out conditions for connecting independent generators to the EdF system and purchasing their supplies.

1965 The *Enrico Fermi F.B.R.* in Michigan commenced operation.

1965 *Experimental Breeder Reactor II* (E.B.R. II) in Idaho commenced operating.

1965 White paper *"A Ten-Year Programme for Electricity Supply in Northern Ireland"*, Cmnd. 478, gave the Government's decision on a survey carried out by their consultant, Sir Joseph Eccles. A new joint body was to be formed (see under 1967) in succession to the existing Joint Electricity Committee, and a nuclear station was envisaged.

1965 *First 400 kV transmission line*—inauguration of the 150-mile section between the Sundon substation (Beds.) and the West Burton power station. With a

normal weather capacity of 1,800 MVA per circuit the line had three times the power carrying capacity of a heavy duty 275 kV line and eighteen times the capacity of the original 132 kV lines.

1965 *District heating*—combined electricity/district heating station, operated by the Ministry of Works for the Ministry of Defence, opened at Aldershot with 4 × 2·14 MW diesel sets; final capacity was expected to be 20–24 MW.

1965 *Electroslag refining (E.S.R.)* under active investigation by steel industry (B.I.S.R.A. have been working for five years on this technique).

1965 *Nuclear Installations Act 1965,* provided for the restriction of certain nuclear installations to licensed sites and the prohibition of certain operations except under permit.

1965 *First main gas turbine stations* commissioned—at Earley power station a 56 MW machine powered by four Rolls Royce "Avon" jet engines, and at the Dunfermline station a 70 MW machine, powered by four Bristol Siddeley "Olympus" engines.

1965 Commissioning of the *first auxiliary gas turbine unit* at the Tilbury "B" station. The 17 MW unit, powered by a Bristol Siddeley Olympus jet engine, provided standby supplies for the auxiliary plant of one of the main steam units and also peak power when required.

1965 *Nuclear commissioning*—two 500 MW stations, viz: *Trawsfynydd* station in the Snowdonia National Park, the only inland nuclear station, with four 145 MW sets; *Hinkley Point "A"* near Bridgwater, Somerset, with six 93·5 MW main sets and three 33 MW auxiliary sets; and *Dungeness "A"* on the Kent coast adjacent to the Romney Marsh, with design output of 550 MW from four 142·5 MW sets.

1965 *Vacuum circuit breakers.* Eastern E.B. carrying out field tests on 11 kV units imported from the U.S.A.

1965 *11 kV "Pocket" substations* being ordered at the South Western E.B.

1965 *"Protective Multiple Earthing"*—any multiple earthing other than that permitted by Regulations 4 and 8 of the "Electricity Supply Regulations, 1937" had to be approved by the Minister of Power with the concurrence of the Postmaster-General. Consents were given to six Area Boards to use p.m.e. in any part of their area of supply and it began to be introduced on a significant scale in medium-voltage distribution systems, leading to the development of c.n.e. cables (see under 1966).

1965 *"The 1963 Domestic Heating Survey"*, Utilisation Research Report No. 48, published by The Electricity Council.

1965 *Isotopic thermoelectric generators.* The U.K.A.E.A.'s *"R.I.P.P.L.E."* (Radio Isotope Powered Prolonged Life Equipment) demonstrated with 75 and 90 mW units. The project reached the commercial stage in 1968 with a 4 W unit for powering an aircraft ground radio-beacon.

1965 *Centre Européen de l'Entreprise Publique* ("C.E.E.P."), formed in Brussels with the object of representing the interest of the "public" undertakings *vis-à-vis* the Commission of the E.E.C. Membership included electricity supply undertakings.

1965 The Electricity Council, on 1 April, established at headquarters the *National Fault and Interruption Reporting Scheme* for the distribution systems of the Area Boards and the two Scottish Boards. The purpose of the scheme was to

show those aspects of system planning and construction which offered the greatest prospects of improved performance.

1965 *H.V. DC transmission.* In the U.S.S.R., the 300-mile link between the Volgograd and Donbas hydro-electric stations, rating 750 MW at 400 kV above and below earth potential, completed in May.

1965 *Electricity Supply Industry Training Board* ("E.S.I.T.B.") established on 24 June, under the Industrial Training Act 1964; was concerned with the development of training within the electricity supply industry in Great Britain and, insofar as it generates and distributes electricity, London Transport. (See also under "Training for the future" 1972.)

1965 *Resale price of electricity.* On 1 July the electricity boards in England and Wales fixed maximum prices at which electricity might be resold for use in domestic premises, using their powers under Section 29 of the Electricity Act, 1957. Maximum charge per unit was fixed at 0·25d above the final unit rate in each board's domestic tariff, plus a daily charge of not more than 4d.

1965 *Status Agreement* for industrial staff in electricity supply, completed in September. Covered a series of major changes in the terms and conditions of employment, negotiated during 1962 and 1965 between the supply industry in Great Britain and five trade unions. Four of the major aspects of the Status Agreement concerned the use of flexibility of work patterns, employee co-operation and movements in hours of work, rates of pay and earnings, and changes in manpower.

1965 *Dungeness "B" A.G.R. project.* Publication by the C.E.G.B. in July of *two booklets*: (i) "Dungeness 'B' Nuclear Power Station" and (ii) "An appraisal of the technical and economic aspects of Dungeness 'B' nuclear power station".

1965 *"The National Plan"* Cmnd. 2764, published in September, provided for a growth of 25 per cent in the gross domestic product up to 1970, equivalent to an average annual growth of 3·8 per cent. The Electricity Council's demand forecast for the year 1971–72 was geared to this plan.

1965 *World's first 735 kV system*—the 226-mile line carrying 300 MW from the Manicouagan hydro-electric power station to the Poste Lévis substation, Quebec, of the Hydro-Quebec transmission system, commissioned in September.

1965 Establishment of *The Electricity Council Research Centre ("E.C.R.C.")* Capenhurst, Cheshire, for research on distribution technology and the utilisation of electricity.

1965 National Board for Prices and Incomes ("N.B.P.I.") Report No. 5 *"Remuneration of Administrative and Clerical Staff in the Electricity Supply Industry"*, Cmnd. 2801.

1965 Commissioning of the first of 4 × 100 MW single-stage reversible pump turbines at the *Cruachan pumped storage station* of the North of Scotland H.-E.B., Loch Awe in Argyllshire. It operated under a head of 1,195 ft., at the time of commissioning the highest in the world for this type of plant.

1965 White Paper *"Fuel Policy"*, Cmnd. 2798, published in October, set out the principles which should govern a co-ordinated national fuel policy and the machinery and measures whereby the Government proposed to secure and maintain such a policy. Consumer freedom of choice was to be an essential guide to the efficient planning of supplies provided that the prices reflected all relevant costs. Among the recommendations was that the *electricity supply industry should continue to give preferential treatment to coal over other fuels.*

1965 *Cooling tower failures.* On 1 November three of the eight cooling towers at the Ferrybridge "C" station collapsed. The C.E.G.B.'s Committee of Inquiry (Chairman: Dr L. Rotherham), which reported in August 1966, found that the failures were primarily caused by a serious under-estimate of wind loading in the design. C.E.G.B. immediately embarked on a programme of tower reinforcement.

1965 *The first find of North Sea natural gas* was made in October by B.P. in the West Sole Field about 40 miles off the Humber. The first supplies came ashore at the Easington shore terminal in 1967.

1965 On 9 November the malfunctioning of a relay at Ontario Hydro's Beck No. 2 hydroelectric plant initiated cascade tripping which led to *supply interruptions in the N.E. U.S.A. and Ontario from* about 5.15 p.m. affecting 30 million people over an area of 80,000 square miles. On the New York system the interruption lasted nearly 14 hours.

1965 N.B.P.I. Report No. 7 *"Electricity and Gas Tariffs. London Electricity Board and Scottish, South Western and Wales Gas Boards"*, Cmnd. 2862.

1965 *Nuclear Installations Act*—S. 24 empowered the Ministry of Power to appoint inspectors. The Nuclear Installations Inspectorate was established—later to be transferred to the Health and Safety Executive under the Health and Safety at Work etc. Act 1974.

1965 *275 kV pipe-type compression cable* installed in Dartford road tunnel under the Thames Estuary, to reinforce supplies to South East England: first circuit commissioned in December.

1965 *350 MW units* commissioned at the *Drakelow "C" L.P.* and *Blyth "B"* stations. The two units at each station are the only ones of this size on the British system. Boiler capacities are 2,350,000 lb/h at Blyth "B" and 2,450,00 lb/h at Drakelow "C" L.P. Steam conditions at the turbine stop valve are 2,300 lb/sq. in. and 1,050°F with reheat to 1,050°F.

1966 *Electronic turbine governor control*—first practical application on the 300 MW No. 5 set at West Thurrock power station.

1966 *950 MW turbo-alternator* unit commissioned at TVA's Bull Run power station.

1966 *First 275 kV substation in London*, commissioned at Tottenham.

1966 *Linear motors.* Herbert Morris Ltd. developed first commercial model.

1966 *Electrolytic sewage treatment.* First commercial installation of new system using electrolysed sea water developed by Constructors John Brown Ltd. in co-operation with The Electricity Council, at La Creux Mahie on the island of Guernsey.

1966 *First single stack chimney* with four flues in the one stack for *2,000 MW power station*, completed at Eggborough.

1966 *Productivity.* South of Scotland E.B. introduced a series of *yardsticks for the assessment of individual performance.* These controls were later amplified and improved, and the N.B.P.I. in their report No. 42, Cmnd. 3405, 1967—*q.v.*—advocated that the board's practices should be widely adopted.

1966 *Sodium conductor cables* under active development for distribution systems in the United States, including a design with polythene insulation for use up to 15 kV.

1966 *First high pressure sodium lamps* in Europe used in experimental street-lighting installation.

1966 *Superconducting DC motor* developed by the International Research and Development Co. for the Ministry of Defence (Navy). Claimed to be the *first in the world*, this homopolar motor is rated at 50 hp. (Three years later the company demonstrated a 3,250 hp superconducting motor—see under 1969.)

1966 *Northern Ireland Development Association* set up to replace the Northern Ireland Area Committee of E.D.A., following the integration of E.D.A. into the Electricity Council on 1 January.

1966 *First Target Nuclear Programme* published in accordance with the Euratom Treaty.

1966 Commissioning of *Sizewell nuclear station*, on the Suffolk coast. Design output is 580 MW from two 325 MW sets. A feature of the station is that both reactors are housed in the one building.

1966 *House service pillars.* South Western E.B. introduced trial installations of pillars providing multi-house service connections on new housing estates, without underground jointing.

1966 *Combined neutral and earth (c.n.e.) cables* for p.m.e. distribution systems—introduction of the C.O.N.S.A.C. cable, the first c.n.e. type to be used in commercial quantity.

1966 *Battery electric vehicles.* Early in the year, The Electricity Council's demonstration of four battery electric cars, *two* of them conversions made under Council research contract, created wide interest.

1966 *The Electricity Council*, on 1 January, took over the responsibility for all national promotional work hitherto carried out by E.D.A. for the Area Boards of England and Wales and the E.D.A. was reconstituted as the *E.D.A. Division* of Council headquarters.

1966 *Computer control of group of power stations.* Experimental project to load 31 generating sets in six stations in the South Western Region under way in January.

1966 *Prototype fast reactor (P.F.R.).* Minister of Technology announced on 9 February the Government decision to authorise the construction by the U.K.A.E.A. of a 250 MW(e) P.F.R. on the Dounreay site. Work started mid-year and commissioning was expected in 1973. This intermediate stage between the D.F.R. and large commercial F.B.R.'s had liquid sodium cooling and used mixed oxides of plutonium and uranium as fuel, clad in stainless steel and made up into clusters of thin pins. Steam conditions at the turbine stop valves were 2,300 lb/sq. in. at 955–1,000°F—a single 300 MW set was used.

1966 *"Second Report from the Select Committee on Nationalised Industries—Gas, Electricity and Coal Industries"*, H.C. Paper 77, published in February, enquired into the current problems of the gas, electricity and coal industries. Representatives of the electricity supply industry gave reasons for the shortfall in commissioning of generating plant.

1966 *SF_6 circuit breakers.* C.E.G.B.'s first 132 kV unit commissioned at Hall Green, Birmingham, substation in March.

1966 Launching of the two new *"roll-on roll-off" vessels* conceived by the C.E.G.B. for carrying heavy electrical and other plant for new power stations under construction. These ships, named "MV Aberthaw Fisher" and "MV Kingsnorth Fisher" were the *first of their type in the world.*

1966 *Ripple control of consumers' appliances.* Midlands E.B. commissioned a pilot scheme at the Feckenham 275/66 kV grid supply point. Water heating of some 400 customers was controlled by a 300 Hz signal injected into the system.

1966 *Semi-automatic control of set start-up, loading, and shutdown* introduced in June as a normal routine for the first time in the U.K. at the Kincardine HP station of the South of Scotland E.B., when the station was transferred from base load operation to two-shift working.

1966 *"The Prospects for Alternative Methods of Generation of Electric Power: A Comprehensive Review"* by F. H. S. Brown. Paper to World Power Conference, Tokyo, published in the Proceedings, 1966, Vol. III, p. 1441 etc.

1966 O.E.E.C. published *"Energy Policy—Problems and Objectives"* a report by their Energy Committee on the energy situation of member countries grouped in three regions, North America, Western Europe and Japan.

1966 *"Report on visit to the United States and British Columbia"* by R. F. Richardson and P. A. Lingard, published in September. The purpose of the visit was to assess the impact of natural gas on electricity growth, particularly in the domestic sector.

1966 *First international Conference on Clean Air,* in London, in October.

1966 Establishment of the *Power Engineering Research Steering Committee* to develop and co-ordinate collaboration in research. The committee included representatives of The Electricity Council and electricity boards and senior executives of electrical manufacturers, cable-makers and boiler-makers.

1966 *Live line working:*
First U.K. scheme for *275 kV* demonstrated by the South of Scotland E.B. on the Clyde's Mill-Stratheven line, in October.
"Bare-hand" technique for *500 kV* demonstrated by the Hydro-Electric Power Commission of Ontario, in November.

1966 *"Power Supply for 1970"* by E. S. Booth. Chairman's Address to I.E.E. Power Division on 26 October (published in "Proceedings I.E.E.", Vol. 114, No. 1 January 1967, p. 89 etc.)

1966 *La Rance Tidal Power Scheme,* France, commissioned. Final capacity 240 MW from twenty-four bulb turbo-generators each of 10 MW. Generated at peak times practically independent of the state of the tide.

1966 *The Electricity Council* granted a patent, in December (applied for in February 1964), for a *thermal storage heater* incorporating an air/water heat exchanger suitable for use with hot-water central-heating systems—called *"Centralec".*

1966 *First 500 MW unit* commissioned in December—at Ferrybridge "C" station, Yorks. The 2,000 MW station was completed in 1968. Each of the four 500 MW sets was steamed from a 3,450,000 lb/h boiler, with steam conditions at the turbine stop valve, 2,300 lb/sq. in. at 1,050°F with reheat to 1,050°F. Plant programmes included 49 of these standard units in 14 new stations.

1967 *Electricity in mining.* N.C.B. commissioned the R.O.L.F. (remotely operated longwall face) automatic control system at Bevercotes colliery, Notts—the *first colliery planned for a complete and integrated system of mining.*

1967 *A.C.E. trailers.* Commissioning of the first trailer equipped with *air cushion equipment,* based on the hovercraft principle, conceived by the C.E.G.B. for the transport of heavy indivisible loads, such as transformers.

1967 *Lighting*—introduction of the *high pressure sodium lamp,* in the City of London.

1967 *Natural gas firing.* A 65 MW unit at *Hams Hall "C"* station was converted, as an experiment, to dual coal/natural gas firing. The full conversion of the six 65 MW units was completed in 1971. In 1972 conversion was completed at a second station, West Thurrock, 1,300 MW.

1967 Opening of The Electricity Council's *Electro-Agriculture Centre* at a permanent site of the Royal Show at Stoneleigh, Warwicks; and *Electric Garden* at the Gardening Centre, Syon Park, Middlesex.

1967 *Aluminium wiring in use* in pilot scheme by the Midlands E.B.

1967 *First supercritical unit* on the British public supply system went into service at the Drakelow "C" HP station. A 2,500,000 lb/h Babcock and Wilcox boiler, developed from the Benson once-through boiler, steamed an English Electric 375 MW set. Stop-valve steam conditions were 3,500 lb/sq. in. 1,100/1,000°F.

1967 C.E.G.B. *bulk supply tariff*—new structure introduced on 1 April with running rates based on the running costs of power stations at the margin instead of on average running costs; and two capacity charges, one related to basic system capacity costs, the other to the cost of plant used during peak periods only. This was an attempt to collect the marginal cost of each unit according to the time it was produced. Marginal cost for any year is the excess of (a) the present worth in that year of system costs with a unit permanent output increment starting then, over (b) the present worth in that year of system costs with the unit permanent output increment postponed to the following year.

1967 Commissioning of the first of four 300 MW units at the *Cockenzie* station, of the South of Scotland E.B., on the Forth Estuary. The set was steamed from a 2,050,000 lb/h boiler. Turbine stop valve conditions were 2,350 lb/sq. in. at 1,050°F with reheat to 1050°F. A leading station in *automatic control*—with control equipment applied to each turbine, to control the preparation of auxiliary plant and the operation of the turbines through all stages of running-up to full power, and in the reverse order for plant shut-down.

1967 Electricity (Supply) Act (Northern Ireland) 1967 established the *Northern Ireland Joint Electricity Authority* in succession to the Joint Electricity Committee, with wider powers to supervise and control generation, transmission and the preparation of generating plant programmes.

1967 *British nuclear set-back*—On 11 May experimental fuel in one channel of *Chapelcross* Reactor no. 2 melted. The reactor was shut down immediately. A piece of graphite from one of the sleeves lining a fuel channel partially obstructed gas flow causing overheating of the fuel. The reactor was out of action until August 1969 because of difficulties in removing the blockage but has since operated satisfactorily.

1967 *Great Canadian Oil Sands* project to produce crude oil from Athabascan tar sands started up.

1967 *Rapsodie* experimental 20 MW (t) *liquid-metal-cooled FBR* commissioned by Commissariat a l'Énergie Atomique (CEA). In 1971 it was uprated to 40 MW (t) (fortissimo version).

1967 At Massachusetts Institute of Technology—a pioneer 45 kVA *prototype superconducting generator* demonstrated—believed to be the first application of superconductivity to a rotating field winding.

1967 N.B.P.I. Report No. 36 *"Productivity Agreements"*, Cmnd. 3311. Included the electricity supply industry's *"Status Agreement"*.

1967 *Support for coal*—Minister of Power announced in the House on 18 July that the supply industry had been asked to increase their coal burn by up to 6 million tons a year in the period to March 1971. Additional costs, resulting from reduced oil burn, would be met from public funds. This was given effect under Section 6 of the *Coal Industry Act 1967,* although such additional costs as those incurred in holding excess coal stocks, and deferring conversions to oil firing, were not reimbursable. Assistance of this kind had already been given to the coal industry for over two years, the costs being borne by electricity consumers.

1967 N.B.P.I. Report No. 42 *"Pay of Electricity Supply Workers"*, Cmnd. 3405.

1967 *District Heating Association* formed in October.

1967 *"Report from the Select Committee on Science and Technology—UK Nuclear Reactor Programme"*, H.C. Paper 381, included the recommendation that the consortium system of tendering for nuclear power stations should be phased out as existing contracts were completed; and that a single Government body should be set up to deal with all aspects of nuclear energy policy.

1967 *Aluminium smelters.* Board of Trade invited proposals from aluminium companies for the establishment of aluminium reduction plants in development areas. The Government announced special arrangements concerning electricity supplies on 4 October. These, with a description of the projects and details of Government financial support were set out in the White Paper *"Industrial Investment. The Production of Primary Aluminium"*, Cmnd. 3819, November 1968. Three projects were agreed—(i) An Alcan plant of 120,000 tons ultimate capacity at Lynemouth, Northumberland, with electricity to be provided from a new coal-fired station owned by Alcan, and coal supplied by the N.C.B. under a long-term contract; (ii) a British Aluminium Co. plant of 100,000 tons initial capacity at Invergordon, in Ross and Cromarty, supplied with electricity by the N.S.H.-E.B.; and (iii) a plant of 100,000 tons initial capacity at Holyhead operated by Anglesey Aluminium Metal (jointly owned by—Rio Tinto-Zinc, B.I.C.C., American Kaiser Aluminium and Chemical) and supplied by the C.E.G.B. The three plants were planned for commissioning in 1971.

1967 White Paper *"Nationalised Industries: a Review of Economic and Financial Objectives"*, Cmnd. 3437, published in November. Reviewed the main considerations which should apply to investment and pricing policies and laid down the principle that *investment appraisal should be based on the use of a test discount* rate. The Government decided that a test discount rate of 8 per cent was a reasonable figure under the circumstances then obtaining. In August 1969, the rate was raised—except for steel—to 10 per cent.

1967 White Paper *"Fuel Policy"*, Cmnd. 3438 published in November, stated the Government's policy for the primary fuels with special reference to the new sources available—natural gas and nuclear power. The policy aimed to make possible a national supply of energy at the lowest total cost to the community having regard to a whole range of relevant considerations—economic and social—and to national and regional economic policies. Government accepted as in the national interest the *rapid introduction of nuclear power and North Sea gas* and that *support be given to the coal industry* to lessen the social consequences of the inevitable contraction of that industry.

1967 *Live-line working.* C.E.G.B. demonstrated, a "bare-hand" technique for changing spacers on live 400 kV quadruple conductors—believed to be a *"first" in Europe.* The linesman wore a conducting suit (*"Faraday cage"*) connected to the high voltage line.

1967 *Oldbury nuclear station* on the Severn Estuary entered service in December. Design output was 600 MW from two 313 MW sets. This was the first British

station with *concrete pressure vessels,* and the first of any power station with a computerised alarm analyser with a cathode-ray-tube display.

1968 *First 2,000 MW steam stations* to be completed—Moss Landing station of Pacific Gas and Electric Co., and C.E.G.B.'s Ferrybridge "C" and West Burton stations.

1968 *Gas and Electricity Act 1968* enabled the supply industry to borrow on overseas capital markets. In 1969 The Electricity Council and the South of Scotland E.B. floated loans on the German market.

1968 1,100 MW single-shaft turbo-alternators—the *largest single-shaft machines yet to be built in Britain,* ordered from A.E.I. by Consolidated Edison of New York; and from English Electric by Detroit Edison for the Enrico Fermi B.W.R. station and Southern California Edison for the San-Onofre P.W.R. station. The New York station was abandoned for environmental reasons.

1968 *"Optimal Pricing and Investment in Electricity.* An Essay in Applied Welfare Economics" by R. Turvey, published by Allen Unwin.

1968 *"Consumer Consultative Machinery in the Nationalised Industries",* a Consumer Council Study, published by H.M.S.O. Covers electricity, gas, solid fuel and public transport.

1968 *"Royalties on Nuclear Stations"*—Report from the Committee of Public Accounts, published as H.C. Papers Nos. 156–1, 233–1 and 314. Criticised an arrangement between Treasury, C.E.G.B. and U.K.A.E.A. which related to the royalties being paid to the Exchequer for nuclear electricity to cover the cost of developing the reactor system.

1968 *Reorganisation of Area Boards.* Several boards were streamlining their organisation by reducing the number of Areas and/or Districts.

1968 Reconstitution of the E.D.A. Division as the *Marketing Department of The Electricity Council.*

1968 *Douglas Point 208 MW nuclear station* of Ontario Hydro commissioned—the first full-scale prototype of the C.A.N.D.U. system.

1968 *Tidal Power*—first Russian pilot plant of 400 kW commissioned at Kislaya Guba, near Murmansk, on the White Sea.

1968 First three 230 MW units commissioned at the Gordon M. Shrum hydro station of the *Peace River Project* in Britain Columbia. Final capacity was planned at 2,270 MW.

1968 U.K.A.E.A.'s prototype *steam generating heavy water reactor (S.G.H.W.R.)* at Winfrith reached full power of 100 MW (e). It used slightly enriched (to about 2·4% uranium −235 content) uranium oxide pellets canned in zirconium alloy, heavy water as a moderator, and light water as a coolant. It employed a direct cycle (no heat exchangers)—with light water boiled in the reactor's pressure tubes passing as steam directly through the turbines via a steam drum. The pressure tubes which contained the fuel elements, and took the place of the massive pressure vessel which is a feature of most other reactors, were located within the tubes of a calandria (tubular tank) containing the heavy water moderator.

1968 *Siting of nuclear power stations.* Minister of Power announced in the House of Commons on 6 February a modification to nuclear siting policy. On the advice of the Nuclear Safety Advisory Committee, the safety of a gas-cooled reactor in a prestressed concrete pressure vessel was such that it *may be located*

much nearer built-up areas than so far permitted. Previous policy was that nuclear stations should be located on remote sites.

1968 *High-voltage single-phase distribution for new housing developments* introduced by the Electricity Supply Board, *Ireland.* The 10 kV system was similar to American U.R.D. practice.

1968 *Distribution system for trainees.* East Midlands E.B. brought into use a complete 11 kV/433 V distribution system with five substations at the Board's new Operational Training School, at Ashover.

1968 *First commercial zinc/air primary battery* announced by Energy Conversion.

1968 *Zinc smelter*—claimed to be *world's largest,* and first metallurgical plant with on-line computer control, load 16 MW, built for the Imperial Smelting Corporation (N.S.C.) Ltd. at Avonmouth, officially opened in May.

1968 *First 132 kV vacuum circuit breakers* installed by C.E.G.B. at West Ham substation.

1968 *"Hoverkiln" for ceramic manufacture*—air cushion conveying in new kiln invented by Shelley Furnaces of Stoke-on-Trent. Two types available—electric or gas heated.

1968 *First industrial total energy gas turbine scheme* in the U.K.—installed at Esso's Milford Haven refinery. Supplied 10 MW of electricity and hot exhaust gas for industrial processes.

1968 *"The 1966 Sample Survey of Domestic Consumers",* Utilisation Research Report No. 75, published by The Electricity Council.

1968 *600 MW single-shaft turbo-alternator set* commissioned at the Porcheville "B" station of EdF.

1968 World Power Conference changed its name to the *World Energy Conference,* after revising its Objects and Constitution to embrace all forms of energy. Meetings would be held at intervals of three years, instead of two years as hitherto. A Survey of World Energy Resources would be published at intervals of six years.

1968 First unit (218·5 MV) commissioned at the *Guri hydro power complex* on the Caroni River in Venezuela. Capacity was expected to reach 10,060 MW by about 1990 and 20,000 MW eventually.

1968 N.B.P.I. Report No. 59. *"The Bulk Supply Tariff of the Central Electricity Generating Board",* Cmnd. 3575.

1968 A *22,000 hp motor* went into service in the Powerformer plant at the Esso refinery, Fawley, in May—claimed to be the *world's largest direct-on-line started induction motor.* The motor operated at 11 kV.

1968 *"Report from the Select Committee on Nationalised Industries—Ministerial Control of the Nationalised Industries"*—Vol. I, Report and Proceedings, Vol. II Minutes of Evidence and Vol. III Appendices and Index, H.C. Paper 371. The committee enquired into the relationship between the nationalised industries, Government departments and Parliament. They recommended the establishment of a single Ministry of Nationalised Industries to deal with these industries as a whole in matters concerning their efficiency, and also that greater managerial freedom should be given to the boards of these industries.

1968 *"Report from the Select Committee on Nationalised Industries—Exploitation of North Sea Gas"*, H.C. Paper 372, concluded that the exploitation of natural gas as planned must be accepted as a fully justifiable capital investment.

1968 N.B.P.I. Report No. 79. *"Electricity Supply Industry. National Guidelines covering Productivity Agreements"*, Cmnd. 3726.

1968 Sir Norman Elliott appointed Chairman of the Electricity Council from 1 November 1968 (until 31 March 1972).

1968 *Submarine cable links.* The DC submarine cable between the mainland of *British Columbia and Vancouver Island* rated at 312 MW and operating at 130 kV was commissioned. Ultimately it operated at ±260 kV to provide 624 MV. This link comprised 33 km of submarine cable and 41 km of overhead line. (Two circuits, at 138 kV AC total capacity 250 MV, were installed in 1956 and 1958.)

1968 Monopolies Commission Second Report on the *Supply of electric lamps* published December.

1968 *"First guidelines for a Community energy policy"* presented by the *E.E.C.* Commission in December to the Council of Ministers; considered by the Council on 13 November 1969; and two regulations adopted by the Council on 31 January 1972—*q.v.*

1968–70 *Centralec* off-peak small-bore system of central heating—field trials carried out on E.C.R.C. developed prototype units.

1969 *400 kV cable*—commissioning of the two 3¼ mile cable circuits laid in the disused Woodhead-Dunford Bridge railway tunnel under the Pennines, linking Thorpe Marsh power station with South Lancashire.

1969 *Sodium cables*—Eastern E.B. carrying out field trials.

1969 *First 275 kV sulphur hexafluoride (SF_6)* circuit breaker to be *made in the U.K. entered service.*

1969 *Remote control in primary distribution substations.* Eastern E.B. drew up plans for equipping the 425 primary substations in its area during the next three years with alarm signalling, state of plant indicators, and remote voltage control.

1969 The first large "all-electric" *Integrated Environmental Design ("I.E.D.")* building with heat recovery air conditioning—North Eastern E.B.'s Testing and Research Building, Wallsend, opened in September; and Merseyside and North Wales E.B.'s head office building, Chester.

1969 *"The future of the Heavy Electrical Plant Industry"*—Report by G. B. Richardson, B.E.A.M.A. Publication No. 232. Suggested that competitive tendering was inappropriate to the special circumstances of the heavy electrical plant market and could prove disastrous for the future of the industry. Trading agreements were the best way of balancing the interests of manufacturers of heavy plant and their supply industry customers.

1969 *1,150 MW cross-compound unit* commissioned at the Paradise station of T.V.A. Steam conditions were 3,500 lb/sq. in. at 1,000/1,000°F from an 8,000,000 lb/h boiler.

1969 Opening of The Electricity Council's *Electric Catering Centre*, in St Martins Lane, London, as a national centre providing a wide range of equipment, planning advice and demonstrations of new techniques.

1969 *Live-line working.* C.E.G.B. demonstrated "bare-hand" working at 400 kV and "hot-stick" working at 132 kV.

1969 Monopolies Commission. *Recommended Resale Prices*—Report on the general effect on the public interest of the practice of recommending or otherwise suggesting prices to be charged in the resale of goods.

1969 N.B.P.I. Report No. 102 *"Gas Prices (Second Report)"*, Cmnd. 3924. The Board's study included *joint meter reading*, collection and billing for gas and electricity. The Electricity Council and the London and Yorkshire E.B.'s assisted in this part of the inquiry.

1969 White Paper *"Report of the Committee of Enquiry into Delays in Commissioning C.E.G.B. Power Stations"*, Cmnd. 3960. The committee under the chairmanship of *Sir Alan Wilson*, reached the general conclusion that strong remedial actions had been taken and new methods introduced which should in the future avoid many of the causes of delay which had dominated the situation for the last ten years. The effectiveness of management and the productivity of labour on some sites remained "distressingly low".

1969 The *test discount rate* for appraising public sector investment projects was raised from 8 to 10% (Treasury 19.8.69).

1969 *Financial objectives* announced for gas and electricity industries for five years 1968/69 to 1973/74—for both a return of 7%, after depreciation, on average capital employed.

1969 *Day/night (White Meter) tariffs* providing cheap night units usually between 11 p.m. and 7 a.m., generally introduced from 1 April in England and Wales and south of Scotland. They were introduced by the North of Scotland H.-E.B. on 1 April 1970. These tariffs had no restrictions as to the type of apparatus which could be supplied and did not necessarily require separate circuits as was the case with off-peak tariffs.

1969 *Transmission Lines.* On 1 April the *financial responsibility* for almost all transmission plant operating at *132 kV and below* was transferred to *Area Boards.*

1969 *"M.H.D. Electrical Power Generation"*—report issued by the International M.H.D. Liaison Group of E.N.E.A. and the I.A.E.A., concluded that the latest evidence from international research suggested that M.H.D. generators would be cheaper and more efficient than turbo-generators, and that development should continue into base-load M.H.D. generating plant, both nuclear-powered and fossil-fuelled.

1969 Official opening, in May, of the new extension to The Electricity Council's *Appliance Testing Laboratories ("A.T.L.")* enabling more emphasis to be placed on performance testing.

1969 White Paper "Ministerial Control of the Nationalised Industries" Cmnd. 4027, gave the Government's reaction to the "Report from the Select Committee on Nationalised Industries—Ministerial Control". The Government did not accept the proposal for a Ministry of Nationalised Industries.

1969 *First Congrès International des Réseaux Electriques de Distribution ("C.I.R.E.D.")* held in Liège during July, under the aegis of the Association des Ingénieurs Sortis de l'Institut Electrotechnique Montefiore.

1969 The Ministry of Power was absorbed into a new Government department, the *Ministry of Technology.*

1969 *The colour code* used for wires in the mains leads of appliances was changed to green and yellow stripes for the earth wire, brown for the live wire and blue for the neutral by SI No. 310.

1969 *Proposal for the reorganisation of the electricity supply industry in England and Wales.* On the 18 July, in the House of Commons, the Minister of Power announced that he proposed "to reconstitute The Electricity Council and rename it the Electricity Authority with new powers to plan and control the policy of the industry as a whole". The boards would remain statutory bodies responsible for the generation, transmission, distribution and supply of electricity, but would discharge these duties within the framework of broad policy for the industry as a whole, which would be settled by the Electricity Authority. The legislation to give effect to these proposals was embodied in the *Electricity Bill* 9 March 1970—*q.v.*

1969 *"Twenty Years of Electricity Distribution under Public Control"*—paper providing a broad survey and appraisal of progress in the public distribution of electricity since nationalisation, presented to the I.E.E. by D. P. Sayers and E. Hill, published in "Proceedings I.E.E." Vol. 116, 1969, pp. 1527 etc.

1969 *Superconducting DC motor.* International Research and Development Co. demonstrated their 3,250 hp variable-speed superconducting homopolar motor in November, at Newcastle—the *largest superconducting machine* yet built. The machine underwent extensive industrial trials at the *Fawley power station,* where it was used temporarily to drive one of the cooling water pumps.

1969 *Fawley oil-fired station* commissioned. Its *control system* was among the most advanced in the world. Each of the four 500 MW units had computer control capable of taking the set from hot conditions to a selected load target, without intervention of the operator, taking corrective action if a fault occurred, and shutting down if necessary. Temperatures, pressures, flows and actions taken were displayed on a cathode ray tube.

1969 To reduce the rate of *steel oxidation at Magnox nuclear stations,* other than Berkeley, gas outlet temperatures were restricted to 350°C compared with the design temperatures of up to 414°C. A secondary shut-down capability was introduced using boron steel balls in addition to the primary system of control rods. Later a third capability based on boron gas was introduced.

1970 The Electricity Council set up an *Overseas Consultancy Service* to act as a focal point for enquiries from home and overseas government departments and other organisations, such as consulting engineers and overseas utilities, who needed specialist technical advice or practical assistance which the industry could provide.

1970 Opening of The Electricity Council's *Air Conditioning Advisory Bureau* in Northumberland Avenue, London, for national promotion of air conditioning in commercial and industrial premises.

1970 *The Electricity (Overhead Lines) Regulations 1970* (S.I. 1970 No. 1355), to come into force on 1 October 1971 replacing Overhead Line Regulations 1947 made by the Electricity Commissioners. They imposed a more flexible system of control on design and erection of new overhead lines and stricter requirements in respect of safety.

1970 *Fuel Cells*—"1970 Final Report Project Fuel Cell' (U.S. Government Printing Office: 1970 0-405-586). Gave results of research in the development of a commercial fuel-cell power generating system using coal as a fuel, undertaken for the U.S. Department of the Interior. Recommended further research aimed at establishing commercial feasibility.

1970 National Radiological Protection Board established by the Radiological Protection Act, 1970 to develop standards and safe practices and recommend these to the regulatory bodies, to advise nuclear power stations and others on their application.

1970 *Main gas-turbine stations*—C.E.G.B. applied for consent to build a gas-turbine peak-load plant of 150 MW on the Watford power station site. This was granted in July 1971. By the end of 1972 applications had been made to build on twelve sites totalling 2,550 MW; the first commissioned at Leicester in 1976 and used industrial-type machines instead of aircraft-type gas turbines.

1970 E.C.A., N.E.C.T.A. and N.F.E.A. were re-organised to form a single Association, again known as the *Electrical Contractors' Association ("E.C.A.")*. It embodied the major aims and objects of all three former Associations.

1970 *C.N.E. cable for p.m.e. networks.* First installation of cable to Specification *TRYDAN* by the South Wales E.B.

1970 *Central Service Units* (C.S.U.). The Eastern E.B. set up, at Norwich, the first of two C.S.U.s to rationalise storage and transport of a wide variety of domestic appliances and contracting and engineering materials. In the second C.S.U., commissioned in 1973, the storage and retrieval of appliances was controlled by computer.

1970 *Glossop Automatic Switching Programme ("G.A.S.P.")*. To provide an increased supply to an industrial consumer in Glossop, the North Western E.B. developed a switching arrangement such that if overload conditions arose, the firm's supply was automatically transferred to whichever more lightly loaded circuits were available.

1970 *"The 1969 Domestic Lighting Survey"*, Utilisation Research Report No. 99, published by The Electricity Council.

1970 *Nuclear Reactor Development.* The Department of Trade and Industry launched a review to test development programmes against national requirements. Two working parties were set up with members drawn from D.T.I., U.K.A.E.A. and the generation boards. They reported in 1972. (See Future Nuclear Strategy under 1972.)

1970 *Pumped storage.* T.V.A.'s Raccoon Mountain project reported as being under construction. Will have four 325 MW reversible pump/turbines with water cooling of both stator and rotor windings—the *world's largest pump/turbine units planned to date.* First units went into service in 1978/79.

1970 *Longannet power station*, Fife, of the South of Scotland E.B. started up in January. Its four 600 MW sets and 4,000,000 lb/h boilers were the largest on the British system. The cross-compound units had turbine stop valve steam conditions 2,350 lb/sq. in. at 1,050°F. with reheat to 1,050°F. A unique feature was the fuel supply arrangement—the output from a complex of four collieries was despatched to the station stockyard along a computer-controlled underground conveyor system of some 5½ miles, with automatic blending to ensure consistent ash content.

1970 *Support for coal*—Minister of Technology announced in the House of Commons on 6 February that as coal was no longer in excess supply the use of additional coal by the supply industry would not be necessary after 31 March.

1970 *Electricity Bill* published 9 March. Based on the proposals for the reorganisation of the supply industry in England and Wales announced by the Minister of Power on 18 July 1969—*q.v.*—the Bill was given a Second Reading in the House of Commons on 6 April 1970 and was being considered by a Committee

of the House when Parliament was dissolved in May 1970. The Bill accordingly *lapsed.*

1970 *"Report from the Select Committee on Science and Technology—Generating Plant Breakdowns: Winter 1969–70".* H.C. Paper 223, published April, concluded that, for conventional plant, without prejudging the reason for the stator failures, the evidence pointed in the case of other faults to a basic failure of engineering design: further, that the prospects for restoring nuclear reactors to full power did not appear good (they had been operating at less than full power because of corrosion problems).

1970 The 1361 km Pacific H.V.D.C. intertie connecting the predominantly hydro Pacific North West power system of Bonneville Power Administration and the predominantly thermal Pacific Southwest power system commissioned, rated at ±400 kV, 1,800 A, 1,440 MW—*the first modern H.V.D.C. transmission in the U.S.A.* It was upgraded to ±500 kV, 2,000 A, 2,000 MW by 1985, with further plans to increase capacity to 3,100 MW.

1970 *Electricity (Borrowing Powers) Act (Northern Ireland)* extended the borrowing powers of the Electricity Board for Northern Ireland from £110M to £160M.

1970 N.B.P.I. Report No. 153 *"Coal Prices (Second Report)"*, Cmnd. 4455, recommended increases of 15 to 16 per cent in the price of coking coal; but no immediate rise in the price of general purpose coal, used mainly by the C.E.G.B. and industry.

1970 *Supply industry dispute.* "Report of a Court of Inquiry under Professor A. D. Campbell, M.A., into a Dispute between the Parties represented on the National Joint Board for the Electricity Supply Industry", Cmnd. 4410, made recommendations concerning *restoration of differentials* with industrial staff.

1970 North Western E.B.'s *Daniel Training Centre,* Chorley, started operating in September. Designed to house training courses for the whole range of the Board's employees, this Centre was an example of I.E.D. which also contributed to the Board's promotions.

1970 Under reorganisation of Government departments the Ministry of Technology, whose responsibilities included fuel and power, became part of the new *Department of Trade and Industry.*

1970 *First commercial deposits of North Sea oil* discovered by B.P. in November in the Forties Field.

1970 *"The next 25 Years in the Electricity Supply Industry"* by Sir Stanley Brown. Lecture to the I.E.E.T.E. on 16 November, published in the "I.E.E.T.E. Journal", January 1971, p. 17 etc.

1970 Anglesey Aluminium Metal's *new smelter at Holyhead* started up in December. C.E.G.B. supplied electricity under special terms based on generation employing the latest technology and the cost of associated transmission reinforcement.

1970 *Grid control.* With the commissioning in December 1970 of the new National Control Centre, the changeover to three-tier operation—District, Area and National Controls—was completed.

1971 First of four 500 MW units commissioned in December at the *Kingsnorth power station,* in Kent—the first station designed from the outset for *dual coal/oil firing.* Each unit was computer-controlled with automatic start-up of individual auxiliaries and pulverised fuel mill, and automatic loading of the turbo-alternator from half load, with automatic control of fuel supply etc. The

number 3 set was the terminal of a 640 MW DC cable link to Willesden and Beddington which was commissioned in 1974.

1971 *Polyacetylene*—a polymer with metal-like electrical properties discovered. Manufacturing variations provided various ranges of electrical conductivity.

1971 *Re-organisation of the C.E.G.B.*—the internal organisation was completely revised from 1 January. A high degree of delegated authority was given to the five Regions and construction and design work was transferred to two new Divisions, the Generation Development and Construction Division, and Transmission Development and Construction Division.

1971 *U.H.V. transmission research* started at C.E.R.L., following the completion of a *1500 kV outdoor test site.*

1971 Formation of the *Electrical, Electronic and Allied Industries Europe Committee* ("E.E.A.I.E.") to study the problems to which U.K. membership of the European Communities would give rise, and to see in what way the members of the associations could best be helped.

1971 *Atomic Energy Authority Act 1971* provided for the transfer to a new company, *British Nuclear Fuels Ltd.* ("B.N.F.L."), formed in February, of the nuclear fuel cycle business of the Production Group of the U.K.A.E.A., including the Calder Hall and Chapelcross nuclear stations. The company started independent activity on 1 April 1971. The Act also established the *Radiochemical Centre Ltd.*

1971 *Centralec* off-peak small-bore system of central heating—general marketing stage reached.

1971 *World's first solid-state electricity meter* announced by Landis and Gyr Co.—a three-phase instrument for measuring bulk supplies.

1971 *Report of a Court of Inquiry into a dispute between the parties represented on the National Joint Industrial Council for the Electricity Supply Industry.* Chairman: The *Rt. Hon. Lord Wilberforce.* Cmnd. 4594, published February. Following a breakdown of negotiations in the N.J.I.C. in December 1970, industrial action had been taken by the unions concerned leading to a major disruption in electricity supplies and the Government declared a State of Emergency. Following publication of the Court's report, negotiations with the unions were re-opened and a settlement was reached in March 1971.

1971 *"Whither Nuclear Power?"* by E. S. Booth. Annual Lecture to the I.E.E. Power Division, 24 March 1971, published in the "Proceedings I.E.E.", Vol. 118, 1971, p. 1215 etc.

1971 *Uranium enrichment by gas centrifuges—URENCO—CENTEC,* an Anglo-German—Dutch uranium enrichment company, was formed to carry out projects to develop and exploit centrifuge processes.

1971 N.B.P.I. Report No. 153 (Supp. No. 1) *"Coal Prices (Second Report—Supp. No. 1)"*, Cmnd. 4455–1, found that domestic coal users subsidised industrial consumers and that the steel and *electricity generating industries* were the *major beneficiaries* of the N.C.B's pricing policies.

1971 Generating *plant margin* over forecast average cold spell simultaneous maximum demand used for planning purposes was increased from 17 per cent to 20 per cent due to allowance for reduced plant availability.

1971 British Aluminium's *new smelter at Invergordon* started up in May. Special power cost arrangements with the N.S.H.-E.B. were based on generation at the Hunterston "B" nuclear station expected to commission in 1973, and the cost of appurtenant transmission reinforcement.

1971 *"Report of the Select Committee on Nationalised Industries—Relations with the Public"*, H.C. Paper 514. Among the recommendations, which mainly concerned the role and working of the consultative bodies, was that studies should be continued to bring down the costs of reading electricity meters from a central point to an acceptable level.

1971 *Battery electric vehicles.* To obtain more extensive experience of these vehicles under everyday operating conditions, *The Electricity Council* announced the industry's intention to purchase 80 electric cars and light vans. Most of these were the *Enfield 8000 Electric City Car.*

1971 *First computerised central appliance store* commissioned at the South-Eastern E.B.'s Central Warehouse at Tunbridge Wells.

1971 *"Report on an Enquiry into the Characteristics of the Electricity Supply System in Northern Ireland"* published by H.M.S.O., Belfast. The enquiry, chaired by Nevill F. Marsh, Deputy Chairman of the Electricity Council, was set up to determine if a more flexible system would give greater security of supply. It recommended, inter alia, a unified electricity supply industry and consideration of a cable link with Scotland.

1971 *Completion of the first nuclear programme* with the commissioning of the last of the "Magnox" stations in November. The *Wylfa* station, Anglesey, had a design output of 1,180 MW from four 335 MW sets. The central computer station control and data processing system was in the van of developments in this field. The two massive concrete pressure vessels, each weighing 80,000 tonnes, were the largest ever built. Later AGR stations, with fuel ratings four times those of the early Magnox stations, needed much smaller physical dimensions of reactor to provide higher capacity.

1971 Ente Nazionale per l'Energia Elettrica (E.N.E.L.) began a *1,000 kV AC transmission* project aimed at commissioning a pilot scheme by 1983 at Suvereto, Tuscany, as a timely and systematic approach to a new transmission voltage level. Previous progressions had been from 145 kV (1920–30) to 245 kV (1940–50) to 420 kV (1960–70).

1971 *800 MW sets in series production in the U.S.S.R.* These 3,000 rpm units had supercritical steam conditions of 3,414 lb/sq. in. (235 bar) and 540°C. The stator was water cooled.

1971 Formation, in December, of a new company *Euro-H.K.G.* from the C.E.G.B., EdF, two West German undertakings, and the German consortium Hochtemperatur Kernkraftwerk. The company's object was to pool experience on the design and operation of *high temperature gas-cooled reactors.*

1972 *132 kV overhead line crossing*—Scotland's longest span, 4,574 ft., across Loch Long completed by North of Scotland H.-E.B.

1972 *District heating scheme.* London E.B. announced their plans for a scheme to be incorporated in the London Borough of Southwark's strategic plan for the development of the area south of the Thames between Waterloo Bridge and Tower Bridge. The scheme would provide for a total energy requirement of 200 MW, of which 100 MW would be supplied in the form of heat.

1972 *"Connection charges for Electricity and Gas"*, Cmnd. 5036, report by the Monopolies Commission, stated principles which the commission considered should govern the level and character of connection charges, and made recommendations for the introduction of standard charges.

1972 *Coal miners' strike.* Following a work-to-rule during the preceding October, a strike began on 4 January and ended on 28 February. The supply industry operated *rota disconnections* from 11 February to 1 March, but voltage reduc-

tions were necessary from the end of January. The strike was settled following the report of the *Wilberforce Committee* (Cmnd. 4903).

1972 *Pumped-storage*—C.E.G.B. applied for and was granted consent to promote a Private Bill to authorise the construction of a 1,400 MW pumped-storage station at *Dinorwig*, near Llanberis, Caernarvonshire.

1972 A *pilot gas-centrifuge system* was commissioned by British Nuclear Fuels Ltd. at Capenhurst as part of Britain's contribution to the British–Dutch–West German joint development of centrifuges.

1972 *World's largest generating unit* completed at the Cumberland station of T.V.A.—a 1,300 MW cross-compound unit with steam conditions 3,500 lb/sq. in. at 1,100/1,000°F.

1972 Commissioning of the *Pickering C.A.N.D.U. nuclear station* of Ontario Hydro. When the last of four 540 MW(e) units entered service in 1973 it became the *world's largest nuclear station:* C. A. Parsons supplied the sets.

1972 First of eleven 475 MW units commissioned at the *Churchill Falls* project in Labrador, some 1,100 km north-east of Montreal—it was completed in 1975. Transmission connection to the Hydro-Quebec system 200 km away was at 735 kV.

1972 E.E.C. Commission's proposals of January for a *Community Energy Policy to 1985.* In order to reduce their dependence on oil, the Commission wanted more use of natural gas, solid fuel and nuclear power, increasing the share of each by one third. In this way reliance on oil would be cut from 60 per cent to 50 per cent of the total by 1985.

1972 E.E.C.'s *"First guidelines for a Community energy policy".* On 31 January, the Council of Ministers adopted *two regulations* proposed to them by the Commission, which stipulated that the latter was to be informed of: (i) investment projects of Community interest in the oil, natural gas and electricity sectors; and (ii) imports of hydro-carbon fuels.

1972 *"Training for the Future. A Plan for Discussion"*, a consultative document published by the Department of Employment, outlining a major reorganisation of industrial training envisaged by the Government. (In consequence, The Electricity Council, with the support of the trade unions, requested the Secretary of State for Employment to consider the dissolution of the *E.S.I.T.B.* and its replacement by a strengthened Education and Training Committee of the N.J.A.C.)

1972 Alcan *aluminium smelter at Lynemouth* started producing metal in March. Electricity was provided from private generation, the power station having three 130 MW coal-fired units.

1972 Mr Peter Menzies (later Sir Peter) was appointed Chairman of the Electricity Council on 1 April (until 31 March 1977).

1972 *H.V. DC transmission.* 900 kV DC line operative—the 895 km line from Manitoba Hydro's Kettle Rapids hydro-electric stations to Winnipeg energised on 20 June. At 450 kV above and below earth potential, *the highest voltage DC transmission in North America.*

1972 *New 132 kV link to Isle of Wight* completed in July—the first large 132 kV cable contract undertaken by the Southern E.B. since they took over responsibility for the 132 kV system in their area.

1972 *Low profile substation*—commissioning in August of the Mark II 400 kV substation at Wymondley, Herts. which used much less solid structures than the standard, with overall height reduced from 72 ft. to 53 ft.

1972 *Future nuclear strategy.* Following a report of a departmental committee of the D.T.I. (Chairman: *F. R. P. Vinter*), the Secretary of State for Trade and Industry announced in August that the first full-scale order for a *sodium-cooled fast reactor* was likely to be placed in the latter part of the 1970s and that from the mid-1980s a major part of nuclear orders would be for this type of station. During the next eighteen months the programme would comprise study of a specific design for the S.G.H.W.R. system; possible improvement to the A.G.R. system; international collaboration in the development of the H.T.R.; and safety of light-water reactors (L.W.R.). In addition the Secretary of State proposed to set up a nuclear power board to advise the government on nuclear reactor policy.

1972 *First 400 kV line in Scotland,* from Hunterston to Neilston, became live in August.

1972 E.E.C.'s *Second Target Nuclear Programme* published in October. Covering the period 1975–1985, the programme set a target of a nuclear capacity of at least 100,000 MW(e) in service in the six original Community countries by 1985. This would represent 33 per cent of their total electricity output and 10 per cent of their total primary energy needs.

1972 *Electricity in sewage treatment*—Europe's first high oxidation plant dealing with sewage disposal, official opened in October at Pirbright, Surrey, for Guildford R.D.C.

1972 *Battery electric vehicles.* In November, E.C.R.C. demonstrated a *sodium-sulphur battery vehicle.* The battery, of capacity 30 kWh based on the well-tried laboratory cells, was demonstrated in a Bedford 18 cwt delivery van which should have 100 km range with virtually normal pay load. International research on new electrochemical couples to produce higher energy densities included lithium chlorine, zinc chlorine, lithium sulphur possibilities as well as sodium sulphur.

1972 Westinghouse Electric Corporation constructed a 5 MVA, 3,600 rpm *superconducting generator.* A 300 MVA generator was expected to be completed by 1983–4.

1972 *Reorganisation of the gas industry.* Gas Act 1972 provided for the reconstitution of the Gas Council as the British Gas Corporation, the dissolution of the Area Gas Boards and the transfer of their responsibilities to the new Corporation. The vesting date was 1 January 1973.

1972 *Support for coal*—On the 11th December 1972 the Secretary of State for Trade and Industry announced in the House of Commons a programme of financial support for the coal industry aimed at ensuring the preservation of a viable coal industry in a situation of possible world energy shortage and uncertainty about future world fuel prices.

1973 *Coal Industry Act*—included provision for payment of grants to cover extra coal burn by the supply industry, but payable to the N.C.B. instead of to the generation boards.

1973 *EHT transmission*—a project for an experimental half-mile of 2,300 kV transmission line, substation and voltage regulating equipment, at Indiana & Michigan Electric Co's Dumont station near Lakeville, Indiana was announced.

1973 *Electrical and Electronic Retailers' Association* formed in February.

1973 *Pumped storage.* C.E.G.B. announced in March that an extra £5.25 million was to be spent on environmental measures around the 1,500 MW Dinorwig pumped storage scheme, mostly for the undergrounding of cables. The North Wales Hydro-electric Act authorising the scheme received the Royal Assent in December.

1973 *National Nuclear Corporation*—Government announced the formation of this new nuclear design and construction company, the shares of which were to be divided between G.E.C. 50%, other engineering firms 35%, and the Government 15%.

1973 The *Northern Ireland Electricity Service,* established by the Electricity Supply (Northern Ireland) Order 1972, S.I. No. 1072 (N.I. 9), commenced operation on 1 April.

1973 *E.E.C. energy policy.* Memorandum "Guidelines and Priority Activities under the Community Energy Policy", submitted by the Commission of the European Communities to the Council of Ministers on 19 April, proposed the strengthening of co-operation between the Community and other energy-importing countries, the establishment of relations of trust with the energy-exporting countries and better organisation of the Community's petroleum market. It was discussed by the Council of Ministers in May.

1973 American Electric Power commissioned a *1,300 MW single-shaft Brown Boveri set* at the *John E. Amos station.*

1973 *33 kV submarine cable linking* the island of Stronsay to the mainland was energised in June. This 12 km long cable was the longest continuous HV distribution cable in British waters.

1973 *"Trident" design temporary 132 kV single-circuit wood pole line* constructed by South Western E.B. based on existing 33 kV line practice. Merseyside and North Wales E.B. developed the concept to a new permanent "Trident II" in 1975, a low profile amenity design based on wood poles of 12 m average height.

1973 *Remote meter reading* was unlikely to be economic in Britain for many years, according to a report by Atkins Planning, "Domestic Meter Reading", pub. by Dept. of Trade and Industry.

1973 *General Atomic Company* formed in June by Shell and Gulf Oil to develop and market Gulf's high temperature reactor (H.T.R.)

1973 Work started on Hydro-Quebec's *James Bay hydro-electric complex* on La Grande River. The four stations will have a total capacity of 10,340 MW and the first, LG2, with a capacity of 5,328 MW from sixteen 333 MW sets, was expected to commission during 1980 to 1982.

1973 "Second Report from the Select Committee on Science and Technology—*Nuclear Power Policy*", H.C. Paper 350, (Minutes of Evidence etc, H.C. Paper 117). Recommended that the proposed G.E.C. shareholding in the new single nuclear design and construction company should be cut from 50 per cent to 30 per cent or less and that the Government's holding should be raised from 15 to at least 30 per cent. Also recommended that the major U.K. nuclear research and development effort should be on the H.T.R. and that there could well be little point in continuing work on the S.G.H.W.R.

1973 *Fast nuclear reactors.* The French Phénix 250 MW(e) fast reactor achieved criticality in August. It reached full power in March 1974.

1973 Tests on what was claimed to be the *world's first experimental 100 kV generator* were completed successfully at the Skodnya hydro station near Moscow. HV generation of this kind might permit direct connection to the transmission system.

1973 *Fast breeder reactor*—Russian 350 MW (150 MW(e)) *prototype "loop-type" fast reactor* at Shevchenko, part of a desalination project, was commissioned. A *commercial fast reactor* of 600 MW(e) capacity commissioned in 1980 at the *Beloyarskaya nuclear complex in the Urals. (q.v.)*.

1973 *Nuclear Power Advisory Board* held its first meeting under the chairmanship of the Secretary of State for Trade and Industry. The Board, which was given wide terms of reference to advise Government on future power policy, included the chairmen of the C.E.G.B., the Electricity Council, and the South of Scotland E.B. among its members.

1973 *"Distribution of Electricity"* by A. G. Milne, Inaugural Address by the President of the I.E.E., published in "Proceedings I.E.E.", Vol. 121, No. 1, January 1974, p. 1 etc., outlined the latest practices in U.K. distribution engineering.

1973 *Crude Oil Prices*—on 16 October Arab governments announced from Kuwait very large price increases—in the ensuing months prices more than quadrupled.

1973 *Fuel Emergency—Oil Supplies*—on 17 October Arab governments announced the use of the oil weapon in the war with Israel—there were production cuts and embargos on some countries. *Pay Claims*—On 1 November the E.P.E.A. started a ban on out-of-hours working which continued until 7 January 1974. The N.U.M. banned overtime from 12 November, and from 10 February to 10 March 1974 were on strike. A.S.L.E.F. engine drivers supported the miners by a 'non-co-operation campaign beginning 12 December 1973 and lasting until the end of January. A *State of Emergency* was declared on 13 November and lasted until 10 March 1974. *The Fuel and Electricity (Control) Act 1973* made Orders restricting lighting and heating; a three-day working week for industry was introduced on 17 December and lasted until 7 March. Offices and shop were only permitted to use electricity on either mornings or afternoons. *Voltage reductions* were in force on 12 November and from 26 November to mid-December due to plant shortages caused by the E.P.E.A. action, and from mid-December to 16 January to conserve fuel stocks, and from 12 February to 10 March 1974 because of the coal strike. *Load disconnections* were necessary on only two occasions. During the emergency, coal-fired plant was run on "thermal efficiency merit order". A ban on television after 10.30 p.m. was relaxed for the General Election on 28 February 1974. A Labour Government was formed on 4 March and on 6 March the N.U.M. accepted a £100 million pay settlement. By 24 March all the emergency S.I.s had been revoked.

1973 *The 1972 Sample Survey of Domestic Consumers*, Load and Market Research Report No. 119, was published by the Electricity Council.

1973 *Eurodif* consortium was established to build a uranium enrichment plant using gaseous diffusion methods at Tricastin in France, of nine million separative work units annual capacity, for commissioning in 1978–79. When Iran joined the consortium in 1975 the national shares were France 43%, Italy 25%, Belgium and Spain 11% each, and Iran 10%.

1973 *On-line computer control of a distribution network.* Midlands E.B. commissioned on-line computer control equipment in the Summer Lane control centre of the Birmingham Area—for the remote control of the more important substations and the presentation of the system diagram and supporting information on electronic displays.

1973 White Paper, *"Nuclear Power Policy: Government Observations on the Second Report from the Select Committee on Science and Technology,* H.C. Paper 350, Session 1972–73", Cmnd. 5499. The Government defended its choice of G.E.C. as the major shareholder in the National Nuclear Corporation with a 50 per cent holding.

1973 *Pumped storage.* First of four 73 MW reversible units commissioned at the *Turlough Hill* station of the Electricity Supply Board, Ireland.

1974 *Department of Energy* established to take over all responsibilities for energy previously exercised by the Department of Trade and Industry.

1974 *Electrical Research Association* set up as an independent limited company on 1 January.

1974 Nuclear Power Company, the operating arm of the National Nuclear Corporation, took over responsibility for completing the A.G.R. programme.

1974 *"First Report from the Select Committee on Nationalised Industries—Capital Investment Procedures",* H.C. Paper 65. Recommended that the electricity supply industry should adopt corporate planning and that urgent consideration should be given to whether the present structure of the industry was conducive to effective and continuous corporate planning. As a matter of urgency there should be a detailed study of the role of the nationalised industries in the economy and the ways in which they should be controlled.

1974 *Safety of L.W.R. pressure vessels*—In a memorandum to the Select Committee on Science and Technology dated 22 January, Sir Alan Cottrell, Chief Scientific Adviser to the Cabinet Office, pointed out that the security of a L.W.R. vessel against fracture depended on the maintenance of rigorous manufacturing and quality control standards and regular crack-detection tests on the vessel during service. The possible growth of small cracks in highly stressed regions and the effect of thermal shock from emergency cooling water in a loss-of-coolant incident needed further scientific examination.

1974 *Statutory Corporations (Financial Provisions) Act* made provision for compensating certain statutory corporations in respect of financial loss due to compliance with the national policy relating to limitation of prices. The Act also empowered the supply industry to borrow in Sterling from the Commission of the European Communities or from the European Investment Bank.

1974 *"First Report from the Select Committee on Science and Technology—the Choice of a Reactor System",* H.C. Paper 73 i–vii, 145. The view of the Committee was that until the H.T.R. and F.B.R. were available on a commercial basis, one of the proven British nuclear technologies should be used—they noted the enthusiasm of the South of Scotland E.B. for the S.G.H.W.R.

1974 *750 kV oil-filled underground cable.* Pirelli announced a cable design capable of operating between 750 kV and 1,100 kV.

1974 *Energy Technology Support Unit* set up by the Department of Energy at the U.K.A.E.A.'s Harwell research laboratories to assess the need for further research into non-nuclear forms of energy.

1974 *"Plan for Coal"*—the N.C.B. recommended planning for a demand estimate of 150 million tons of coal in 1985, and capital investment of £600 million to provide 42 million tons of new capacity to replace depletion. Output per man shift was expected to rise by four per cent per annum. Suggested research projects included fluidised bed combustion and the production of gas and oil from coal.

1974 *Energy storage by compressed air.* Nordwest Deutscher Kraftwerke announced a 290 MW gas turbine plant with associated compressed air storage, went into operation in December 1978.

1974 Commonwealth Edison Co. commissioned two *single-shaft sets of 1,100 MW and 1,040 MW capacity* respectively at the *Zion P.W.R. nuclear station.*

1974 *Consolidated Edison Co.* announced in April that for the first time since 1885 they would not be paying a quarterly dividend to their shareholders.

1974 *London to Glasgow railway electrification* inaugurated in May. The Royal Scot created a record for the run of 4h 58 min.

1974 *Fuel cost adjustment* was applied for the first time to domestic and other quarterly-billed customers from 1 May. It was withdrawn in December 1978 because of representations from the Electricity Consumers' Council, Price Commission and others.

1974 *"Towards a new energy policy strategy for the European Communities"* Document R/1472/74 published by the European Communities Commission, recommended that by the year 2000 nuclear energy should provide at least 50 per cent of the Community's energy requirements. The Select Committee of the House of Lords on the European Communities (H.L. Paper 114) considered the nuclear target too optimistic, and the Secretary of State for Energy said in the House on 11 February 1975 that it was unrealistically high.

1974 *Chloride Silent Power Ltd.* established as a joint undertaking by the Chloride Group Ltd. and the Electricity Council to develop and commercially exploit the sodium sulphur battery for traction purposes.

1974 The *first 660 MW unit commissioned*—at the Drax coal-fired station in the West Riding of Yorkshire. The original intention was to use supercritical pressures, but in 1966 it was decided to employ subcritical steam conditions similar to those of the 500 MW units namely, 158·58 bars at 565°C (T.S.V.) with re-heat to 565°C, steamed from a 561 kg/s boiler.

1974 *Advisory Council on Energy Conservation* established (Chmn. Prof. Sir William Hawthorne) to advise and assist the Secretary of State for Energy in carrying out his duty of promoting economy and efficiency in the use of energy, in particular by identifying areas for improvement and methods of conservation.

1974 White Paper *"Nuclear Reactor Systems for Electricity Generation"*. Cmnd. 5695—set out the Government's nuclear policy that the S.G.H.W.R. should be selected for future nuclear station orders. Reactor units of 600–660 MW would make up an initial programme of not more than 4,000 MW over the four years to 1978, for commissioning after 1981.

1974 A White Paper *"United Kingdom Offshore Oil and Gas Policy"*, Cmnd. 5696 foreshadowed the establishment of a British National Oil Corporation and extended Government control over offshore operations.

1974 *"Domestic Tariffs Experiment"*, Load & Market Research Report No. 121, published by the Electricity Council, gave the results of an experiment into novel structures of domestic electricity pricing. Seasonal and seasonal time-of-day tariffs seemed promising in terms of customer response, but metering costs were a major problem.

1974 An Electricity Council *demand profile recorder of advanced design* was developed in collaboration with Normalair-Garrett Ltd. to monitor customers' demand patterns.

1974 A *fish hatchery* was established by the White Fish Authority using warm water from Hunterston "A" power station, to investigate the possibilities of commercial fish farming.

1974 The Electricity Council submitted memoranda to the Energy Resources Sub-Committee of the Select Committee on Science and Technology on the *pricing policy of the electricity supply industry* (included in H.C. Paper 127–I) and on *inverted tariffs* and the *price elasticity of electrical demand* (included in H.C. Paper 127–II).

1974 *Coal industry examination*—endorsed the N.C.B.'s "Plan for Coal" (*q.v.*) following tripartite discussions between the N.C.B., the Government and the unions. Anticipated that electricity supply would have coal-burning plant needing 100 million tons a year by 1985.

1974 *"Energy and the Environment"*, published by the R.S.A.—a report by a working party (Chmn. Lord Nathan) set up jointly by the Committee for Environmental Considerations (the forum for the main conservation and amenity bodies in Britain), the R.S.A. and the Institute of Fuel. Recommended the establishment of an Energy Commission to plan energy programmes, the discouragement of open competition between energy suppliers, and an independent body to consider possibilities of small-scale decentralised generation making use of reject heat.

1974 *"The Increased Cost of Energy—Implications for UK Industry"*, National Economic Development Office, estimated the effect on the U.K. economy of the sharp increase in the price of energy between the middle of 1973 and early 1974.

1974 *"Energy Conservation: A Study by the Central Policy Review Staff"* (Chmn. Lord Rothschild) made recommendations which included the consideration of wave power as a possible source of electricity generation.

1974 Israel used *lasers for uranium enrichment*, producing 70g of uranium with 60 per cent U–235 content.

1974 *France launched a programme of PWRs* amounting to 5,000 MW a year. By February 1986, 32 × 900 MW and 4 × 1,300 MW units were in service and 2 × 900 MW, 15 × 1,300 MW and 1 × 1,400 MW units were under construction.

1974 *Niederaichbach* (K.K.N.) in German F.R. was the *first commercial nuclear station to close down.* This 100 MW carbon dioxide gas-cooled, heavy-water moderated, pressure-tube reactor went critical in late 1972, but commissioning difficulties and high costs led to its closure on 31 July. It was put in protective storage (entombment).

1974 Bilibino C.H.P. nuclear station at Chukota in the Soviet Arctic commissioned. Four 12 MW(t) B.W.R. reactors provided heat and by-product electricity. By 1981 C.H.P. reactors of 500 MW(t) were under construction to heat the cities of Gorky and Novo-Vovonzh.

1974 *Domestic off-peak tariffs*—on 29 July the Secretary of State for Energy announced that the percentage relationship between quarterly off-peak and standard electricity rates was to be restored from 1 August to that which existed in March before the introduction of fuel cost adjustment to domestic tariffs.

1974 A *direct current link of* 640 MW capacity from Kingsnorth to Willesden operating at ± 266 kV was completed by the C.E.G.B., the first in the world to integrate short-distance DC transmission with a closely interconnected AC system in an urban area. It was disconnected from the system in 1986.

1974 White Paper *"Choice of Thermal Reactor System.* Report of the Nuclear Power Advisory Board", Cmnd. 5731, published in September, set out the Board's earlier advice to the Government that the choice of a thermal reactor system for the U.K. should be either P.W.R. or S.G.H.W.R. They had been unable to reach a unanimous recommendation on which would be the most suitable.

1974 *U.S. Atomic Energy Commission* was dissolved in October. Its research and development function was transferred to a new Energy Research and Development Administration (E.R.D.A.).

1974 *"Energy Conversion to Electricity"*—paper presented by D. Clark to the Royal Society and published in their Philosophical Transactions, Ref. A.276, p. 559 etc. (1974). Looked at the scope for innovation in the technology of conversion of fossil fuels to electricity.

1974 *Foyers pumped-storage station* on Loch Ness commissioned with two 150 MW reversible pump turbines, part of the North of Scotland Hydro-Electric Board's Great Glen Group of stations under remote control from Fort Augustus.

1974 Russia commissioned the *first R.B.M.K–1000* (high-capacity boiling water) *reactor* at the Leningrad 4 × 1,000 MW complex—channel type, water-cooled, graphite-moderated. Uranium dioxide enriched to 1·1–1·8 per cent U235 content clad in zirconium alloy was contained in 1,693 × 80 mm. diameter channels in graphite columns. Boiling water pumped at a pressure of 6·5 MPa through the tubes of the channels washed the fuel assemblies and entered four drum separators in the form of water-vapour emulsion. Separated steam powered 2 × 500 MW turbines and the water, slightly cooled by mixing with pre-heated feed water, was pumped back through the fuel channels.
A similar reactor commissioned at Chernobyl in 1984—on 26 April 1986 it became "prompt critical" (power levels rose by several orders of magnitude in a few seconds) due to a series of operator errors and a substantial explosion destroyed the upper part of the reactor core.

1974 *"Cable Practice in Electricity Board Distribution Networks: 132 kV and Below"*—review paper by A. Ross to the I.E.E. published in the "Proceedings I.E.E.", Vol. 121, No. 11R, November 1974, p. 1307 etc.

1974 *Advisory Committee on the Safety of Household Electrical Equipment* set up by the Secretary of State for Prices and Consumer Protection to advise on the administrative guidance to be provided concerning the proposed Electrical Equipment (Safety) Regulations. (*q.v.*)

1974 *"Electricity in Agriculture"*—a review paper by R. A. Bayetto, H. Paterson and P. O. Wakeford to the I.E.E., published in the "Proceedings I.E.E.", Vol. 121, No. 11R, November 1974, p. 1244 etc.

1974 *International Energy Agency* (I.E.A.) established by O.E.C.D. to implement the International Energy Program for developing a common level of emergency self-sufficiency in oil supplies and to reduce dependence on imported oil. Its establishment was noted in a White paper *"Agreement on an International Energy Program"*, Cmnd. 5826, which set out the I.E.A.'s programme. The Agreement was signed by the U.K. on 18 November.

1974 *Cross-Channel cable extension*—joint C.E.G.B./EdF investigations into a proposed reinforcement of the link with France indicated that a new 2,000 MW HVDC link could produce significant economic savings in the early 1980's.

1974 In his November budget the Chancellor of the Exchequer stated his objective to *eliminate subsidies to the use of energy* through artificial prices for the products of nationalised industries.

1974 *Thermal insulation standards for new buildings* were increased under "The Building (Second Amendment) Regulations 1974" S.I. No. 1944, which came into operation on 31 January 1975. (Later incorporated in "The Building Regulations 1976", S.I. No. 1676.)

1974 *Energy conservation—The Electricity (Advertising Lighting) (Control) Order 1974,* S.I. 1974, No. 2159, prohibited the daylight use of electricity for advertising purposes (later repealed under the Energy Act 1976); *The Fuel and Electricity (Heating) (Control) Order 1974,* S.I. 1974, No. 2160, prohibited the use of fuel or electricity to heat premises above a temperature of 68°F (20°C). They came into operation on 13 January 1975.

1975 *"Save-It" campaign*—the biggest and most concentrated publicity exercise undertaken by the Government to date was launched by the Secretary of State for Energy on 20 January to bring home to consumers the need to save energy and to explain how it could be done.

1975 *National Consumer Council* established, as foreshadowed in the White Paper "National Consumers' Agency", Cmnd. 5726, September 1974, a non-statutory body to represent the consumer's view to central and local government.

1975 *Joint reading of electricity and gas meters*—the Under-Secretary of State for Energy said in the House on 20 January that consideration of this question had revealed that any saving would be very marginal if anything at all.

1975 The Biblis "A" 1,200 MW P.W.R. nuclear station of Rheinisch-Westfalisches Elektrizitätswerk A.G. commissioned. It was constructed under a turnkey contract awarded to Kraftwerk Union A.G. on 13 June 1969. The 1,200 MW single-shaft generator was claimed to be *the world's largest set and the first four-pole machine to feature a water-cooled rotor.* Liquid cooling of both armature and field windings was necessary because of German railroad limitations on the transport of large stators. The fuel was enriched to about 2·6 per cent U–235 content and clad in Zircaloy 4.

1975 *Consultative councils*—From 1 February the responsibility for appointing the chairman and members of the consumer councils for the coal, gas, electricity and transport industries and the Post Office was transferred to the Secretary of State for Prices and Consumer Protection.

1975 North of Scotland Hydro-Electric Board put in hand design studies for a pumped storage station at *Craigroyston* on Loch Lomond of up to 3,200 MW capacity.

1975 Electricity Boards adopted a voluntary *Code of Principles* aimed at providing prompt and efficient *appliance servicing* within about three days at a reasonable cost, with an associated complaints procedure operating through electricity consultative councils, and provision for arbitration.

1975 *Domestic off-peak tariffs*—on 25 March the Secretary of State for Energy announced the phasing out of the concession on the price of off-peak electricity introduced on 1 August 1974. (*q.v.*)

1975 *Higher electricity prices*—during the year domestic tariffs were increased by 40 per cent including fuel cost adjustment and there were large increases in other tariffs in a move towards economic pricing after a period of price restraint.

1975 *Uranium Enrichment Corporation* of South Africa (U.C.O.R.) began to operate their pilot plant based on what was claimed to be a unique process for uranium enrichment.

1975 *"Electricity and Heat Production: Energy Efficiency Versus Cost Efficiency"*—paper by P. A. Lingard to the District Heating Association on 13 May considered the economics of district heating schemes supplied from steam power stations.

1975 *North Sea Oil*—on 18 June Hamilton Brothers group delivered *Britain's first offshore oil* from the Argyll field, ferried by the Liberian tanker Theogennitor to British Petroleum's Isle of Grain refinery. In October the first oil from B.P.'s Forties field was piped to Cruden Bay near Peterhead, then on to the Grangemouth Refinery; and the Phillips group piped the first supplies from Norway's Ekofisk field to Seal Sands, Teesside.

1975 *The Uranium Institute* was established in London by international uranium producers to act as their trade association.

1975 *Effect of V.A.T. change on selected domestic appliances*—the Domestic Appliances Working Group of the Electrical Engineering Economic Development Committee estimated that the increase in V.A.T. from 8 per cent to 25 per cent would reduce sales of the most important electrical appliances by up to 20 per cent.

1975 *"The Electrical Equipment (Safety) Regulations 1975"*, S.I. No. 1366, made under the Consumer Protection Act 1961, laid down compulsory comprehensive safety criteria for all equipment designed and suitable for domestic use and offered for sale in G.B. They came into force on 1 April 1976.

1975 *Advisory Council on Energy Conservation* reported to the Secretary of State for Energy (Energy Paper No. 3, pub. Dept. of Energy). Among its recommendations were—energy prices should reflect the full cost of production, any strongly promotional element in pricing should be eliminated, the Electricity Council and Scottish electricity boards should be encouraged to take positive roles in developing combined heat and power schemes.

1975 *Statutory Corporations (Financial Provisions) Act*—made provisions for compensating certain nationalised industries for their losses due to price restraint in the years 1974–75 and 1975–76. The Act also transferred financial responsibility for the electricity consultative councils to the Secretary of State for Prices and Consumer Protection as from 1 October.

1975 *"Overhead—Line Practice"*—review paper by E. H. Cox published in "Proceedings I.E.E.", Vol. 122, No. 10R, October 1975, p. 1009 etc. covering overhead-line developments in the U.K. since 1882.

1975 *"Development, Design and Use of Ripple Control"* review paper by W. L. Kidd published in "Proceedings I.E.E.", Vol. 122, No. 10R, October 1975, p. 993 etc. covering the history of ripple control developments.

1975 "First Report from the Select Committee on Science and Technology—*Energy Conservation*", H.C. Paper 487, (and H.C. Papers 127 i–ii, 155 and 156 i–iv) called for a Government energy conservation policy that would reduce U.K. energy consumption by 15 per cent within two or three years.

1975 First 1,200 MW set completed in the U.S.S.R.—*claimed to be the largest two-pole 3,000 rpm t/a in the world.* Steam conditions were 235 bar and 540°C with direct water-cooling of the stator.

1975 The *Fort St Vrain nuclear station*, near Denver, of the Public Service Co. of Colorado, the world's *first commercial-size high temperature gas-cooled reactor* (H.T.G.R.) began its rise-to-power test programme. The 330 MW station was helium cooled, and its uranium/thorium fuel was clad with layers of pyrolytic carbon. The graphite moderator configuration had good heat transfer properties. These features permitted high operating temperatures. The startup programme was delayed by technical troubles over several years. Although it achieved firm power at the end of 1976, by 1984 its cumulative load factor amounted to no more than 18 per cent.

1975 White Paper "The Attack on Inflation", Cmnd. 6151 proposed the use of *cash limits in the public sector.*

1975 *The 250 MW Prototype Fast Reactor* (P.F.R.) at Dounreay began supplying electricity to the grid. The liquid-sodium-cooled station's fuel charge amounted to 900 kg P_uO_2 and 3,000 kg UO_2. Fuel elements of mixed plutonium/uranium oxides were surrounded by a blanket of uranium, and plutonium was produced in the uranium in both the fuel elements and the blanket. It was intended as a precursor to a full size demonstration prototype fast breeder reactor (C.D.F.R.).

1975 The *Milne Museum* at The Slade, Tonbridge, was opened by the South Eastern Electricity Board, housed in the former Tonbridge power station.

1975 *Co-ordination of sodium sulphur battery research*—Chloride Silent Power Ltd. agreed to co-ordinate their research and development with that being undertaken by British Rail and the Atomic Energy Research Establishment at Harwell.

1975 At *Bruce-Mansfield* coal-fired station of Pennsylvania Power Co. the first of three 825 MW units commissioned. This was *the U.S.A.'s first coal-fired station to satisfy new Federal and State effluent regulations*—the auxiliary load accounted for 10 per cent of gross generation, double the previous amount.

1976 *White Paper "The Structure of the Electricity Supply Industry in England and Wales—Report of the Committee of Inquiry', Cmnd. 6388,* published January. The Committee was set up by the Secretary of State for Energy in December 1974, with Lord Plowden as Chairman. Their main recommendation was that the supply industry in England and Wales should be unified, with a new single statutory body, the Central Electricity Board, to take over the responsibilities of the Electricity Council, the C.E.G.B. and the area boards. The Secretary of State for Energy announced in February that the report provided an opportunity for all concerned to have the widest possible discussion on the shape of the industry.

1976 The O.E.C.D.'s *Dragon experimental high temperature reactor* (H.T.R.) project at Winfrith terminated on 31 March.

1976 Results of a *feasibility study of district heating* for a redevelopment area around the old Pinkston Power Station, Glasgow, made by the South of Scotland E.B. in collaboration with Kennedy and Donkin Associates, showed that the district heating consumer would have to pay more for his heat than for alternative forms, and if electricity were produced in conjunction with the district heating scheme it would be more expensive than that generated by conventional methods.

1976 *U.S.* Government declared a temporary *moratorium on reprocessing* nuclear spent fuel. In 1977 it was extended indefinitely.

1976 *"The Russian Graphite Moderated Channel Tube Reactor"*, internal report by the Nuclear Power Co., made public by National Nuclear Corporation in May 1986. Compared the Leningrad R.B.M.K. station with the S.G.H.W.R. and found some design inadequacies in terms of British safety requirements—they concerned emergency core cooling, lack of full containment, mechanical instability of graphite core, protection against pressure tube failure, loss of water coolant, back-up to control rods for reactivity shutdown, high temperature of graphite core. Reactor had a "positive void coefficient" in that a steam filled fuel channel would increase neutron population.

1976 *British Electricity International Limited,* a wholly-owned subsidiary of the Electricity Council, was established on 15 April to strengthen the overseas consultancy services of the U.K. electricity supply industry.

1976 *"Solar Energy: A U.K. Assessment"*—paper presented at the Royal Institution by the U.K. Section of the International Solar Energy Society (Chmn. J. K.

Page) stated that, in the long term, solar energy could supply 10 to 20 per cent of U.K. energy requirements.

1976 *Electricity and gas showrooms*—Secretary of State for Energy announced that the Government had accepted the advice of the electricity and gas industries that their showrooms should not be merged; and advice from consumers' representatives that when one industry closed an uneconomic showroom the possibility of providing a service through the showrooms of the other industry should be considered.

1976 *"Nuclear Power and the Environment"*, Sixth Report of the Royal Commission on Environmental Pollution (Chmn. Sir Brian Flowers), Cmnd. 6618, considered that the Government's nuclear power proposals carried unjustifiable risks to the public, the F.B.R. should be delayed as long as possible on environmental grounds, but the fusion reactor would involve much less hazard from radiation.

1976 *"Energy R. & D. in the U.K.: a discussion document"* based on studies carried out for the Advisory Council on Research and Development for Fuel and Power (A.C.O.R.D.) (Chmn. Dr W. Marshall) estimated the expected gap between energy demand and home supplies of fossil fuels by the turn of the century according to various criteria.

1976 "Fourth Report from the Select Committee on Nationalised Industries—*Gas and Electricity Prices*", H.C. Paper 353. Recommended inter alia the abandonment of fuel cost adjustment in domestic tariffs, and that the Department of the Environment should give guidance on the running costs of heating systems and other appliances.

1976 *First National Energy Conference*—Held on 22 June, a one-day conference organised by the Secretary of State for Energy to encourage and stimulate discussion amongst a wide range of interests and to draw on their advice in preparing a national energy policy. The Electricity Council's paper "Flexibility in Long-Term Energy Policy" called for a reduction in government direct intervention in energy decision making, and ground rules set by Government as a framework for flexible planning. The Secretary of State announced in the House on 19 July that the energy forum had indicated a need for a more permanent body to consider energy policy and that he was considering what form this body should take.

1976 *National Joint Co-ordinating Council (Great Britain), for the Electricity Supply Industry in Great Britain, (N.J.C.C. (G.B.))* was established on an interim basis in place of the two existing National Joint Advisory Councils (one for England and Wales and one for Scotland), to consider matters of importance or of common interest to the whole industry, including negotiations where it would advise on general matters which affected more than one of the existing negotiating machineries.

1976 White Paper *"Energy Conservation. The Government's Reply to the First Report from the Select Committee on Science and Technology, Session 1974–75"*, Cmnd. 6575. The Government did not accept that energy tariffs were promotional nor that the large consumption of gas and electricity was synonymous with wasteful consumption. Stated inter alia that inverted tariffs would tend to encourage multi-fuel use which was inefficient in natural resource terms, and would also have an adverse impact on energy-intensive firms, and in the domestic sector would have adverse social consequences for low-income consumers with unavoidable large energy requirements.

1976 *National Nuclear Corporation*—U.K.A.E.A. increased its shareholding from 15 per cent to 35 per cent by acquiring shares from G.E.C., whose holding was reduced to 30 per cent. The remaining 35 per cent was held by British Nuclear Holdings, a consortium of industrial companies. G.E.C. would continue to

exercise a supervisory role in support of the N.N.C.'s operating company, the Nuclear Power Company.

1976 *Low income groups and fuel bills—*

Supplementary benefit claimants and fuel disconnections. Arrangements were agreed between the Electricity Council and Department of Health and Social Security which would enable the Supplementary Benefits Commission to make payments direct to electricity boards by means of regular deductions from supplementary benefits in order to help to avoid disconnections through non-payment of bills.

"Energy Tariffs and the Poor"—a report by a Government interdepartmental group of officials appointed to review the scope for helping low-income consumers concluded that possibilities such as concessionary tariffs were not a satisfactory way of helping low-income groups with their fuel bills.

"Fuel Debts and the Poor"—Poverty Pamphlet No. 24 from the Child Poverty Action Group recommended that Supplementary Benefits should include increased fuel allowances, there should be a much wider choice of payment methods to help households to budget weekly, the fuel advisory service should offer free advice on comparative fuel and appliance costs, arrears in fuel bills might be paid back at an agreed weekly sum.

Token operated pre-payment meters—the Electricity Council commenced two-year trials using standard pre-payment meters adapted for operation by plastic tokens.

Tariff structures and pricing policies of electricity and gas—"Third Report from the Select Committee on Nationalised Industries". H.C. Paper 352. Recommended that coin meters should be more readily available, that pay-as-you-burn schemes should be encouraged, and that local authorities should allow council tenants to pay fuel bills with the rent.

"Review of Payment and Collection Methods for Gas and Electricity Bills" (Chmn. Mr G. Oakes) This informal review body's principal recommendation was that the electricity and gas industries should no longer disconnect supplies to domestic customers for non-payment of bills but should rely, instead, on other means of recovering debts.

An electricity discount scheme was announced in November under which the Government would pay 25 per cent of the electricity bills for householders on Supplementary Benefit or Family Income Supplement in respect of meter readings made in February, March or April 1977.

A code of practice for payment of domestic electricity and gas bills was agreed by the electricity and gas industries which provided reasonable procedures for the settlement of bills in cases of hardship.

1976 *S.G.H.W.R.*—on 22 July the Government announced that the commissioning of the first Sizewell reactor would be delayed until August 1985 as part of measures to reduce the public sector's claims on the nation's resource.

—In a memorandum to the Secretary of State for Energy ("Thermal Reactor Review", 23 July) and evidence to the Select Committee on Science and Technology (13 October) the South of Scotland E.B. stated that the S.G.H.W.R. represented a viable reactor choice with good operational flexibility and ease of repair.

—In a memorandum to the Secretary of State for Energy ("Reactor Policy", 26 July) the U.K.A.E.A. recommended that the S.G.H.W.R. programme should be replaced by A.G.R.'s or P.W.R.'s.

—On 22 October the Secretary of State for Energy announced his support for a new assessment of reactor designs to be carried out by the Nuclear Power Company.

—"First Report from the Select Committee on Science and Technology—*The S.G.H.W.R. Programme*", H.C. Paper 89 (1977) recommended inter alia that the S.G.H.W.R. programme should only be cancelled if it were more expensive than other types of reactor designed to the same safety standards, if other types had significantly greater export potential, and if the construction of alternative reactors could begin in early 1979, the date scheduled for Sizewell "B" and Torness S.G.H.W.R.'s.

—The UKAEA recommended that on grounds of effort and cost the S.G.H.W.R. should be replaced by AGR's or PWR's.

1976 *"The Electricity Supply Industry—Yesterday, Today and Tomorrow"*—by E. S. Booth. Inaugural Address of the President of the I.E.E. published in "Proceedings I.E.E.", Vol. 124, No. 1, January 1977.

1976 *"An Assessment of the Integrity of P.W.R. Pressure Vessels"*, report of a study group headed by Dr Walter Marshall, Deputy Chairman of the U.K.A.E.A., which considered the question of the possibility of P.W.R. pressure vessel failure. Recommended that the Nuclear Inspector could now be satisfied about the safety of such vessels built in Britain.

1976 *Selby coal-mine project* inaugurated—the first completely new coalfield for 70 years. It would provide 10 million tons a year at a capital cost of £400 million.

1976 *Accelerated ordering of power stations.* According to a report by the Heavy Electrical Machinery Working Group of the Electrical Engineering Industry E.D.C. the ordering of a 2,000 MW fossil-fuel-fired station in 1977, some four years before required, could yield net savings if inflation offset interest charges. But the C.E.G.B. indicated that advanced ordering would result in substantially higher costs although a better case could be made for nuclear plant.

1976 The *Watt Committee on Energy* was established with the object of promoting the study of energy demand and supply. Members were drawn drom the principal learned societies.

1976 A White Paper *"Cash Limits on Public Expenditure"*, Cmnd. 6440, introduced the concept of limits on annual borrowings which supplemented the nationalised industries' targets of profitability.

1976 *Nationalised Industries Chairmen's Group* formed by Chairmen of 21 leading state-owned bodies to offer to the Government a collective view on major issues. Later a *Nationalised Industries Overseas Group* was established to promote collaboration between the nationalised industries with the object of raising U.K. exports.

1976 The 500 MW, 240 km. *Skagerrak DC link* between Denmark and Norway commissioned, operating at ±250 kV.

1976 Three *experimental greenhouses* for growing tomatoes and lettuces constructed by C.E.G.B. with the Ministry of Agriculture, using reject heat from the Eggborough power station in Yorkshire.

1976 *"Report on the Present and Projected Financial Position of the Northern Ireland Electricity Service"* published by H.M.S.O., Belfast. This Report to the Minister of State for Northern Ireland by Mr G. T. Shepherd, Chairman of the Midlands Electricity Board, recommended inter alia that the second stage of the Kilroot power station should be abandoned and the capital liabilities should be restructured in order to reduce the burden of interest charges.

1976 The *Leicester main gas turbine* station commissioned, the first in a new programme comprising seven of these stations. While Leicester had two 51 MW industrial type gas turbines, the others had 70 MW units powered by aero-jet engines.

1976 The *world's largest single-shaft turbo-alternator* commissioned at Biblis "B" P.W.R. nuclear station of R.W.E. The 1,300 MW K.W.U. four-pole, 1,800 rpm set was water cooled.

1976 *Electric and Hybrid Vehicle Research, Development, and Demonstration Act* increased U.S. development work on electric vehicles.

1976 *Electricity (Financial Provisions) (Scotland) Act 1976* included provisions to compensate the North of Scotland Hydro-Electric Board for the deficits incurred in supplying British Aluminium Company's smelter at Invergordon due to the late commissioning of Hunterston "B" A.G.R. station.

1976 *Coredif*, a new consortium to build a gaseous diffusion plant to produce enriched uranium was provisionally established. Shares were split between Eurodif (*q.v.*) 51 per cent, France 29 per cent and Iran 20 per cent. About 10 million separative work units annual capacity was envisaged, with the first commissioning expected by 1990.

1976 *C.E.G.B.* Headquarters Research Department was re-designated a *Research Division* and the title Controller of Research changed to Director-General, Research Division.

1976 Accelerated *power station closure programme*—the C.E.G.B. closed down 23 stations and partly closed 18 on 25 October involving 2,884 MW of plant. A second tranche, implemented in March 1977, involved closing six further stations and partially closing two, totalling 649 MW.

1976 *First A.G.R. nuclear stations* commissioned—Hinkley Point "B" near Bridgwater, Somerset and Hunterston "B" near Largs, Strathclyde. The CO_2 gas-cooled graphite-moderated two-reactor stations, with one 660 MW set per reactor, employed slightly enriched uranium in the form of ceramic UO_2 canned in stainless steel.

1976 At *Ontario Hydro's Bruce nuclear station* the first of four 750 MW(e) C.A.N.D.U. reactor units entered service. The 800 MW set, one of four to be supplied by C. A. Parsons, was the largest so far built in Britain. The station will also supply steam for a heavy water plant built alongside with an annual output of 800 tons.

1976 *"Consumers and the Nationalised Industries"*—a report of the National Consumer Council to the Secretary of State for Prices and Consumer Protection, which for the electricity supply industry recommended that the existing area electricity consultative councils and their district committees should be abolished and that in their place there should be a National Electricity Consumers' Council and 12 "regional presences", each consisting of a secretariat working under the National Council's control and the regional member of that Council.

1976 *"Energy Act 1976"*—contained powers for the control of fuel and electricity and for conservation measures. It replaced the Fuel and Electricity (Control) Act 1973 (*q.v.*) passed during the 1973–1974 fuel emergency, parts of which were renewed annually by Order.

1976 *"A Study of U.K. Nationalised Industries: Their Role in the Economy and Control in the Future"*—a report to the Government from the National Economic Development Office which concluded that the system of control and government relationships with the nationalised industries was highly unsatisfactory and in need of radical change. Recommended that for each major nationalised industry there should be a Policy Council to agree corporate objectives and strategies, establish performance criteria and monitor performance; and a Corporate Board which would manage the corporation within the framework agreed by the Policy Council.

1976 *International Electro-technical Commission* (I.E.C.) completed their draft technical specification for a 16 A plug and socket intended for world-wide acceptance.

1976 The Brown's Ferry, Alabama, B.W.R. station of T.V.A. became the *world's largest nuclear station* with the commissioning of the third 1,067 MW unit.

1976 *"The Future of the United Kingdom Power Plant Manufacturing Industry: A Report by the Central Policy Review Staff"* (Chmn. Sir Kenneth Berrill) suggested possible measures for action which included the rationalisation of the power plant manufacturing industry through mergers, bringing forward one power station order, a Government commitment to a firm and steady order programme, and the ordering of a prototype 1,300 MW unit.

1977 White Paper *"Industrial Democracy*—Report of the Committee of Inquiry" (Chairman, Lord Bullock) Cmnd. 6706, recommended that employees should have the right to be represented on the top policy boards of the largest companies in the private sector.

1977 The *"Cyclocontrol" system of load control*, invented by the London Electricity Board and produced by G.E.C., was used to control 500 street lamps and signs in the City of London—the first local authority installation in the country.

1977 South Western Electricity Board introduced *"cash and carry appliance repairs while you wait service"* at Bristol and Plymouth.

1977 *"Coal for the Future"*, published by the Department of Energy on behalf of the tripartite coal industry working group consisting of Government, the National Coal Board and the mining unions, proposed strategic plans to expand coal production to 170 M tonnes a year by 2000.

1977 *Dounreay Fast Reactor* (D.F.R.) closed down in March after 17 years of operation. Its role as a development and test facility was taken over by the P.F.R. (*q.v.*).

1977 *Mr F. L. Tombs* (later Sir Francis) appointed Chairman of the Electricity Council from 1 April (until 31 December 1980).

1977 *Japan's first F.B.R.*—The Power Reactor and Nuclear Fuel Development Corporation's "Joyo" 100 MW(t) experimental unit at Oarai-Machi reached criticality.

1977 *National Joint Co-ordinating Council for the Electricity Supply Industry in Great Britain (N.J.C.C.(G.B.))* established in place of the two existing National Joint Advisory Councils (one for England and Wales and one for Scotland). With equal numbers of members from Electricity Boards and Trades Unions it considered a wide range of matters of common concern.

1977 White Paper "The Government's Reply to the Fourth Report from the Select Committee on Nationalised Industries—*Gas and Electricity Prices*", Cmnd. 6806. Pointed the need for a return to economic pricing and for the phasing out of subsidies to the nationalised energy industries and drew attention to measures designed to protect the poorer consumer.

1977 White Paper "The Government's Response to the Sixth Report of the Royal Commission on *Environmental Pollution*", Cmnd. 6820, accepted the bulk of the Commission's recommendations.

1977 *"Call-out Charges"*, published by the Price Commission. Recommended that people should become more accustomed to doing minor repairs themselves and, to make this possible, manufacturers should design their products to combine reliability with ease and safety of maintenance.

1977 The final report of the *Ranger Uranium Environmental Inquiry* (Chairman Mr Justice Fox) made recommendations to the Australian Minister of the Environment about the environmental impact of uranium mines on the Ranger Ore-

body in the Northern Territory of Australia. Because of the long and exhaustive work undertaken by the Commission it seemed unlikely that further public enquiries concerning uranium mining would be necessary.

1977 *Association of Members of State Industry Boards* formed with Mr Dennis Dodds, Chairman of the Merseyside and North Wales Electricity Board, as the first Chairman.

1977 Details of a £25 million scheme to *help recipients of Supplementary Benefit and Family Income Supplement with their electricity costs* during the winter was announced by the Department of Energy. More than three million people were eligible for help.

1977 London E.B. introduced their first *Centron II automatic weather-sensitive charge controller* for water and space heating systems—it triggered a cyclo-control system of mains borne signalling for 1,000 consumers at Stonebridge Park with 11·6 MW storage radiator load and 2·8 MW of off-peak water heating load.

1977 The Secretary of State for Northern Ireland announced a re-structuring of the finances of the Northern Ireland Electricity Service based on a recommendation of the Shepherd Committee (*q.v.*). Interest charges were greatly reduced by writing off borrowings and grants were made to bring tariffs more in line with the rest of the U.K.

1977 *U.S. National Energy Plan* included policy to defer U.S. commitment to advanced nuclear technologies including the Clinch River Breeder Reactor Demonstration Project (Tennessee) and commercial reprocessing and recycling of plutonium. However, backing from Congress maintained Clinch River and it was expected to commission in the late 1980s, but in the event the project was terminated on 9 December 1983.

1977 *Energy Commission* formed to advise the Secretary of State for Energy on energy policy. Membership was drawn from the energy sector, TUC, industry and consumer interests. It was dissolved in 1979.

1977 *Teaching Fellows* sponsored by the electricity supply industry were appointed at Cambridge University and the University of Aston in Birmingham to further electroproduction education.

1977 *Northern Engineering Industries Limited (N.E.I.)* formed by a merger of Clarke, Chapman and Reyrolle Parsons (A. Reyrolle had merged with C. A. Parsons in 1968; Clarke Chapman merged with John Thompson in 1970 and with International Combusion in 1974).

1977 *New York blackout on 13 July*—lighting faults commencing 20.37 on the Consolidated Edison transmission system cut off all supplies to New York City by 21.36, amounting to 5,860 MW. Full service was restored only after 25 hours.

1977 "Third and Fourth Reports from the Select Committee on Science and Technology—The Development of *Alternative Sources of Energy* for the United Kingdom; the Exploitation of *Tidal Power* in the Severn Estuary", Session 1976–77, H.C. Papers 534–1 and 564, published. Concluded that Government spending on renewable sources of energy has been "grossly inadequate" and its attitude to a possible tidal power project "excessively timid".

1977 The generating *plant margin* over forecast average cold spell simultaneous maximum demand used for planning purposes was increased from 20 per cent to 28 per cent to allow for reduced plant availability and for forecasting uncertainty.

1977 *Incident at Hinkley "B"* A.G.R. station. On 29 June an 18 in. pipe supplying sea water to the reactor auxiliary cooling system fractured leading to extensive flooding of one half of the sea water pump house. The water supply could not be restored from the other half of the pump house because of a failure in a sectionalising valve, and an alternative cooling water supply was provided within three hours when five hose connections were made to a town's water supply from a one million gallon storage tank on the site. The one reactor operating was shut down when the fracture was discovered. Reactor cooling was not affected, the cooling gas temperature was reduced to the normal shutdown value and there was no risk of radioactive release. The temperature of the gas circulation and concrete pressure vessel, which were indirectly cooled by the sea water, did not rise to unacceptable levels. Later designs of A.G.R. were provided with a back-up cooling water supply.

1977 The Secretary of State for Energy announced in July that a Bill would be introduced to create a *new central body for the electricity supply industry in England and Wales*, with overall responsibility for financial, commercial engineering, research and industrial relations policies, the promotion of industrial democracy and the safeguarding of consumers' interests.

1977 *Advance ordering of Drax II*—the Secretary of State for Energy announced in the House in July that in order to help plant manufacturers the C.E.G.B. should order the Drax II coal-fired station immediately instead of in 1979 as planned. Compensation would be paid. The station was completed in 1986 within programme and budget.

1977 *Support for coal*—the Government announced the provision of about £2M to the N.C.B. to meet part of the cost of increased consumption of low volatile Welsh coal at Aberthaw "B" and Carmarthen Bay stations up to March 1978—subsequently extended to September 1978 and to include medium volatile coal at Didcot power station.

1977 *Thermal efficiency figures for domestic heating systems* at the point of consumption announced by the Parliamentary Under-Secretary of State for Energy. They included electric direct acting space heaters 100 per cent, electric storage heaters 80–90 per cent; gas radiant and convector fires 50–60 per cent, gas central heating 60–70 per cent; electric water heating 75 per cent, gas water heating 40–55 per cent.

1977 *P.W.R. safety*—Nuclear Installations Inspectorate announced that although their present knowledge prevented final conclusions on certain safety aspects of the P.W.R., they were satisfied that this would not prejudice an immediate decision in principle on its suitability for commercial use.

1977 The 1,920 MW DC line from the *Cabora Bassa hydro complex* on the Zambesi River in Mozambique to the Appollo substation between Pretoria and Johannesburg in South Africa, commissioned. The 1,414 km line operated at ± 533 kV—the *highest DC voltage yet in service.*

1977 *"The Role of British Rail in Public Transport"*, First Report from the Select Committee on Nationalised Industries, H.C. 305–1, recommended inter alia that further consideration should be given to additional railway electrification. The Government set up a steering group for this purpose in 1978 (*q.v.*).

1977 *Unofficial strike by some power station employees*, mainly in the Midlands and the North, occurred on 6 and 7 September in support of shift pay increases, free transport and concessionary fuel. Load reduction on the Grid was three per cent mainly by voltage reduction. A work-to-rule and overtime ban lasted until 11 November. There were load reductions by voltage reduction and disconnection between 25 October and 12 November. The operation of uneconomic plant increased total system costs by £17M.

1977 *At U.S. Shippingport nuclear power station,* where the nuclear component is Government owned, a *demonstration water-cooled breeder reactor core* (L.W.B.R.) commissioned, using uranium dioxide and thorium dioxide as fuel.

1977 *British Electricity International Limited* signed an agreement with Riyadh Electric Co. and Suburbs of Saudi Arabia to operate the company as from 1 February 1978 for two years. It was later extended to run until October 1981.

1977 *"District Heating Combined with Electricity Generation in the United Kingdom"*, Energy Paper No. 20, published. This first report from the Combined Heat and Power Group (Chairman, Dr Walter Marshall), set up by the Secretary of State for Energy's Advisory Council on Research and Development (A.C.O.R.D.), suggested that large district heating schemes might be economically attractive in the longer term if fuel costs rose substantially in real terms or a lower discount rate were used for assessment purposes.

1977 *"Energy Policy Review"*—Department of Energy Paper No. 22, stated that the aim of energy policy was to secure that the nation's needs for energy were met at the lowest cost in real resources, consistent with security and with environmental, social and other objectives.

1977 *"Nuclear Power and the Environment"* Cmnd. 6820—Govt's reply to Flowers Committee report (*q.v.*) set out policy objectives for radioactive waste management.

1977 *"Freight Transport—Short and Medium-term Considerations"*, Advisory Council on Energy Conservation, Department of Energy Paper No. 24. Made wide ranging proposals for cutting the amount of energy used by freight transport.

1977 *"Energy for Transport—Long-term Possibilities"*, Advisory Council on Energy Conservation, Department of Energy Paper No. 26. Concluded that electric forms of transport seemed inevitable in the long-term and that the move to electric vehicles should be encouraged immediately.

1977 The Electricity Council launched two new campaigns to promote electricity as good value for money when used properly, the *Heating Plan* and the *Medallion Award Scheme* for energy saving homes.

1977 *U.S. Department of Energy established*—it encompassed the Federal Energy Administration, Federal Power Commission, Energy Research and Development Administration, the marketing of generation from State-owned undertakings, domestic and industrial energy conservation, oil pipeline regulations, and the Navy's oil-shale and petroleum reserve.

1977 The North of Scotland Hydro-electric Board launched their *"Heat seal" award scheme* for houses combining high insulation with closely controlled off-peak space and water heating.

1977 *Substation Alarm, Load and Operational Monitoring Equipment (S.A.L.O.M.E.)* first entered service—in the Highlands and Dundee areas of N.S.H.E.B. Existing radio communications and channels were used to monitor and control the operation of primary substations.

1977 E.E.C. Research Minister decided to build the *Joint European Torus* (J.E.T.) thermonuclear fusion experiment at the Culham Laboratories of U.K.A.E.A.

1977 *Electricity Consumers' Council* established on 31 October to consider any matter affecting the interest of electricity consumers in England and Wales. The Chairmen of Area Electricity Consultative Councils in England and Wales were ex-officio members. Given statutory status by Energy Act, 1983.

1977 Iran signed a letter of intent with Siemens of West Germany for the construction of four nuclear reactors, with a total capacity of 4,800 MW, *the world's largest single contract for nuclear power.*

1977 Electricity Council advised the Secretary of State for Energy in November that there should be *a clear commitment to the A.G.R.* and, as a fall back, there should also be a reasonable development of the P.W.R.

1978 Price Commission report *"Fuel Cost Adjustment for the Supply of Electricity"*, criticised the practice of Area Electricity Boards in passing on increases in fuel prices to the consumer through the Fuel Cost Adjustment mechanism and suggested that it should either be abolished or simplified to take account only of significant changes in the price of fuel.

1978 In January the Government authorised the C.E.G.B. and S.S.E.B. to order one *A.G.R. station* each, and endorsed the ordering of a *P.W.R. station* subject to the necessary clearances being obtained. In 1980 the Central Policy Review Staff recommended that these A.G.R. stations were still needed even though electricity demand was falling. They were ordered at the end of 1980—the C.E.G.B.'s at Heysham, Lancashire and the S.S.E.B.'s station at Torness, Lothian for commissioning in 1987.

1978 Green Paper *"Energy Policy: A Consultative Document"*, Cmnd. 7101, set out the Government's energy strategy proposals.

1978 *Standing Commission on Energy and the Environment* (Chairman Sir Brian Flowers) formed to provide the Government with authoritative advice on the interaction of energy policies and the environment.

1978 *The Windscale Inquiry* (Chairman Justice Parker) recommended that outline planning permission should be granted for B.N.F.L.'s T.H.O.R.P. (thermal oxide fuel reprocessing plant) without delay. "The Town and Country Planning (Windscale and Calder Works) Special Development Order 1978 (S.I. 1978 No. 523)" came into operation on 15 May 1978.

1978 *"The Challenge of North Sea Oil"* Cmnd. 7143. Explained how the benefits of North Sea Oil would help the British economy by boosting national income; helping the balance of payments; and by giving the Government £4,000M a year extra revenue by the mid-1980s. It was proposed to channel the extra resources into investing in industry; improving industrial performance; investing in energy; and increasing essential public services.

1978 White Paper *"The Nationalised Industries"* Cmnd. 7131, the Government's response to N.E.D.O.'s "A Study of U.K. Nationalised Industries" (*q.v.*), described a number of institutional changes designed to improve the relationship between the ni's and Government, unions, customers and suppliers and explained how information on their main objectives and performance would be published. Discussed the financial and economic framework within which the industries would operate, and in particular the role of the financial targets which would be published for all the industries and used as a measure of their success. Recommended that the ni's should treat the opportunity cost of their capital as five per cent in real terms before tax, to be earned on new investments over their working life.

1978 U.S. *Nuclear Non-Proliferation Act* placed a three-month embargo and other constraints on the supply of enriched uranium to E.E.C. and other countries.

1978 *Eastern E.B.* introduced an *Area-based management structure* from 1 April—comprising Headquarters, three Groups and eight Areas under Area Managers each assisted by three managers responsible for engineering, commercial and administrative functions. In 1979–80 the commercial and administrative posts were merged in the post of Customer Services Manager.

1978 White Paper *"Re-organisation of the Electricity Supply Industry in England and Wales"*, Cmnd. 7134, contained a draft Bill with Government proposals for the reorganisation of the electricity supply industry in England and Wales that had been prevented by Parliamentary constraints. The fragmented structure would have been replaced by a unified organisation under a single statutory Electricity Corporation.

1978 White Paper *"Industrial Democracy"*, Cmnd. 7231, proposed greater employee involvement in making and carrying out company policy. Emphasised the voluntary approach to increased participation.

1978 *Radioactive Waste Management Advisory Committee* (Chairman Sir Denys Wilkinson) formed to advise the Secretaries of State for the Environment, Scotland and Wales on the management of radioactive waste.

1978 *"Railway Electrification"*—a discussion paper published by the British Railways Board, made the case for large-scale electrification. The Secretary of State for Transport established a Steering Group to Examine the recommendations.

1978 *"Energy Conservation Research, Development and Demonstration. An Initial Strategy for Industry"*, Energy Paper No. 32, suggested that theoretical long-term energy savings in industry through technological change could amount to 30 per cent of industrial fuel consumption, equivalent to 38 mtce. A £21·5M energy saving demonstration programme provided up to 25 per cent of the cost of plant and equipment in six technologies (including fluidised bed boilers) and six industrial sectors selected for priority. The aim was to save £5 in energy per £1 of Government support.

1978 *Support for coal*—Government assistance to the N.C.B. coal burn at South Wales power stations extended to include additional consumption at Aberthaw "B" as well as Aberthaw "A", Carmarthen Bay and Didcot stations, for the period to October 1978.

1978 Price Commission Report—*"South of Scotland Electricity Board—Price Increases in the Supply of Electricity"* H.C. 535, criticised the accounting practices adopted by the S.S.E.B. as a result of which it was alleged that the Board had increased its prices by four per cent. Also criticised the Board for consistently using conservative asset lives for calculating depreciation which was inappropriate in a relatively low risk industry; for not capitalising interest which arose during the construction of new plant; and for failure to give details of its £10M contingency provision for 1978–79.

1978 An *eel farm* to produce 200 tonnes a year completed by C.E.G.B. and Rank Hovis McDougal Ltd. as a joint venture *using reject heat from* the *Drax* power station in Yorkshire. The station also heated half-an-acre of *glasshouses* for tomato growing built jointly by the C.E.G.B. and Express Dairy Fuels Ltd.

1978 *Nuclear Safeguards and Electricity (Finance) Act* included in Section 5 provision for a Government subsidy of up to £50M to the C.E.G.B. for the construction of Drax II ahead of requirement.

1978 *Ateliers de Vitrification de Marcoule (A.V.M.)* was commissioned for the storage of high-level waste in glass blocks by Compagnie Générale des Matières Nucléaires (C.O.G.E.M.A.) and the Commissariat à l'Energie Atomique (C.E.A.).

1978 U.S. *Power Plant and Industrial Fuel Use Act* prohibited the use of oil and natural gas in new power stations.

1978 "*Reports and Accounts of the Energy Industries*—Seventh Report from the Select Committee on Nationalised Industries, Session 1977–78" H.C. 583, criticised the conflicting practices used by the nationalised energy industries in producing their annual accounts; was concerned that some of the enterprises appeared to be more occupied with the presentation of their annual profit or loss and less with longer-term considerations of comparability.

1978 "*Re-organising the Electricity Supply Industry; Pre-Legislative Hearings* Ninth Report from the Select Committee on Nationalised Industries, Session 1977–78" H.C. 636. Concluded that there was a general desire for legislation to re-organise the electricity supply industry; and that successive Governments had failed to give sufficient priority to the legislation over a period of years.

1978 *British Electricity International Limited* agreed with China Light and Power to provide consultancy services and commissioning staff for the new *Castle Peak "A" station.* The first of four 350 MW units was expected to commission in 1982.

1978 Construction began on the U.S. 350 MW(e) *Clinch River Breeder Reactor Plant,* a liquid-metal cooled F.B.R.—due to commission in 1984. In late 1983, Congress elected not to endorse on alternative financing policy which would have increased private funding; the project was formally terminated on 9 Dec. 1983.

1978 "*Third Special Report from the Select Committee on Science and Technology,* Session 1977–78" H.C. 610. Contended that the Government should not wait until a firm proposal was made for the construction of a commercial-sized demonstration fast reactor (C.D.F.R.) before holding a public enquiry and suggested that the Select Committee itself be an appropriate body to conduct the inquiry.

1978 Generating *plant margin* used for planning purposes was increased from 20 per cent to 28 per cent.

1978 *Syncrude project* to produce crude oil from the Athabascan tar sands started production.

1978 "*Transverse Flux Induction Heating* First Report from the Select Committee on Science and Technology, Session 1977–78" H.C. 611. Outlined the history of the work on transverse flux induction heating by the Electricity Council Research Centre.

1978 *Support for coal*—Secretary of State for Energy announced an assisted coal-burn scheme—a Government contribution of £17M to increase C.E.G.B. winter coal consumption by 3M tonnes. The payment to the N.C.B. enabled reduced prices to be offered to the C.E.G.B.

1978 A new off-peak tariff known as the *"Economy 7" tariff* was introduced in October. If featured a seven-hour night rate some 20 per cent cheaper than most night-time tariffs, made possible by economies in the night-time operation of the system.

1978 The Prime Minister asked the Central Policy Review Staff to study *rival turbo-alternator designs* with regard to future nuclear commissioning. The alternatives were N. E. I. Parsons six-flow and G.E.C. four-flow exhaust designs. C.P.R.S. were unable to decide on this technical issue. In the event the S.S.E.B. Torness station employed the G.E.C. design and C.E.G.B.'s Heysham II the N. E. I. Parsons design.

1978 C.E.G.B. announced that the environmental aspects of a *pumped storage station near Tintwistle* in Derbyshire, about 13 miles east of Manchester, were being studied.

1978 The *world's first air storage system energy transfer (A.S.S.E.T.) plant*—at Huntorf (290 MW) was commissioned by Nordwestdeutsche Kraftwerke A.G. (N.W.K.). Air compressed into two 150,000 m^3 caverns to 50–70 bar by eight hours of pumping provided two hours of full load generation.

1978 On 20 December there was a *national power failure in France* lasting four to five hours affecting 22M consumers. At 08.00 EdF noticed that frequency was falling throughout Western France. Voltage was reduced by five per cent, and imports from Western Germany increased. A 400 kV line between Bezaumont in Eastern France and Creney near Paris became overloaded producing a chain reaction throughout the Grid system.

1978 The first 640 MW unit of the *hydro station at Sayano-Shushenskoye* on the river Yenisei in Siberia commissioned. The station reached capacity of 6,400 MW by February 1986.

1978 *"The Durability and Efficiency of Filament and Discharge Lamps*—Third Report from the Select Committee on Science and Technology, Session 1977–78" H.C. 683–i. Recommended that lamp manufacturers should make long-life bulbs more readily available and provide more information about bulb performance. Recommended that Area Electricity Boards should take the lead in offering both 1,000 and 2,000 hours life coiled-coil bulbs for sale to the general public. Rejected the suggestion that there had been collusion among manufacturers to keep quality low.

1978 A *crisis in Iran* led to a cutback in oil production, and the cessation of exports at the end of 1978.

1978 *High-temperature heat pump* developed by the Electricity Council Research Centre at Capenhurst—it operated at a temperature (80°C) suitable for drying in industry. Early demonstrations were in a dehumidifier kiln for drying timber.

1978 *Financial targets* set by Government for electricity and gas industries for 1979/80—10 per cent on assets and 6·5 per cent on turnover respectively.

1979 *Fuel cost adjustment* in quarterly-billed tariffs was consolidated into basic tariffs with effect from 1st January 1979.

1979 *Eurodif's uranium enrichment plant* at Tricastin in the Rhone Valley between Montelimar and Orange produced its first enriched uranium hexafluoride. Full production of 10·8M separate work units (SWU) was expected by the end of 1981.

1979 *Events in Iran* and reaction by other members of O.P.E.C. restricted supplies of heavy fuel oil to power stations.

1979 British, Dutch and German governments agreed that *Urenco* (*q.v.*) should more than double the capacity of its plant at Capenhurst to 400 tonnes per annum, and at Almelo in the Netherlands to 600 tonnes per annum.

1979 *"Heavy Current Electricity in the United Kingdom: History and Development"* by Lord Hinton of Bankside, published by the Pergamon Press, Oxford. (ISBN 0–08–023247–7).

1979 The *International Energy Agency* agreed a programme for participating countries to reduce their demand for oil by about two million barrels a day, five per cent of consumption. U.K. contribution included a substantial reduction in power station consumption.

1979 *"Electricity before Nationalisation: A Study of the Development of the Electricity Supply Industry in Britain to 1948"* by Leslie Hannah, published by The Macmillan Press, London. (ISBN 0–333–22086–2)—the first volume of an official history sponsored by the Electricity Council on behalf of the electricity

supply industry of Great Britain. The second volume by the same author, "Engineers, Managers and Politicians: the First Fifteen Years of Nationalised Electricity Supply in Britain", was published in 1982.

1979 The *budget* increased the *tax on fuel oil* by 20 per cent to approximately £8 per tonne.

1979 *Electricity (Scotland) Act* consolidated the principal enactments relating to electricity supply in Scotland.

1979 *Accident at Three Mile Island* nuclear power station Unit No. 2 near Harrisburg, Pennsylvania—on 28 March this pressurised-water reactor was extensively damaged when a valve stuck open leading to a gradual loss of the cooling water pumped through the reactors heat-producing core. Although automatic protection shut the reactor down very quickly there was eventually insufficient water to remove the heat that continued to be generated by the radioactive decay of fission products in the fuel rods. When the metal cladding of the fuel rods partially melted they reacted chemically with the reactor water and a relatively small quantity of radioactive material was released into the reactor cooling water circuit.

1979 Japan's Power Reactor and Nuclear Fuel Development Corporation commissioned the *"Fugen" prototype heavy-water moderated, boiling lightwater cooled pressure-tube reactor of 165 MW(e) at Tsuruga.* The fuel was uranium dioxide enriched to 1·5 per cent U–235 content and also a mixed oxide of plutonium and uranium.

1979 *"Consumers and the Nationalised Industries:* Pre-legislative Hearings—Second Report from the Select Committee on Nationalised Industries, Session 1978–79" HC 334. Recommended that the Electricity Consumers' Council should have a right to be notified of major proposals relating to the industry's main services before they came into effect; and that the Government should provide for consumer representation on the Electricity Council and the C.E.G.B.

1979 The Leader of the House of Commons announced a *new Select Committee structure,* one Committee for each principal Government Department, to give MPs greater access to information from Ministers and Civil Servants. Electricity supply would mainly be covered by the work of the Select Committee on Energy. The Select Committee on Science and Technology was retained by Parliament, but as a Committee of the House of Lords. The departmental committees began their work in February 1980.

1979 The Electricity Council made available its annual *Medium Term Development Plan* for the first time. It covered the period 1979 to 1986, setting out the corporate objectives of the supply industry in England and Wales.

1979 *Energy Commission* scrapped in July. The Secretary of State for Energy considered that there were better forms of consultation for energy policy.

1979 On 23 July C.D.N. Ltd, *thermal insulation contractors* working at the *Isle of Grain* power station, gave three months' notice of termination of the site agreement with its laggers because of a *dispute* over a bonus scheme operating on the site. There had been a considerable shortfall in site construction performance due to exceptional labour relations difficulties, the first unit had been delayed nearly four years. On 6 December C.E.G.B. terminated C.D.N.'s contract; other contractors would not tender for their work. The C.E.G.B. threatened to suspend all work on the station from 21 April 1980, but the work continued when men from other unions were trained as laggers. The problem developed into an inter-union dispute. It was settled in May 1981 when the site workforce agreed to the terms of a T.U.C. peace formula.

1979 *"A Review of Cmnd. 884: 'The Control of Radioactive Wastes': A Report by an Expert Group made to the Radioactive Waste Management Committee,"* Department of the Environment, recommended that average effective dose equivalent, excluding natural background and medical radiation, to representative members of a critical group (groups which receive the highest doses) should not exceed 5 mSv (0.5 rem) in any one year. This limit would usually result in an average dose rate equivalent of less than 1 mSv (0.1 rem)/y for life-long whole body exposure—a lifetime effective dose per individual not exceeding about 70 mSv (7 rem).

1979 *German Ordinance on General Tariffs for Electricity Supply* gave households with electric heat pumps used for space heating two additional concessions—utilities were not allowed to levy a capacity surcharge (applicable to households running certain high consumption equipment) or to apply a domestic tariff with a "linear component" (applicable where consumers had an above-average consumption and which provided for a surcharge in the cost of marginal units above a certain threshold).

1979 *B.G.C. stopped promoting load* building domestic appliances and severely curtailed new gas supplies to consumers. The substitution of gas for oil had resulted in a sudden very large increase in gas demand.

1979 Eastern E.B. introduced a scheme for *payment of bills by large customers* with many separate addresses such as local authorities and chain stores. It eliminated billing and intermediate steps of processing accounts by *exchanging information on computer tapes* and directly debiting the customers accounts.

1979 *"Combined Heat and Electrical Power Generation in the United Kingdom"* Energy Paper No. 35, a report by the Combined Heat and Power Group (Chairman, Dr Walter Marshall), recommended that one or more lead city schemes to use heat discharged from power stations should be set up as soon as practicable since the waste could eventually provide 30 per cent of Britain's space heating and hot water needs, saving 30 mtce a year. A National Heat Board should be established to implement a national strategy. The potential heat load was estimated by a Heat Load Density Working Party (Chairman Prof. J. M. Cassels) which reported in *"Heat Load in British Cities"* Energy Paper No. 34.

1979 The *first "Chemelec" electrolytic cells* developed by the Electricity Council Research Centre at Capenhurst for metal recovery were installed by an electroplating company. The cell incorporated a bed of non-conducting particles fluidised between mesh electrodes and provided high rates of mass transfer from dilute solutions.

1979 Hydro-Québec's *James Bay scheme* started up. On completion, with a final capacity of 5,328 MW, it would be the *largest hydro scheme in North America.* The initial phase comprised five sites along the La Grande River with three power stations housing 33 generators, and adjoining Rivers Grande Baleine, Nottaway, Broakback and Rupert, were also to be developed.

1979 *"The British Electrical Industry 1875–1914: The Economic Returns of a New Technology"* by I. C. R. Byatt, published by the Clarendon Press, Oxford (ISBN 0–19–828270–2).

1979 *Japan—Moonlight Project* launched by the Agency for Industrial Science and Technology of the Ministry of International Trade and Industry to develop energy conservation technology—including gas turbines, Na S, Zn Cl_2, Zn Br_2 advanced batteries, Stirling engine, phosphoric acid fuel cells, a chemical heat pump based on Ca0 and a compression type, and MHD.
Sunshine Project launched by the same Ministry to develop new energy sources.

1979 Price Commission report *"Area Electricity Boards—Electricity Prices and Certain Allied Charges"*, HC 132, reviewed proposed tariff increases from 1 April and recommended that there should be no restrictions on the notified increases. With regard to the proposed re-organisation of electricity supply, it commented that there was a need for a more tightly structured organisation and a greater measure of central control.

1979 Monopolies Commission report *"Electricity Supply Meters"*, urged Area Electricity Boards to reconsider their buying policies and ordering procedures for electricity supply meters.

1979 *"Enquiry into Private Generation of Electricity in Great Britain 1977"*—a survey report published by the Department of Energy. It showed that back pressure and passout sets accounted for 65 per cent of private plant capacity and generation.

1979 The *British Civil Uranium Procurement Directorate* was established to handle the supplies of uranium for British Nuclear Fuels Ltd, the South of Scotland Electricity Board and the Central Electricity Generating Board. A Uranium Procurement Organisation located at C.E.G.B. headquarters was the operating arm responsible for obtaining uranium for the civil nuclear programme.

1979 *Parallel operation between the electricity systems* of the countries belonging to the *Council for Mutual Economic Assistance* (C.M.E.A.), known as "Peace", and the *Unified Electric Energy System of the USSR* began. It was achieved by a single 750 kV interconnection from Vinnitsa in the USSR to Albertirsa in Hungary. This continental size electricity supply system saved, by means of this link, about 730 MW of generating plant capacity through the reduction of maximum demand and a further 850 MW from lower plant margins.

1979 *Support for Coal—the Coal Industry (Limits on Grants) Order 1979*, SI No. 1011 increased the amount of operational grants from £100M to £175M, for promoting the sale of coal to power stations and financing stocks.

1979 The *world's first fast reactor fuel reprocessing plant* commissioned at Dounreay, to reprocess the plutonium fuel from the 250 MW(e) PFR on the site. The separated plutonium nitrate was transferred to Windscale for the manufacture of new fuel.

1979 *C.E.G.B. reorganisation—a new Transmission and Technical Services Division* formed from the Transmission Development and Construction Division and Engineering Services Department.

1979 *"Review of Main Line Electrification: Interim Report"*—by a joint Department of Transport/British Railways Steering Group found that electric traction could reduce the direct cost of operating trains and offer better services, but needed a more costly infrastructure. It could be justified where traffic was dense enough.

1979 *Civic Award Scheme for Energy Saving Homes* introduced by the electricity supply industry. The award was given to local authorities' and housing associations' housing with high standards of thermal insulation combined with modern electric heating.

1979 *"Energy Projections 1979"* published by Department of Energy, showed that U.K. primary fuel demand could rise from 360 mtce in 1978 to 445–510 mtce by 2000. The projections updated those in the Energy Policy Green Paper of 1978.

1979 A 1,100 MW B.W.R. unit commissioned at *Fukushima No. 1* nuclear station of Tokyo Electric Power Co., bringing the total site capacity to 4,696 MW in six units—*the world's largest nuclear station.*

1979 C.E.G.B. and N.C.B. signed a *Joint Understanding on Coal Supplies and Prices* up to 31 March 1985. C.E.G.B. would use its best endeavours to take 75 Mt of coal a year from N.C.B. and the latter to supply that amount, provided that the supplies were at pithead prices which increased by no more than the rate of U.K. inflation.

1979 Mr Norman Lamont, Parliamentary Under-Secretary of State, Department of Energy, outlined *Government energy policy* at a Financial Times Conference in Dusseldorf. The key element was pricing—the price of fuel should not be held below the long run cost of supply, and should bear a reasonable relationship to the price of competing fuels.

1979 Secretary of State for Social Services announced that from 12 November an additional 260,000 families on low incomes would receive *help with winter fuel bills.*

1979 *John G. Kemeny Commission* reported on the *accident at Three Mile Island* nuclear station (*q.v.*) on October 31. It criticised the U.S. electricity undertakings and Nuclear Regulatory Commission for being "unable to provide an acceptable level of safety in nuclear power". The fundamental cause of the accident was found to be a series of interwoven mechanical, human and institutional failures but, principally, seriously deficient training and confusing operating procedures. There were no fatalities.

1979 *Public enquiry* commenced on the N.C.B. proposal to develop the Vale of Belvoir coal fields.

1979 *Ayatollah Khomeini's Revolutionary Council* assumed control in Iran, and supplies of Iranian crude to world markets were cut.

1979 *Ente Nazionale per l'Energia Elettrica* began a series of *trial power cuts* in November in preparation for winter load shedding through plant shortages.

1979 Tokyo Electric Power's Sodegaura Research Centre demonstrated the *world's first cryogenic LNG electricity generation.*

1979 Letchworth, Ocker Hill, Taylors Lane and Watford *main gas turbine stations* commissioned, based on 70 MW units powered by aircraft-type gas turbines.

1979 A *programme of nuclear power station orders* was announced by the Secretary of State for Energy in the Commons on 18 December. Because it would be difficult, if not impossible, to meet long-term energy needs without a sizeable contribution from nuclear power, 15,000 MW of new nuclear capacity, from at least one new nuclear station a year in the ten years from 1982, represented a reasonable prospect.

1979 The Secretary of State for Energy announced that the Boards of the *National Nuclear Corporation* and its operating subsidiary, the *Nuclear Power Company,* would be brought together into a single-tier structure, the supervisory management agreement between N.N.C. and G.E.C. terminated and N.N.C. built up into a strong and independent design and construction company.

1979 The first of five 660 MW units commissioned at the *Grain* oil-fired power station—the largest in Europe.

1979 *"The accident at Three Mile Island: Comments by the Health and Safety Executive"* published. The principal conclusions of the Executive and the Nuclear Installations Inspectorate were that the accident did not arise from any serious inherent weakness in the concept or design of the PWR. The Executive still held the view that a PWR could be designed, constructed and operated in a way which would satisfy the Executive's conditions for a licence in Britain.

1980 *Financial targets for gas and electricity* announced by Secretary of State for Energy. For the period 1980/1 to 1982/3 the target for the electricity supply industry in England and Wales was an average annual rate of return of 1·8 per cent on net assets valued at current replacement cost. For the gas industry the target was an average annual rate of return over the period of nine per cent on net current cost assets (subsequently amended to 3·5 per cent when the gas levy was imposed in 1981 (*q.v.*) and current cost accounting introduced).

1980 Drilling of first deep exploratory borehole in *U.K.'s geothermal energy programme* began at Marchwood power station near Southampton. A depth of 2,615m was reached and water obtained at a rate of 25–30 l/s at a surface temperature of 70°C.

1980 The French President, Giscard d'Estaing, offered *cut-rate electricity to people living within three miles of a nuclear reactor*—to compensate for inconvenience caused by heavy construction work. Domestic customers saved 20 per cent.

1980 *"Engineering our Future"* Cmnd. 7794, report of the Committee of Inquiry into the engineering profession (Chairman Sir Monty Finniston). The principal recommendation was that the Government should establish a new statutory organisation, a national Engineering Authority, with power to advance "the engineering dimension".

1980 The *Severn Barrage Committee* stated in an internal progress report that large scale tidal power from the Severn Estuary was technically feasible, but it seemed unlikely that its cost could compete with nuclear generation. It might compete with fossil-fuel generation if coal and oil prices continued to rise in real terms.

1980 *"The role of the Comptroller and Auditor General"* Cmnd. 7845. A Green Paper in which the Government said that the proper division of responsibilities between Ministers and the nationalised industries was appropriately underpinned by existing arrangements for the industries' audit and accountability, to which the work of the Monopolies and Mergers Commission would contribute. They did not think it would contribute to the efficiency of the industries if the Comptroller and Auditor General were involved as well.

1980 *"Energy Consumption Labelling of Household Appliances*—A Consultative Document" published for Department of Energy, invited comments on an EEC proposal that electricity and gas appliances should carry labels giving energy consumption.

1980 *Long-life lamp*—Philips launched their SL 18W lamp, equivalent in light output to a 75W tungsten filament lamp. Its life was expected to be 5,000 hours, five times that of a conventional lamp.

1980 A *Central Policy Review Staff unpublished report* commented on the effects on the nuclear manufacturing industry of the cancellation or postponement of two new AGR stations (Heysham II and Torness).

1980 *South Western E. B.* introduced a new *management structure* with the number of managed units reduced from 17 to 4 on 1 April.

1980 *International Nuclear Fuel Cycle Evaluation (I.N.F.C.E.)*—a technical and analytical study involving 40 countries and four international organisations—considered the possible misuse of the nuclear fuel cycle for military purposes. Its reports were published by the International Energy Agency in nine volumes.

1980 *Competition Act* made it possible to refer nationalised industries' activities to the Monopolies and Mergers Commission for investigation.

1980 A *1200 MW single-shaft turbo-alternator* commissioned at the 4,800 MW Kostroma (8 × 300 MW; 2 × 1200 MW) coal-fired station. The supercritical steam conditions were 235 bar and 540°/540°C.

1980 *Russia's first commercial fast reactor,* the BN-600, entered service *at Beloyarsk,* 25 miles from Sverdlovsk in the Urals. The sodium metal cooled "pool-type" reactor, with a capacity of 600 MW(e) (1470 MW(t)), was *the world's largest FBR.* A 1,500 MW station, at the design stage, was expected to be able to compete with fossil-fuel-fired units.

1980 *Hereford combined heat and power project* commissioned by Midlands E. B. supplied steam to the Sun Valley Poultry Company and H. P. Bulmer cider makers. Base-load steam was produced by exhaust gases from two 7·5 MW diesel generating sets and peak and standby steam from standard industrial boilers.

1980 *Coal—Bridge to the Future: Report of the World Coal Study* (W.O.C.O.L.), pub. Ballinger Pub. Co., Cambridge, Mass. This examination of the future needs for coal and prospects for exporting coal supplies, under the leadership of Professor Carroll L. Wilson of M.I.T., found that requirements of coal might lead to a trebling of coal production and a 15-fold increase in the international coal trade.

1980 U.S. legislation—*Power Plant Fuels Conservation Act* provided for converting 80 U.S. power stations from oil-firing to coal-firing—*Magnetic Fusion Energy Engineering Act* increased national research on fusion power. New installations were a Tokamak Fusion Test Reactor at Princeton, New Jersey; the Mirror Fusion Test Facility at Livermore, California; the Elmo Bumpy Torus Proof-of Principle Experiment at Oakridge, Tennessee; and Materials Fusion Irradiation Test Facility at Hanford, Washington. Act sought to commission a demonstration fusion power station by 2000—*Wind Energy Systems Act* set a target for installing 800 MW of wind generation capacity in the U.S.A. by 1988—*Ocean Thermal Energy Conversion Research, Development and Demonstration Act* established a national U.S. target of 10,000 MW of O.T.E.C. generating capacity by 1999.

1980 *U.S. utilities faced an energy squeeze* because of difficulties of financing or obtaining permits to build new plant. For example, to prevent winter load shedding, Puget Sound Power & Light Co., with authority from Washington State Utility & Transportation Commission, could refuse new domestic connections for space heating (unless heat pumps were used) and for hot water until mid-1984 in areas where natural gas could be substituted.

1980 *"Energy in Transition 1985–2010"*, a report by the Committee on Nuclear and Alternative Energy Systems (C.O.N.A.E.S.) of the National Research Council, an arm of the U.S. National Academy of Sciences, that took four years and $4M to complete. It found, inter alia, that in terms of public risks nuclear generation was considerably safer than coal-firing; solar energy could only become important with massive Government help; and it would be inadvisable to count on significantly further supplies from hydro or biomass; dry-rock geothermal was still an unknown factor; but fusion power warranted sufficient technical effort to assess its real potentiality; energy consumption per increment of G.D.P. could be cut by a half over several decades given proper pricing.

1980 *Gas Act* relieved British Gas Corporation of their obligation to supply any consumers with more than 25,000 therms a year. This preferred statutory right had to be withdrawn because of the difficult gas supply situation following increases in oil prices and uncertain oil supplies.

1980 *Italy* approved a *ten-year energy plan*, which included 10,000 MW of new nuclear plant and 13,500 MW of coal-fired plant, to reduce oil-fired generation from 70 per cent of fuel burnt to 42 per cent by 1990.

1980 *Synthetic Fuels Corporation* (SFC) established by US Government to provide financial assistance to large-scale synthetic fuel ventures.

1980 *Low Level Radioactive Waste Policy*—made each U.S. state responsible for the low-level radioactive waste generated within its borders.

1980 A 50 MW(+) MHD Component Development and Integration Facility commissioned at Butte, Montana.

1980 *Eastern E. B.* installed the *U.K.'s first 33 kV vacuum switchgear*, by G.E.C. at their Sundon substation.

1980 On 14 July the Secretary of State for Energy announced that there would be *no new legislation to change the organisation of the electricity supply industry in England and Wales* (see Plowden Committee report). Improved working relationships between the Boards and the Electricity Council would be developed within the existing statutory framework on matters of capital programmes, retail and bulk supply tariffs, financial reporting and performance indicators. The relationship between C.E.G.B. Regions and the Area Boards would also be strengthened. The Chairman of the Electricity Council would be the Government's main policy adviser within the supply industry on the development of industry-wide policies. For instance, the Secretary of State would seek specific comments from the Electricity Council before approving the supply industry's capital programme.

1980 *Electricity Council Research Centre* at Capenhurst applied *single-chip microcomputers* to equipment for use on the distribution system. Five instruments were licensed for commercial manufacture—a fault current recorder, transformer demand recorder, feeder protection unit, substation load controller and transformer loss minimiser. They featured a high immunity to radiated interference and suitability for use in hostile electromagnetic environments.

1980 Government *oil depletion policy* announced on 23 July—it deferred some oil production over the 1980's.

1980 The *development of a unique wind turbine* costing £0.45M approved by Department of Energy. It involved a design study by a consortium of Sir Robert McAlpine & Sons, Aircraft Design Ltd, Engineering and Power Consultants Ltd and N. E. I. Clarke, Chapman Cranes Ltd. The vertical axis wind turbine of 130 kW capacity, with blades 25 m in diameter, was based on an invention by Dr Peter Musgrove of Reading University. The project complemented work on a horizontal axis design by Taylor Woodrow and British Aerospace.

1980 *"Domestic Gas Appliances: A Report on the Supply of Certain Domestic Gas Appliances in the United Kingdom"* by the Monopolies and Mergers Commission, HC 703, recommended that in the public interest the appliance retailing activities of the British Gas Corporation should either be discontinued, or accounting and other procedures modified to restrict the Corporation's monopoly powers and its ability to subsidise appliance selling from the profits of gas sales.

1980 The Engineering Recommendation (G22/1) covering *Superimposed Signals on Public Electricity Supply Networks* was issued by the Electricity Council. Its aim was to prevent a consumer's signal penetrating beyond his supply terminals.

1980 *The Fuel and Electricity (Heating) (Control) (Amendment) Order 1980, SI No. 1013* reduced the maximum heating limit in non-domestic buildings to 19°C as

from 1 October. Resultant energy saving would be one million tonnes of oil equivalent a year.

1980 Impending legislation to remove *monopoly powers of generation by the generating boards* was announced by the Secretary of State for Energy. As soon as a suitable opportunity arose he would remove the prohibition on the generation of electricity as a main business (under S.23 of the Electric Lighting Act 1909).

1980 *Sizewell magnox nuclear station was the first in the world to generate 50 TWh, and was also the world's most reliable.* No. 2 reactor ran continuously at full rated load (revised rating) from 24 August 1975 to 7 June 1977, beating Haddam Neck PWR (U.S.A.) by one week.

1980 The Chancellor of the Exchequer announced on 4 August agreement with *Nationalised Industries' Chairmens Group* on changes in the system of financial control—how *external financing limits* (EFLs) might be adjusted and a measure of year-end flexibility introduced (House of Commons Official Report cols 41–42). The adjustments had been recommended by a Treasury Working Party under Mr William Ryrie.

1980 Following a public outcry, the *North of Scotland Hydro-electric Board withdrew a general surchage* of 0.3p per unit imposed on consumers in the islands with high-cost diesel generation.

1980 General Electric U.S.A. introduced a *new excitation system known as GENEREX* based on stationary power sources, rectification and control equipment. Overall length of the turbo-alternator was reduced and accessibility for R & M improved by eliminating the shaft-driven exciter.

1980 *EdF's capital restructured*—Fr 12,400M of debt was written off and a further Fr 1,900M injected as capital and loans; interest payments and repayment of principal were deferred.

1980 Successful laboratory demonstration of *full-sized aluminium/air battery* developed jointly by U.S. Department of Energy and private industry. It was expected to provide electric vehicles with a range of up to 250 miles and an acceleration to 30 mph in six seconds by the 1990's.

1980 *Giraud Amendment restricted strike action* by employees *in French nuclear stations.* André Giraud, Minister of Industry, introduced the measure on safety grounds as an Amendment to a Bill on the safety and supervision of nuclear fuels.

1980 *Sir Francis Tombs resigned from the Chair of the Electricity Council* w.e.f. 1 December because a proposed re-organisation of the electricity supply industry in England Wales following the Plowden Committee Report had not been implemented by the Government.

1980 *Ente Nazionale per l'Energia Elettrica's* Plant Development Programme *forecast a deficit in the supply of electricity* of 105 TWh by 1991, equal to 30 per cent of total requirements, unless planning procedures could be accelerated.

1980 National Federation of Sub-Postmasters agreed to sell *gas and electricity saving stamps* at sub-post offices.

1980 *Low income groups and fuel bills—*
—Secretary of State for Social Services announced *new measures to help low income consumers* with their bills. There were increases in heating allowances under the Supplementary Benefits system and in grants for home insulation.
—Area Electricity Boards and British Gas Corporation agreed to accept each others' *saving stamps in payment of bills* from 4 August.

—The *Supplementary Benefit (Deductions and Payments to Third Parties) Regulations, SI 983, 1980* came into operation in November. For a consumer receiving Supplementary Benefits, in return for a weekly deduction designed to meet current bills, plus a contribution towards arrears, if any, the consumer's household was free from the risk of disconnection of supply for non-payment of accounts (known as the *"Fuel Direct" Scheme*).
—Policy Studies Institute's (formerly Political and Economic Planning and Centre for Studies in Social Policy) *review of the code of practice on fuel debts* was commissioned by the Electricity Council and British Gas Corporation, the Electricity Consumers' Council and the National Gas Consumers' Council. Their interim report published in December stressed the importance of providing realistic alternative payment methods for hardship customers and the need for a more complete way of dealing with the intractable problem of the very small minority of electricity customers who simply could not solve their debt problems.

1980 *"Electric Vehicles".* First Report from the Select Committee on Science and Technology. House of Lords Paper 352. Concluded that electric transport would have a significant, though probably not a dominant, role to play soon after the year 2000.

1980 Government announced four new research contracts for *wave energy.* Expenditure on research was increased by £0.65M to £4M.

1980 Two U.S. *Fast Flux Test Facilities reached full power—at Hanford Reservation,* Washington (400 MW(t)) in December, the main U.S. effort on liquid metal fast breeder reactors; and at Richland, Washington (300 MW(t)), a materials testing FBR.

1980 The first test of a *coal-fired magnetohydrodynamic* (M.H.D.) system completed at the University of Tennessee Space Institute.

1980 *Small scale hydro power in England and Wales*—studies commissioned by the Department of Energy of possible installations up to 10 MW indicated that some 130 MW producing the equivalent of 0·25 mtce, could economically be developed on sites with capacities exceeding 50 kW.

1980 *Main plant for new AGR stations* ordered—at Heysham II, civil engineering by Taylor Woodrow and two 660 MW turbo-alternators from N. E. I. Parsons—at Torness, civil engineering by Sir Robert McAlpine and two 660 MW sets from G.E.C. The boiler contracts were signed in April 1981 with roughly 80 per cent going to N.E.I. and 20 per cent to Babcocks.

1980 *"C.H.P. Feasibility Programme Interim Report—Shortlisting of Cities for Lead City Selection".* This report by W. S. Atkins and Partners recommended that, out of some 25 locations studied, six cities should be contenders for Britain's first major combined heat and power/district heating project—Glasgow, Newcastle, London (Central and East), Sheffield, Belfast and Liverpool. The first three offered the best prospects.

1981 *Mr Austin Bunch was appointed Chairman of the Electricity Council* from 1 January.

1981 Chloride Silent Power Ltd and U.S. G.E.C. combined their programmes of *sodium sulphur battery development.* G.E. work, financed by the Electric Power Research Insitute, had been concentrated on batteries for peak operation on electricity supply systems after off-peak charging, while C.S.P.L. had concentrated on traction batteries.

1981 C.E.G.B. applied for planning consent to build a *1,200 MW PWR station at Sizewell.* A public enquiry was planned for January 1983. The National Nuclear Corporation would use Westinghouse Electric Corporation tech-

nology in designing the station—similar to the Calloway station of Union Electric Company, U.S.A.

1981 *Peterhead Station* of the North of Scotland Hydro-electric Board commissioned—it was completed in 1982. × 660 MW units comprised boilers by Babcock & Wilcox and sets by G.E.C.—with No. 1 set at Duvha ps, So»th Africa, they were the first of the latest G.E.C. four-cylinder turbines with two double-flow low pressure cylinders to enter service. The station burnt surplus gas and natural gas liquids, for which there were no alternative outlets, after methane separation by the British Gas Corporation, and also residual fuel oil. The station replaced the Stake Ness SGHWR station when the Government decided not to proceed with that type of reactor.

1981 *"Review of Main Line Electrification:* Final Report"—by a joint Department of Transport and British Railway Board Steering Group—indicated that a substantial programme of main-line electrification would be worthwhile.

1981 *"Harmonisation of Energy Prices and Taxes"* HL 36, 2nd Report from the House of Lords Select Committee on the European Communities. Regretted the slow progress of development of Community energy policy in face of the precarious prospects for supplies of energy.

1981 *Framatome,* the French nuclear plant manufacturers, *and Westinghouse, terminated their licensing agreement* for the construction of PWR stations. The French had caught up with U.S. technology and were now free to build and export their own PWRs.

1981 *Closure of four West German BWRs* announced because of faults found by the Bonn Reactor Safety Commission, namely—Wurgassen, Brunsbüttel, Phillipsburg I, and Isar I. Their primary cooling circuits required replacing.

1981 Thorn introduced their *2D low-energy long-life domestic lamp*—a 21W lamp equal to a 100W tungsten filament lamp. Though five times more expensive than the tungsten bulb, it lasted five times longer and used only a fifth as much electricity.

1981 *Support for coal*—following industrial action by the N.U.M. against proposals for pit closures the Government convened the Coal Industry Tripartite Group (Govt., N.U.M. and N.C.B.) which withdrew the list of closures and agreed to reduce imports of coal towards the irreducible minimum. The Secretary of State announced in the House on 16 June that the resultant increase in subsidies would amount to an extra £300M in the amount available for grant and an increase of £231M in the EFL for 1981/82.

1981 *"The Government's Statement on the New Nuclear Power Programme"* HC 114–1. First Report from the Select Committee on Energy. Examined the arguments advanced by the C.E.G.B. and the Government in favour of the programme. Expressed doubts about both the C.E.G.B.'s electricity load forecasts and the overall energy projection on which they were based, and questioned the need for such a large programme of replacement of coal and oil-fired stations by nuclear plants.

1981 *"Report on Industrial Energy Prices".* This report of a Task Force set up by N.E.D.C. confirmed that, while most industrial customers did not suffer a disadvantage from the pricing of their supplies of electricity and gas against their European competitors, for bulk users, who accounted by volume for some 50 per cent of industrial electricity consumption and a significant proportion of industrial gas use, the position was sharply different.

1981 The Government announced that more detailed feasibility work on *combined heat and power/district heating* would commence in Belfast, Edinburgh, Glas-

gow, Leicester, Liverpool, London (East/Central), Manchester, Newcastle and Sheffield.

1981 The Secretary of State for Energy asked the Electricity Council to review the structure of the C.E.G.B.'s *bulk supply tariff.*

1981 The Budget included a £168M package to help large industrial energy consumers. *Electricity supply would offer new flexibility in its pricing arrangements* to consumers who could take advantage of load management terms by adjusting their demand at short notice. Grants towards converting boilers from oil to coal would total £50M over two years. Renewal prices for interruptable gas supplies would be held until 1 December 1981. The external financing limit for electricity was raised by £45M and for gas by £35M.

1981 *Contract for the Castle Peak "B" coal-fired station* in Hong Kong, owned by China Light and Power and Exxon's subsidiary Eastern Energy, awarded to G.E.C. Turbine Generators for four 660 MW sets and to Babcock Power for the boilers. British Electricity International were to provide consultancy services.

1981 *Gas Levy Act* imposed on the British Gas Corporation a levy on Petroleum–Revenue–Tax–exempt supplies of one penny a therm in 1980/81, three pence in 1981/82 and five pence in 1982/83. The financial target was modified to compensate for the levy so that gas prices would not be affected.

1981 Generation ceased at the 33 MW experimental *AGR at Windscale.* It first came on line in February 1963 and exported over three TWh to the Grid.

1981 *Organisational changes—*

At C.E.G.B. HQ—the *Corporate Strategy Department* was formed from parts of the Planning Department concerned with corporate planning. The remainder of Planning Department was spread between different management formations. The *Nuclear Operations Support Group* was set up to provide expert support for the operation of nuclear plant. *Grid control was gradually reorganised*—the three-tier transmission hierarchy of National Control (London), Area Control Rooms (Regions) and District Control Rooms (Areas) being changed to two-tier by merging the Area and District Control Rooms.

At Area Boards—London reorganised its structure from 1 April, five Divisions were created from 10 Districts. *South Eastern* reduced the number of Districts from 14 to 11 on 1 April. *Southern* started a reorganisation of their management structure on 1 July. Four Area Offices were to close and the number of Districts reduced from 19 to 13. *Midlands* announced that its four Areas and 22 Districts would be restructured to eight Divisional Units on 1 April 1982. *South Wales* reduced the number of their District Management Units from nine to five.

1981 The *Wedgwood Electrical Collection* was opened in the former Christchurch power station building at Bargates. In 1986 it was renamed the Southern Electricity museum.

1981 British Electricity International Limited won a contract to develop *electricity supply in Saudi Arabia,* by co-ordinating 38 separate undertakings in the central part of the country to form the Saudi Consolidated Electric Co.

1981 *"Central Electricity Generating Board: A Report on the Operation by the Board of its System for the Generation and Supply of Electricity in Bulk".* H.C. 315. This major report by the Monopolies and Mergers Commission found that the C.E.G.B.'s operations were efficient. The Commission criticised the C.E.G.B.'s purchasing policy, which was affected by Government policy: and their investment appraisal, particularly with regard to the nuclear stations, which the Commission considered operated against the public interest.

1981 *"How Safe is Nuclear Energy?'* by *Sir Alan Cottrell* published by Heinemann. Found that fears expressed about the safety of nuclear power were not justified and that most objections were political rather than technical.

1981 *2,000 MW ± 270 kV DC cable link with France*—on 16 June C.E.G.B. and EdF signed the agreement for the scheme. The AC/DC converter stations were at Sellindge in Kent and, on the French side, near Sangatte. The link was fully commissioned in November 1986. The £500M link would provide increased security of electricity supplies and economic electricity transfers between the two countries.

1981 The *Ince "B"* oil-fired station commissioned. Instead of three standard cooling towers associated with its two 500 MW sets, a single *prototype assisted draught tower* of the same size provided condenser cooling. The three-fold capability was provided by 35 large electric fans around the base of the tower.

1981 *Electricity Council Research Centre at Capenhurst*
—demonstrated the *multi-layer coil induction heater.* The use of multilayered windings in the coil construction doubled the efficiency. Aluminium, copper and steel billets were heated to their respective hot working temperatures of 500, 800 and 1,050°C.
—A *transverse flux induction heater* reached the stage of customer evaluation. This form of flameless energy involving the use of magnetic fields was particularly applicable to metallic strips.
—An *electrochemical process for the production of iron foil from scrap iron* by continuous electrodeposition reached the demonstration stage. It involved the electrolysis of ferrous chloride between a rotating cathode and a non-consumable anode.

1981 *Energy Conservation Act* included powers for setting and enforcing standards of energy efficiency for new gas appliances and also for other new appliances for space and water heating.

1981 The Secretary of State for Transport announced that while the Government were not prepared to give an unconditional commitment to extensive *railway electrification,* they had invited British Rail to prepare a ten-year programme of schemes covering the potentially profitably main-line routes, the approval of which would be conditional on their profitability and on improvements in productivity.

1981 *Current cost accounting* used for 1980–81 accounts of the electricity supply industry in England and Wales, based on Statement of Standard Accounting Practice No. 16 (S.S.A.P. 16). It allowed for inflation in the cost of replacing plant and equipment and material from stock, and in money owing. For power stations the C.C.A. value was calculated on the basis of "modern equivalent assets" to allow for technological change.

1981 *South Eastern E.B.* embarked on C.A.L.M.S. long-term development project—a *Credit and Load Management System* based on a combined metering and load control device with advanced microprocessors and other microelectronics. Its main uses included remote meter reading and load switching.

1981 The Minister for Consumer Affairs announced that the *British Gas Corporation should cease retailing domestic gas appliances* and dispose of their showrooms over a five year period—a half within two years, a further quarter in the following year, and the remaining quarter in the final two years. The sell-off was subsequently delayed (House of Lords Official Report 11 May 1982, col. 121).

1981 *"Tidal Power from the Severn Estuary"*, a Report to the Secretary of State for Energy prepared by the Severn Barrage Committee (Chairman Sir Hermann Bondi) recommended that attention should be concentrated on a single basin ebb generation scheme with a barrage running from Brean Down to the vicin-

ity of Lavernock Point on the Welsh Coast. The £5,600M (at 1981 prices) scheme would generate about 13 TWh from a capacity of 7·2 GW, some six per cent of national requirements.

1981 A *National Task Force* (Chairman Dr Walter Marshall) set up by the Secretary of State for Energy to accelerate the design phase of the proposed Sizewell "B" PWR nuclear station. Members were drawn from the National Nuclear Corporation, C.E.G.B. and U.K.A.E.A.

1981 On 17 July *gas workers staged their first ever national strike*—for 24 hours to protest against Government plans to sell off the British Gas Corporation's 900 showrooms.

1981 S.S.E.B. decided to extend the use of *portable billing machines* during 1981/82. These hand billing machines incorporated mini-computers developed by Plessey.

1981 An unpublished report by the *Central Policy Review Staff* recommended a radical overhaul of the *relationships between the nationalised industries and their sponsoring Ministers.*

1981 The *world's first solar power station* to be connected to a national grid commissioned at Adrano, near Catania, Sicily; jointly owned by E.N.E.L. and the E.E.C. Banks of mirrors (heliostats) focussed the sun's rays on a boiler at the top of a tower from which steam powered a turbo-alternator.

1981 *U.S. wind power—*
—A 3 MW wind generator was commissioned by Southern California Edison.
—Three 2.5 MW wind-generators were installed near Goodnoe Hills, Washington, to provide the first data on how machines operated in a cluster.

1981 *World's first electric utility fuel cell power plant* commissioned in New York. The 4·8 MW prototype comprised 14 modules.

1981 Work started on a *1,500 kV DC line Ekibastuz in Central Siberia* (Soviet Kazakhstan) of initial capacity 1·5 GW for a 2,412 km line. This section was due for completion in 1985 and three others were to commission annually until 1988 when the completed project would have a capacity of 6 GW. Generation would be provided from five 4 GW stations on the Ekibastuz coal field.

1981 A device announced which had the effect of reducing by some five per cent the *power input to AC motors* running at less than full load. Developed by Dr Peter Unsworth at Sussex University, and subject to patent applications filed by N.R.D.C., it improved the power factor by adjusting the wave form of the mains cycle.

1981 White Paper *"Nuclear Power"*, Cmnd. 8317, commented on the Select Committee on Energy Report "The Government's Statement on the New Nuclear Power Programme" (H.C. 114 i-iv *q.v.*). It reaffirmed the Government's belief that one new nuclear station a year would need to be ordered in the decade from 1982 and in the choice of the PWR as a potential alternative to the AGR. C.A.N.D.U. as an alternative would be more expensive and would divert resources within the nuclear manufacturing industry. Uranium supplies in the 1990s would not present a problem.

1981 *Severn Tidal Power Group*, comprising G.E.C. Power Engineering, Balfour Beatty, Sir Robert McAlpine and Sons and Taylor Woodrow Construction announced their joint investigation of a £5,000 M private-sector scheme for a Severn Barrage.

1981 *Industrial Energy Pricing Policy.* Second Report from the Select Committee on Energy, Session 1980–81. H.C. 422–1. Summarised the main complaints

voiced by industry, the N.E.D.O. Task Force findings (*q.v.*) and the Government's response so far. It set out the reasons underlying international energy price disparities.

1981 *Nationalised Industries: Capital Structure.* Fifteenth Report from the Committee of Public Accounts, Session 1980–81. H.C. 349. Pointed out that, although formally the Government retained the same control over nationalised industries' internally financed capital programmes as over those requiring external finance, retention of profits and build up of internal reserves reduced dependence on external finance and was likely to increase an industry's ability to determine its future development.

1981 On 5 August *electricity supplies failed in the South of England, the West Country and South Wales.* At 09.08 the heavy duty 400 kV line from Feckenham to Minety, the connection between the West Midlands and Bristol, tripped, and coincidently at 9.10 the Dungeness to Canterbury and Dungeness to Ninfield to Lydd 400 kV lines also tripped; and then at 09.18 the line from Bramley in Hampshire to West-Weybridge, Surrey also failed. Supplies were restored at 10.43.

1981 *National Joint Negotiating Committee* for the electricity supply industry established to consider working conditions of all employees.

1981 *Financing of the Nationalised Industries.* Eighth Report from the Treasury and Civil Service Committee H.C. 348–1. Examined the rationale for the present system of financial controls on nationalised industries.

1981 *Fuel Debts and Hardship*—a review of the electricity and gas industries' Code of Practice was undertaken by the Policy Studies Institute. It concluded that the Code of Practice had not been adequate to achieve the radical minimisation of hardship. The deficiencies did not seem to lie so much in the industries' operation of the Code as in the Code itself.

1981 Calder Hall 'A' nuclear station completed 25 years of successful operation.

1981 A *prototype water-cooled generator* was installed at the *Cruachan* pumped-storage station in place of a conventional 100 MW unit.

1981 Phasing out of work on *gas-cooled fast reactor* in the U.S.A. completed. Because of success of the liquid-metal cooled FBR it was no longer required to provide a back up.

1981 C.E.G.B. closed 3,402 MW of generating plant on 26 October under an *accelerated power station closure programme.* Plant permanently closed amounted to 2,082 MW in 16 stations, and 1,320 MW was retained unmanned in a reserve category of decommissioned plant.

1981 Mr Austin W. Bunch's appointment as *Chairman of the Electricity Council* extended to 31 March 1983.

1981 Department of Trade published "Consumers' Interests and the Nationalised Industries—A Consultative Document" which proposed that the *nationalised industries consumers' councils* should be streamlined to make them more effective.

1981 Severe weather led to *power failures* affecting over 250,000 mainly rural consumers. The Secretary of State for Energy set up two enquiries—into the procedures and methods for restoring supplies in severe weather conditions (Chairman Mr A. W. Bunch) and the technical standards of overhead lines (Chairman Mr A. Baldock).

1981 The Secretary of State for Transport approved the *electrification of rail services* to Ipswich, Norwich and Harwich at a cost of £30M.

1981 British Aluminium announced that it intended to close its *smelter* at *Invergordon* that entered service in 1971 (*q.v.*), due to heavy financial losses.

1981 *Solar Energy—*
Japan—"Sunshine Project"—two 1 MW pilot solar plants commissioned at Nieo in Shikoku Island—a curved surface concentration system and a tower concentration system both of which produced steam to drive a generator.
—Ocean thermal energy conversion plant of 100 kW commissioned by Tokyo Electric Power at Nauru Island in the central Pacific.
France—Thémis 2·5 MW power station commissioned at Targasonne in the Pyrenees. Sun's rays were directed to a central receiver by 200 heliostats where a circuit of molten salts (sodium and potassium nitrites and nitrates) exchanged heat with a steam circuit which powered a turbo-alternator.

1981 *"Report on the Inquiry into the Failure of Electricity Supplies over the Period 24 April to 27 April, 1981 during Blizzards and the Steps Taken to Restore Supplies"*—to Mr Alan Plumpton, Deputy Chairman of the Electricity Council—recommended inter alia improved specifications for new lines built to ESI 43–10, identification and strengthening of weak points on BS 1320 and older lines, the sampling of instances of elongation and loss of strength in copper conductors through annealing, bringing up-to-date programmes of tree cutting and general contingency plans, and a review of communications including the use of helicopters.

1981 An *experimental* 20 MW *superconducting generator* was commissioned in Russia.

1981 *Centenary of the first public electricity supply* marked by an exhibition at the Science Museum, London, and special events at Godalming, where the first supply was provided (*q.v.*).

1981 *E.E.C. Recommendation on electricity tariff structures* (81/924/EEC)—tariffs should reflect costs on a two-part basis and include differential rates where appropriate, avoid unjustifiable consumption and should not be artificially low on social grounds or for anti-inflation reasons (Official Journal No. L337/12, 24.11.81).

1981 *C.E.G.B. organisational changes—Technology Planning and Research Division* created by the amalgamation of the Research Division with the System Technical and Generation Studies Branches.

1981 *U.S.A.—ban on the commercial reprocessing of spent nuclear fuel elements* lifted by the President.

1981 *External Financing Limit* for the E.S.I. in England and Wales for 1982/83 set by Secretary of State for Energy at −£319M (net repayment of borrowings), subsequently reduced to −£148M. Outturn was −£153M.

1981 *"Financing of the Nationalised Industries. Second Special Report from the Treasury and Civil Service Committee; Observations by H.M. Treasury on the Eighth Report from the Committee" H.C. 496.* Chancellor of the Exchequer endorsed the need for more vigorous investment appraisal and shared Committee's concern about past nationalised industry performance. On balance he was against direct market finance because of the extra cost.

1981 *"Introduction of a new general policy for public purchasing. Third Report from the Committee of Public Accounts". H.C. 29.* Endorsed policy set out in March 1981, aimed at achieving a closer relationship between public purchasers and suppliers in order to help develop design, technology and competitiveness of suppliers.

1981 *Australia*—To contain borrowings Electricity Commission for New South Wales sold the *Eraring Power Station* to a consortium of leading Australian banks and industrial and mining companies. Purchasers were guaranteed an agreed return, station continued to be operated by the Commission who retained an option to buy it back. First of 4 × 660 MW units commissioned in March 1982 and the last set commissioned in May 1984.

1981 *Review of the Bulk Supply Tariff Structure*—by the Electricity Council with the Area Boards. Considered alternative forms of BST and concluded that there was no major defect in the present BST although effects of possible new developments such as the predetermination of capacity shares and of remote signalling would be kept under review.

1981 A.E.R.E. Harwell and Energy Research Laboratory, Odense University, Denmark jointly began work on developing a *rechargeable battery* with a lithium anode, a film polymer electrolyte and a titanium disulphide or vanadium dioxide cathode. Potential energy density was 200–400 Wh/kg.

1981 *"The Financing of State-owned Industries"*, by the Hundred Group of Chartered Accountants, criticised the financial arrangements of the nationalised industries for being rigid and inflexible and proposed that each industry should adopt a form more nearly modelled on the debt/equity capital structures typical of private sector companies.

1981 *Power failures*—in south west, southern and parts of eastern Britain on 13 and 19 December caused by severe winter weather and gale-force winds. Exceptional mechanical loading of overhead lines due to icing caused some 300 transient faults on the transmission system and losses of supply at some bulk supply points in C.E.G.B.'s South Western Region. Flooding at Hinkley Point nuclear station also led to loss of bulk supplies. There were a large number of permanent faults on Area Board overhead distribution systems. Blizzard on 13 December lost bulk supplies to 1·06M consumers and faults on the distribution system lost supplies to 809,000 consumers. Severe conditions on 19 December in south west and western coastal regions caused more faults on overhead distribution lines interrupting supplies to 75,000 consumers. All supplies were restored by 24 December.

1982 *"Report on the Effect of Difficult Weather Conditions on Electricity Supplies during December 1981"* by Sir Austin Bunch, Chairman of the Electricity Council, to the Secretary of State for Energy recommended that Electricity Boards' emergency plans should at least meet UNIPEDE standards, an emergency should be declared when a unit could not restore supplies within 24 hours from its own resources, Chief Engineers should make better use of meterological information and be fully in charge of restoration measures, full provision should be made for using outside resources, use of helicopters and associated communications should be developed, and emergency communications with consumers improved.

1982 *Russia*—commissioned a *coal-fired bypass plant* at the *U-25 prototype (MHD) generator* in North Moscow using coal combustion products as the working MHD fluid. The existing natural gas-fired unit had supplied up to 20 MW to the Mosenergo system.

1982 *"Industrial Energy Pricing Policy. First Special Report from the Energy Committee; Government Observations on the Second Report of the Committee Session 1980–1981", H.C. 169.* Government could not agree that pricing criteria should be based on average cost pricing rather than prices which reflected continuing costs of supply. Electricity costs were predominantly determined by fossil fuel costs and the cost structure would begin to alter significantly only when nuclear capacity was increased and cheaper coal could be purchased.

1982 *"The Electricity Generating Stations and Overhead Lines (Inquiries Procedure) Rules 1981" S.I. 1981 No. 1841* came into operation on 1 February—prescribed the procedure to be followed at public inquiries held under S. 34 of the Electricity Act 1957 in connection with applications to construct generating plant under S. 2 of the Electric Lighting Act, 1909 or to construct overhead lines under S. 10(b) of the Schedule to the Electric Lighting (Clauses) Act 1899.

1982 *Nationalised industries—accountability to Government*—on 15 March Secretary of State for Industry announced in the Commons that strategic objectives would be agreed with each nationalised industry in order to provide a clear framework for their operations. The Government were also putting more emphasis on efficiency, with an increase in references to the Monopolies Commission. Size of Boards would be reduced where appropriate and would have an adequate proportion of non-executive directors. Business expertise in Whitehall would be strengthened in order to deal with the nationalised industries.

1982 *"The Department of Energy's Estimates for 1981–82. Second Report from the Energy Committee." H.C. 231*—criticised Government's handling of the £231M rescue package for the National Coal Board in 1981 which allowed more than 20 loss-making pits to be kept open in order to avoid a national miners' strike.

1982 *Generation Security Standard.* Arising out of the investigation by the Select Committee on Energy into the nuclear power programme, and Monopolies and Mergers Commission report on the C.E.G.B. in June 1981, the Secretary of State for Energy asked the Electricity Council to carry out a study of the generation security standard and to advise on its continuing appropriateness. An interim report was sent to the Secretary of State in March.

1982 *Special tariff arrangements* offered to large industrial consumers in 1981 were continued and extended under the Budget by means of a relaxation of £87M in the E.S.I.'s External Financing Limit for 1982/83. Bulk Supply Tariff for 1982/83 included Contracted Consumer Adjustments under which some large consumers could obtain savings up to 16 per cent provided they were able to reduce load on request, at a minimum of two hours notice, by not less than 3 MW or 25 per cent of their average winter daytime demand over a contracted period of three years.

1982 *Code of Practice on the payment of domestic electricity and gas bills*—Area Boards introduced improvements in the scheme to help customers who had difficulty in paying their bills.

1982 *"Energy Management and Load Control. Report by the Energy Management Task Force"* of the Electricity Council mentioned developments in microelectronics and improved methods of communication and resulting very large number of load management options. Recommended extensive and co-ordinated field trials.

1982 *"London Electricity Board—an investigation under Section 3 of the Competition Act 1980. Report by the Director General of Fair Trading"*—Concluded that the L.E.B. had followed a course of conduct in its retailing activity that constituted an anti-competitive practice and recommended that the matter be referred to the Monopolies and Mergers Commission.

1982 *"North Sea Oil Depletion Policy. Third Report from the Energy Committee, Session 1981–82." H.C. 337.*—Concluded that it was unlikely that Governments would always be able to stand back and leave the pace of development of North Sea oil entirely to market forces. A specific controlled rate of depletion might be justified, depending on judgements about the future price of oil. Government involvement should be limited to "monitoring" rather than "managing" the rate of production.

1982 *Organisational changes*—on 1 April *North Eastern Board* reduced its Districts from seven to five and *North Western Board* its Sub-Areas from six to five.

1982 *"Mainline railway electrification*—Second Report from the Transport Committee" H.C. 317–i—recommended inter alia that further mainline electrification was financially justified.

1982 Advisory Council on Research and Development, which advised the Secretary of State for Energy, recommended that *no new wave power development work should be undertaken* once existing research contracts came to an end in September 1982.

1982 *"Radioactive Waste Management"*, Cmnd. 8607, accepted the objectives for dose limitation formulated by Expert Group and presented in "A Review of Cmnd. 884 . . .", 1979 (*q.v.*).

1982 *"Government Observations on the Second Report of the Committee, Session 1981–82 (The Department of Energy's Estimates for 1981–82). Fourth Report from the Energy Committee, Session 1981–82." H.C. 366.* Government denied that withdrawal of N.C.B.'s closure programme meant that a decision had been taken that any identified pit should be kept open for social reasons or that reversion to the industry's normal procedures would bar further pit closures. Noted that compensation paid to the C.E.G.B. for reducing its coal imports fell far short of the true costs.

1982 *Multi-layer coil induction heater* for non-ferrous metals industry *developed by the Electricity Council Research Centre.* Commercial scale trials were 40 per cent funded by E.E.C. under its Energy Saving Demonstration Project Scheme.

1982 *German F.R.—Clean Air—Large Combustion Installation Act* limited flue gas emissions—for plants exceeding 300 MW(th) capacity expected still to be in operation by 1991, SO_2 emissions should not exceed 400 mg/m^3, nitrous oxides 200 mg/m^3 and dust 50 mg/m^3 by 1988. Sulphur content of fuel should not exceed 15 per cent.

1982 *Financial target for E.S.I. in England and Wales*—for 1980/81 to 1982/83 reduced from 1·8 per cent to 1·71 per cent (later modified to 1·67 per cent) return on average net assets because of new arrangements to help large industrial users of electricity announced in the Budget.

1982 *France*—Eurodif (Cogema's shareholding 27 per cent) fully commissioned their 1,800 te capacity *uranium enrichment plant at Tricastin.*

1982 *USA—Coal liquefaction*—two large pilot plants completed trial operations—Exxon D.O.N.O.R. solvent plant in Baytown, Texas and H-Coal plant at Catlettsburg, Kentucky.
—*Shippingport Light Water Breeder Reactor (L.W.B.R.)* core completed its burnup. Spent fuel assemblies were removed for examination to determine core performance and breeding characteristics.

1982 *Japan*—Atomic Energy Commission announced a long-term *programme* for the development *of nuclear energy.*

1982 *Wind turbines*—
USA—between 1982 and 1984 over *2,000 wind turbines* of 50 kW and 100 kW capacity were installed at a *wind farm* at Altamont Pass, California. Another 550 were planned.
—Cluster of three *experimental horizontal axis 2·5 MW wind turbines* (M.O.D.–2) at Goodroe Hills, Washington, achieved full rated power.
UK—C.E.G.B. commissioned a *200 kW wind turbine* at Carmarthen Bay—model MP1–200 by W.T.G. Energy Systems Inc., U.S.A., built by James Howden. It was expected to generate about 380 MWh a year, enough to supply

a small village. Represented the first stage in C.E.G.B. strategy to assess the commercial potential and environmental acceptability of wind power on lowland sites. In 1985 it was uprated to 300 kW. A MW size machine was planned for Richborough power station when a proven design became available.
Sweden—National Swedish Board for Energy Science Development commissioned a *3 MW wind turbine* at Maglarp—the W.T.S.3 machine and a *2 MW wind turbine* at Na Sudden on the Island of Gotland—Model W.T.S.75—operated by the Swedish State Power Board.

1982 *Solar energy*—
USA—two plants commissioned—*"Solar One"* near Barstow, California, a 10 MW central receiver pilot plant, and—*"Solar Total Energy Project"* at Shanandoah, Georgia, the *world's first complete dish system.*

1982 *Spain—world's first up-draught (solar chimney) power station* commissioned at Manzanares. A large circular area covered with a foil canopy let in short-wave solar radiation but prevented escape of long-wave heat radiation from the heated soil. In the centre a "chimney" drew up heated air to drive a vertical-axis wind turbine connected to a 50–100 kW generator.

1982 *Australia—solar hybrid power station* commissioned at Meekatharra, Western Australia. Output was 100 kW, 50 kW from solar energy and 50 kW from waste heat from an existing diesel station. Solar collectors heated thermal oil which was piped to a heat storage tank and further heated by the diesel's waste heat; then via a heat exchanger steamed a unique two-stage wet operating screw expansion engine connected to a generator.

1982 *"Energy Conservation in Buildings. Fifth Report from the Energy Committee, Session 1981–82." H.C. 401–I.* Concluded that while many conservation measures were more cost effective than many supply investments, quite different investment criteria were applied resulting in misallocation of resources.

1982 *Coal–oil mixed fuel*—Bartow power station (115 MW), Florida, began test operation.

1982 *Sir Walter Marshall* appointed Chairman of the C.E.G.B. for five years from 1 July 1982, in succession to Mr Glyn England.

1982 *"Engineers, Managers and Politicians: the first fifteen years of Nationalised Electricity Supply in Britain"* by Leslie Hannah. Published by The Macmillan Press, London (ISBN 0 333 22087 0)—the second and final volume of an official history sponsored by the Electricity Council.

1982 *Nuclear Industry Reactive Waste Executive (N.I.R.E.X.)* established as foreshadowed in the White Paper "Reactive Waste Management", Cmnd. 8607. Founders were British Nuclear Fuels Limited, Central Electricity Generating Board, South of Scotland Electricity Board, and United Kingdom Atomic Energy Authority. Comprised a Directorate of senior representatives of these organisations and an Executive Unit based at the U.K.A.E.A.'s Harwell Laboratory. Provided a mechanism by which a fully integrated system could be developed for the disposal of low and intermediate level radioactive waste.

1982 *German F.R.—experimental Volklingen 230 MW coal-fired station* commissioned near Saarbrucken, combining fluidised-bed combustion with a 32 MW gas turbine and a pf fired Benson type once-through boiler steaming a 195 MW set. Pass out steam from the set, and waste heat via a heat exchanger in the fluidised beds, supplied heat to the Saar district heating network. Station had no chimney—flue gases from the boiler entered a Saarberg-Holter desulphurisation plant located in the cooling tower. After wet scrubbing the cleansed flue gases mixed with the cooling tower air and discharged together.
—*A.E.G Telefunken*, Germany's second largest electrical manufacturing com-

pany, sought protection from its creditors through composition proceedings (Vergleich). In 1984, after a capital reconstruction, it discharged its bankruptcy by paying 40pf in the DM to its creditors.
—*First building licence for a nuclear station in five years* granted—Isar II 1350 MW P.W.R., Bavaria, due to commission 1988. Nuclear construction had been delayed by the complexity of licensing procedure, changes in regulations and opposition from environmentalist lobby.

1982 *"Sizewell "B": a review by H.M. Nuclear Installations Inspectorate of the pre-construction safety report"*, H.M.S.O., found no fundamental reason for regarding safety as an obstacle to the selection of a pressurised water reactor for commercial electricity generation, although more work was needed on a number of safety issues and more information needed to satisfy the Inspectorate.

1982 *Review of Technical Standards for Overhead Lines Following Storm Damage in December 1981 and January 1982"*—report from a Government/E.S.I. Joint Panel of Inquiry chaired by A. T. Baldock, Chief Engineering Inspector, Department of Energy, recommended inter alia that tree growth control should be improved; Electricity (Overhead Lines) Regulations 1970 revised to ensure that statutory requirements more closely related to actual weather conditions; overhead lines built to B.S. 1320 strengthened by shortening spans and increasing conductor spacing in vulnerable locations; designs of heavy-duty 33 kV and 11 kV wood pole lines reviewed and span lengths shortened in exposed locations; new 11 kV and 33 kV lines should restrict span lengths to those specified in the severe environment requirements of E.S.I. 43–10 and 43–20; C.E.G.B. should urgently investigate conductor galloping; wood pole line designs should aim to restrict failures to conductors, and potential for insulated overhead lines should continue to be assessed.

1982 *"Department of Energy: Proof of Evidence for the Sizewell "B" Public Enquiry"* set out Government's general fuel policy, energy projections up to the year 2010, prospects for electricity supply and the role of nuclear power.

1982 *"Efficiency Audit of the South of Scotland Electricity Board", Coopers and Lybrand Associates.* Concluded that activities reviewed namely, management and cost information and control, system operations, fuel purchasing and capital programming, were generally organised and performed to a good standard.

1982 *External Financing Limit for 1983/84* set by Secretary of State for Energy for E.S.I. in England and Wales was −£300M (net repayment of borrowings), subsequently amended to −£418M. Outturn was −£485M.

1982 *International comparison of industrial electricity prices*—by Electricity Council and Chemical Industries Association, showed that at 1 October 1982 industrial electricity prices in England and Wales were broadly in line with those on the Continent, except in France, where significant hydro-electric generation and a substantial nuclear programme contributed to making their prices the lowest in the E.E.C.

1982 *Electricity pricing*—Secretary of State for Energy reaffirmed in November Government's commitment to economic pricing. Cost of meeting marginal increases in demand might be lower than previously estimated mainly because of the lower level of demand and surplus capacity and E.S.I.'s performance had improved. Agreed that there should be no increase in the average level of electricity prices in 1983–84.

1982 *First direct water-cooled generator/motor* in U.K. installed a 100 MW unit at Cruachan pumped storage hydro station.

1982 *"An assessment of the radiological impact of the Windscale reactor fire: October 1982"* by M. J. Crick and G. S. Linsley, National Radiological Protection Board, N.R.P.B.—R 135, November 1982, published estimates of population dose resulting from the release of radioactivity amounting to $1{\cdot}2 \times 10^3$ man Sv (sievert) overall radiological impact; and an upper estimate of radiation induced total health effects of 13 deaths from cancer of the thyroid and seven from hereditary effects. The estimate excluded fatalities due to skin cancer and hereditary defects beyond the second generation.

1982 *"The Nationalised Industry Consumer Councils: A Strategy for Reform", Department of Trade.* Stated that N.I.C.C.'s should further encourage ni's to develop performance yardsticks, contain costs and improve arrangements for handling complaints. They needed close and direct contact with industry management and sponsor Departments. New legislation would be introduced to establish a more uniform legal basis.

1982 *France*—at the request of the Minister for Industry a *Working Group* under M. Raimond Castaing was appointed by the Chairman of the Supreme Council for Nuclear Safety to make recommendations that would enable France to maintain the advanced technology proficiency necessary *to guarantee spent fuel management in the best conditions.* Recommended establishment of an underground laboratory to examine effects of heat liberation from deeply buried high-level wastes, alpha emitter contamination from wastes stored on the surface should not exceed that from natural formations, and potential advanced reprocessing technology studied with a view to stripping out from wastes very long half-life alpha emitters for separate packaging and then incineration by neutron bombardment or dumping in outer space—the remaining wastes could safely be stored at shallow depth.

1982 160 MW *cross-Channel cable* link *decommissioned* on 31 December.

1983 *Electricity supply industry collection of historic plant*—Greater Manchester Musuem of Science and Industry agreed to establish a National Electricity Gallery at Liverpool Road Station, Castlefield, Manchester—it opened in 1986. Gallery included No. 6 12·5 MW English Electric turbo-alternator from Bolton (Back o' th' Bank) power station that commissioned in 1923.

1983 *USA—Superconductivity magnetic storage system* of 30 MJ capacity connected to Bonneville Power Administration's transmission network at Tacoma, Washington, to assist in stabilising AC lines on the Pacific Intertie connecting utilities in California with those in Oregon and Washington.
—Nuclear Waste Policy Act included a commitment to permanent geological nuclear waste disposal although, in the interim, provided for monitored retrieval storage of high-level waste. Provided federal storage for 1,900 te of spent fuel from stations at the limit of on-site storage. Since 1973 U.S. Department of Energy charged utilities 0·1c per kWh generated by nuclear stations.

1983 *Silver Jubilee of the Electricity Council*—established January 1958 as the central body for the supply industry in England and Wales under the Electricity Act, 1957.

1983 *In Memoriam—*
—Rt. Hon. Lord Citrine, PC, KBE (Baron Citrine of Wembley) died on 22 January, aged 95. Walter Citrine, renowned General Secretary of the Trades Union Congress from 1926 to 1946, was appointed a member of the new National Coal Board in 1946 and then Chairman of the British Electricity Authority when it was formally constituted on 15 August 1947. He was outstandingly successful in laying the foundations for the nationalised electricity supply industry and remained Chairman until the end of 1957. From the commencement of nationalisation Lord Citrine worked to broaden the understanding of his workpeople by placing a high priority on extending the arrangement for joint consultation, which became one of the most consistent

and successful attempts yet made in Britain to bring together management and workers.

—*Lord Hinton of Bankside, OM, KBE, FRS, F.Eng*, died on 22 June, aged 82—engineer and industrialist who, in the words of Margaret Gowing, "bestrode his profession like a colossus." A leading figure in the development of nuclear energy in Britain, his most heroic phase began in 1946 when he was charged with producing the fissile material needed for nuclear weapons. He created a new industry comprising very different plants, all on the furthest scientific–technological frontier—gaseous diffusion plant at Capenhurst, the Windscale reactor which he referred to as "this monument to our initial ignorance", Springfields uranium metal plant, Calder Hall power station, and the chemical separation plant at Windscale. From 1 September 1957 until 3 December 1964 he was Chairman of the C.E.G.B.

1983 *World's largest reactor* commissioned at Ignalinsk, Lithuania, with the *world's largest generating set*—1500 MW. The type R.B.M.K.–1,000 reactor (*q.v.*) was water-cooled, graphite-moderated, with pressure-tubes using slightly enriched uranium.

1983 *Southern Electricity Communications and Telecontrol (S.E.C.A.T.)* commissioned—one of the largest distributed processor systems yet installed for monitoring and controlling an electricity distribution network. Central Control Centre at Head Office controlled all the 132 kV, 66 kV, 33 kV, and 22 kV networks. Subordinate Control Centres at 13 District Offices coverd the 11 kV and L.V. networks. Altogether over 500 major substations were monitored and controlled remotely, and some 6,500 individual circuits scanned by the system every few seconds and, when requested, information presented on visual display screens in appropriate control centres. Information included circuit loading and voltage levels, circuit breaker status and alarm indications when a circuit tripped. Improvements in operational efficiency included reduction in time taken to restore supplies after faults, and system loading data that permitted enhanced load transfers and corresponding reductions in plant margins, reduction in distribution system losses by switching out large transformers at times of low load and, at times of emergency, better load spreading.

1983 *Sizewell "B" Public Local Inquiry* main hearing began on 11 January before Sir Frank Layfield QC (The Inspector) and Dr J. Vennart, lately Director of the Medical Research Council's Radiobiology Unit, Professor W. B. Hall, Professor of Nuclear Engineering at the University of Manchester, and Professor C. D. Foster, Visiting Professor of Economics at the London School of Economics and a Director of Coopers and Lybrand (The Assessors). Inspector was appointed by Secretary of State for Energy under S. 34 of the Electricity Act, 1957 to inquire into the application by the C.E.G.B. for consent under S. 2 of the Electric Lighting Act 1909 for the construction of a P.W.R. nuclear station at Sizewell, Suffolk, and for a Direction under S. 40 of the Town and Country Planning Act, 1971 that the planning permission for the station should be deemed to be granted. Inquiry was subject to the Rules of Procedure laid before Parliament in 1981 for Inquiries held under the Electricity Acts and was held, in the main, at the Maltings, Snape, Suffolk. The hearings were completed on 7 March 1985—the longest public inquiry ever held.

1983 *"Analysis of Generation Costs"* published by C.E.G.B. to provide a more comprehensive analysis of the production costs of the different types of power station. Aim was to answer questions in respect of existing stations—how did the stations compare in terms of costs in 1981/82, and from the dates of commissioning to 1981/82, and how were they likely to compare over the life of the station? Also gave some expected generation costs for power stations under construction and which might be built in the future.

1983 *Unified field theory*—confirmation at C.E.R.N. that *electromagnetism* and the *weak force* were *unified at high levels of energy* (90 "proton masses"). With gravitation and the strong force, there were now three forces in physics.

1983 *"North of Scotland Hydro Electric Board: Review of Selected Operating and Administrative Activities"*, Arthur Young McClelland Moores and Co. (Consultants). Examined use of computers and management accounting information, and maintenance and operation of hydro-electric plant. Found there were opportunities to reduce cost and increase efficiency. Greater emphasis was needed in business planning, organisational changes and more effective means of measuring management performance.

1983 *"Pit closures". Second Report from the Energy Committee, Session 1982–83, H.C. 135.* Reported that very high cost of marginal surplus capacity imposed a considerable drain on public funds. N.C.B. was attracting a total level of investment vastly in excess of Belgium, France or West Germany. Scale of expansion plans conceived in mid-1970s was inappropriate to present interpretations of future energy demands. Capacity should be brought more into line with demand.

1983 *Dinorwig pumped storage station* at Llanberis, North Wales commissioned. Built underground in a high amenity area it was the largest of its kind in the world. Six 290 MW reversible Francis generator pump units could provide 1,320 MW in ten seconds. The upper reservoir, Marchlyn Mawr, had sufficient capacity for 1,680 MW generation continuously for five hours.

1983 *Mr T. P. Jones CB* (Deputy Secretary of the Department of Energy), appointed Chairman of Electricity Council from 1 April in place of Sir Austin Bunch CBE who had been Chairman since 1 January 1981.

1983 *External Financing Limit 1982–83* for E.S.I. in England and Wales reduced from −£319M to −£148M because of new tariff arrangements for large industrial consumers, reduction in employers' national insurance surcharge, and extra funds needed to finance record levels of coal stocks.

1983 *New financial targets and performance aims* for E.S.I. in England and Wales for 1 April 1983 to 31 March 1985 agreed with Secretary of State for Energy—a return of 1·4 per cent on average total net assets at replacement cost and a reduction of controllable unit costs of 4·25 per cent.

1983 *"The Rational Use of Energy in Industry. 8th Report from the House of Lords Select Committee on the European Communities, Session 1982–83." H.L. 83.* Recommended inter alia formation of single agency responsible for efficient use of energy. Potential savings amounted to 30 per cent of 1973 use (40 mtce).

1983 *"London Electricity Board. A report on the direction and management by the L.E.B. of its business of retailing domestic electrical goods, spare parts and ancillary services. Monopolies and Mergers Commission". Cmd. 8812.* Concluded that L.E.B.'s management of retail sales involved an anti-competitive practice. A persistent loss on the business, had been financed out of profits from electricity supply where it had a monopoly.

1983 Electricity Supply (Staff) Superannuation Scheme and Electricity Supply (Industrial Staff) Superannuation Scheme merged on 1 April to form *Electricity Supply Pension Scheme*, (S.I. 1983 No. 353).

1983 *Domestic Standing Charge Rebate Scheme* introduced by Area Boards whereby domestic standing charge should not exceed 50 per cent of any bill. For England and Wales revenue loss in 1983/84 was £14·5M, number of rebates given was 3·76M, benefiting just over 2M households. It was withdrawn in April 1986.

1983 *France—Energy Control Agency* established by Government to control energy consumption. The technological expertise created would present export opportunities.

1983 *"Combined Heat and Power. Third Report from the Select Committee on Energy Session 1982–83"*, H.C. 31. Recommended inter alia that combined heat and power and district heating were the best options for heat recovery and uncertainties concerning them would only be resolved through expertise.

1983 *Financial targets and performance aims* for three years to March 1986 set for *North of Scotland Hydro-electric Board* and *South of Scotland Electricity Board* by Secretary of State for Scotland—jointly to earn an average return of 1·75 per cent on average net assets valued on a current cost accounting basis; reduce joint controllable costs of generation and transmission by 4 per cent in real terms by 1984/85 and hold them for 1985/86; and reduce controllable distribution costs—N.S.H.E.B. by 4½ per cent and S.S.E.B. by 8 per cent.

1983 *Organisational changes—North Western Electricity Board* reduced their Districts from 17 to 12.—*C.E.G.B.* announced that regional management was becoming inappropriate as number of power stations decreased and their size increased. The five geographical operating regions would be phased out and replaced by a single corporate management. There would still be a geographically dispersed management but with different reporting chains and accountability.

1983 Part of the *Kemsley-Canterbury 400 kV line* conductor system was adapted to 75°C working instead of 50°C, increasing the line rating by over 50 per cent.

1983 *Energy Act, 1983* gave private enterprise the right to play a larger part in supplying electricity; obliged electricity boards to adopt and support combined heat and power schemes; and gave statutory status to Electricity Consumers' Council. Providing terms and conditions were reasonable an electricity board had to satisfy the request of a private generator or supplier for a supply of electricity either for his own use or that of his customer; had to purchase electricity generated by the private generator and allow the private generator to use the electricity board's transmission and distribution system.

1983 *"Combined Heat and Power Associated with District Heating—a Stuty of Alternative Schemes for Edinburgh and Glasgow"*—report by South of Scotland Electricity Board and Kennedy and Donkin, pub. S.S.E.B., showed that small combined heat and power schemes, while offering reduced capital investment and smaller negative cash flows without a major fall in financial rates of return, like larger schemes could not offer tariffs sufficiently attractive to ensure adequate rates of heat load connection.

1983 *"The Application of Economic Theory Utilising New Technology for the Benefit of the Consumer"*—by R. A. Peddie et al, pub. South Eastern Electricity Board, contended that dynamic pricing (spot pricing), related to short-run marginal costs, which responded rapidly to changes in conditions of supply and demand, were of maximum benefit to consumers. One means of application was Credit and Load Management System (C.A.L.M.S.) developed by the S.E.E.B.

1983 *"British Gas Efficiency Study for the British Gas Corporation and the Department of Energy"*, Deloitte, Haskins and Sells. Recommended more precise pricing, improved profitability without abusing its monopoly position, organisation review, improved efficiency within Regions, improvements to project management and management reporting systems and a more formal relationship with Government.

1983 *London Electricity Consultative Council* asked London Electricity Board to "return the £23M excess profit it made above that required by the Government's financial target" to its consumers.

1983 *"A report on the efficiency and costs in the development, production and supply of coal by the N.C.B."*, Cmnd. 8920.—Monopolies and Mergers Com-

mission recommended that major formations should operate as business units subject to financial targets; and fundamental problems of over-capacity and high-cost pits should be tackled. Coal industry had failed to close capacity amounting to 3–4 Mt accepted by N.C.B., unions, and Government in interim report of Tripartite Examination of 1974.

1983 *Energy Efficiency Office* established within Department of Energy under a Director-General with four Directorates—general policy and domestic and public sectors, industry and commerce, research and technical matters, information and publicity.

1983 *Portable transient earth voltage discharge locator* for mass screening of energised distribution equipment developed by Electricity Council Research Centre, and licensed to Power System Data for production. Early signs of insulation failure could be detected—the first equipment able to test HV plant energised and in situ.

1983 *Electricity supply industry objectives*—Secretaries of State for Energy and Scotland announced objectives for C.E.G.B. (House of Commons Official Report 18 March), Electricity Council (Official Report 27 July), and Scottish Boards (Official Report 12 May). Chairmen of Council and C.E.G.B. were required inter alia to increase scope for competition, review prospects for injection of private risk capital into the industry, develop co-operation with private generators and ensure that contracting and sales of appliances yielded a proper return on assets employed. C.E.G.B. were charged with exploiting full potential of nuclear power and Council with encouraging electricity boards to adopt and support schemes for combined production of heat and power. Similar objectives were set for Scottish Boards.

1983 *"Report on a Review of Standing Charges for the Electricity Council" by Deloitte, Haskins and Sells*—examined appropriateness of standing charges to domestic consumers and scope for cost saving in consumer service and non-operational capital components of the standing charge on the basis of a study of Midlands, North Western and Eastern Electricity Boards. Concluded that costs covered by standing charge were, as intended, independent of consumption and demand and that standing charge was the fairest and easiest way to recover these consumer-related costs. Made recommendations on standing charge calculations that would reduce average standing charge by nine per cent to £16.13. Found that costs per consumer were significantly lower in Eastern Board and suggested that there should be significant scope for cost savings in Midlands and North Western Boards. Recommended a strengthening of role of Electricity Council by creating within it a Central Efficiency Studies Unit to investigate apparent cost differences between Boards.

1983 *German FR*—utilities faced expenditure of £1,600M–£3,200M to install *desulphurisation plant* under the 1982 *Large Combustion Installation Act* (*q.v.*). Aim was to reduce SO_2 emission from 850 mg/m^3 to 400 mg/m^3 for all power stations with a life beginning 1987/88.

1983 *Micro-scale hydro-electricity* for remote villages in *Solomon Islands*; the first was at Iriri funded by United Nations Industrial Development Organisation and built by Apace of Australia. Capable of 8 kW it operated at 3 kW.

1983 C.E.G.B. decided to remove *asbestos* from redundant power stations before selling sites—employed reputable contractors supervised by C.E.G.B. engineers under direction of Health and Safety Executive.

1983 *U.S.A.—Washington Public Power Supply System* defaulted on $2·25 billion worth of bonds raised to build two nuclear power stations which were cancelled and never finished.

1983 *Grain No. 5 Unit* cancelled by C.E.G.B.—oil fired unit could bring no economies in operating costs at current oil prices. Possibility of converting

other units to coal by installing new coal-fired boilers was under consideration.

1983 *"Electricity Supply in Northern Ireland: A Strategy for the Future"*, discussion document by Northern Ireland Electricity Service—recommended that urgent consideration should be given to converting some oil-fired capacity at Kilroot Power Station to coal firing, and to construction of a small hydro scheme on the River Bann.

1983 *Hydrogen diffusion phenomenon* discovered during evaluation of optical fibre trial system strung on 400 kV line between Fawley and Nursling. Exposure of silicate glass optical fibres to hydrogen can cause increases in spectral attenuation (loss of power) at wavelengths important for long-distance communication systems. Optical fibres carry information in very large quantities encoded in pulses of light along very pure hair-thin fibres of glass using lasers as light source. An inner core carries light pulses and is surrounded by an outer layer of less pure glass (cladding) which confines the light to the inner core, since core has a higher refractive index than the cladding. Rays of light which enter at an angle continually bounce off the core/cladding interface by total internal reflection and are thereby conducted to the far end of the fibre. Hydrogen related effects can be reduced by prevention of electrolytic action between metals, use of flow pressurisation for cables, reduction of phosphorus content of multimode fibres, and application of an hermetic coating to the silica fibre to act as a diffusion barrier against the ingress of hydrogen.

1983 *"Memorandum from the Secretary of State for Energy. Government Observations on the Fifth Report from the Energy Committee Session 1982."* Department of Energy. Government were prepared to further energy conservation in buildings by offering advice and information, intervention where significant imperfections in the market distorted allocation of resources and increased promotion of efficient use of energy.

1983 *China*—Commissioned a 500 kW *tidal power* scheme at Jiangxia.

1983 *Power for Efficiency and Productivity* (P.E.P.) Award Scheme introduced by the North Western Electricity Board to reward manufacturing companies which had significantly improved their tariffs by adopting new electric processes or services. The scheme became nationwide in 1985.

1983 *Wind Turbines*—two were commissioned in the Orkneys at Burgar Hill—a 250 kW machine installed by Wind Energy Group (Taylor Woodrow Construction Ltd., British Aerospace Dynamics Group and G.E.C. Power Engineering) and a prototype 300 kW machine under test by James Howden.

1983 *German FR—Growian experimental 3 MW wind turbine* on the North Sea Coast at Kaiser—Wilhelm—Koog commissioned. It was reported after one year of operation (to European Wind Energy Congress at Hamburg) that only 100 hours running free of faults had been achieved—numerous defects were likely to tax engineers for years. According to M.A.N., the manufacturers, at least five years of engineering development was needed.

1983 *"Medium Term Development Plan, 1983–1990"*—estimated electricity sales in England and Wales would increase from 199 TWh in 1983/4 to 213 TWh by 1989/90. Electricity price rises in early years would be lower than rate of inflation, but beyond 1984/85 real increases in price of coal would mean that non-fuel costs would have to be controlled to contain price rises below inflation.

1983 *C.E.G.B. and N.C.B. 'joint understanding' on coal supplies* to power stations for 1 November 1983–31 October 1987. C.E.G.B. agreed to take a minimum of 70 Mt a year and to use best endeavours to sustain this take, subject to level of electricity sales and performance of nuclear plant. N.C.B. agreed to keep average coal price increases below rate of inflation and allow a price discount

on coal bought in excess of 65 Mt. Regard would also be paid to world coal prices.

1983 *"Yorkshire Electricity Board—a Report on the Efficiency and Costs of the Board." Cmd. 9014, Monopolies and Mergers Commission.* Found there was a need for more effective cost control, although Board was well run on the whole with effective and responsible management. Concluded that Board was not pursuing a course of conduct contrary to the public interest.

1983 *External Financing Limits*—target of −£300M set for England and Wales in November 1982 for 1983/84 amended to −£418M; debt reduction achieved was £550M. Target set for 1984/85 was −£746M, and for North of Scotland Hydro-electric Board −£3M.

1983 *Area Boards' tariffs for private generator or supplies published*—'Use of System Tariff', 'Purchase of Electricity Tariff' and 'Supplies to Private Generators Tariff'.

1983 *N.U.M. overtime ban*, which lasted until 8 April 1985. Overtime was usually for safety inspections, repair and maintenance work, often statutorily required. As a result of the ban the Scottish Bogside colliery was abandoned.

1983 *Tidal power*—a *Mersey barrage* was feasible according to a study by Marine Tech North West, a consortium of marine technologists from universities of Manchester, Liverpool, Salford, Bangor and U.M.I.S.T., funded by Merseyside Enterprise Forum.

1983 *Severn Barrage*—between Severn Reach, Avon and Sudbrook Point, Gwent proposed by Wimpey Construction—W. S. Atkins consortium at a cost of £885M. 42 × 24 MW units would generate 2·43 TWh pa. Provision for a road crossing would avoid need for a second Severn Bridge.
—between Brean Down and Lavernock Point—technical and financial viability of a barrage built and operated by private sector was the subject of a £0·5M two-year study jointly funded by Government and Severn Tidal Power Group.

1983 *Solar power*—Experimental 30 kW installation at C.E.G.B.'s Marchwood Engineering Laboratories began supplying power. Funding was provided by BP, Department of Trade and Industry, and E.E.C.

1983 *Small-scale hydro—first private generation resulting from Energy Act 1983* at Wookey Hole caves in Somerset Mendips—90 kW generator driven by a cross-flow water turbine by Armfield Engineering of Ringwood, and an electronic controller by Headley Associates. Electronic load controls were developed by Evans Engineering and G.P. Electronics in conjunction with Technology Industrial Services, with financial assistance from Overseas Development Administration.

1983 In November unplanned *release from Sellafield of radionuclides* (mainly Ruthenium–106) plus solvent and other material, resulted in the beach between St Bees and Eskmeals being contaminated with unusual quantities of Ruthenium–106. Public were advised for a time not to frequent the beaches unnecessarily.

1983 *"The Nitrogen Cycle of the United Kingdom: Report of a Royal Society Study Group"* London. The Royal Society, December 1983. Accepted evidence that about a third of rainfall acidity of northern U.K. was due to nitric acid, but concluded that insufficient basic information was available on relative sources and roles of oxides of nitrogen, ammonium ions and oxides of sulphur in contributing to acid deposition to say with certainty that man-made deposition was a significant environmental problem. Recommended a detailed study of acid deposition.

1983 Three *intermediate vector bosons* (W^+ W^- Z^o) discovered at C.E.R.N., providing further understanding of the unified nature of the weak force and the electromagnetic force (*q.v.*).

1983 The Commission of the *European Community* submitted a proposal for a Council *Directive on combating air pollution*, 'COM (83) final', for combustion plants in excess of 50 MW to reduce total annual emissions by 31 December 1995—60 per cent for SO_2, 40 per cent each for dust and oxides of nitrogen.

1984 *U.S.A.—William H. Zimmer nuclear station,* jointly owned by American Electric Power's Columbus and Southern Ohio Electric Co., Cincinnati Gas & Electric Co., and the Dayton Power and Light Co., to be converted to coal firing. In November 1982, the Nuclear Regulatory Commission halted safety-related construction when power station was 97 per cent complete.

1984 Trials began on three *load management* options, each lasting a year—

Radioteleswitching—utilised B.B.C.'s low-frequency radio transmitters. Trial was carried out across the country under control of the East Midlands Electricity Board. Coded signals from Droitwich, Burghead and Westerglen transmitters used phase modulation on the 200 kHz carrier for Radio 4 sound broadcasting. Each Area Board had about 20 receivers installed at normal metering locations. System involved one-way communication only (i.e. Board to consumer) and was designed to switch on and off all or part of a consumer's load.

Mainsborne telecontrol—system developed by Thorn EMI with joint sponsorship from Department of Trade and Industry. Trial was funded by D.T.I. and electricity, gas and water industries. Digital signals were transmitted in coded form from central controllers located at local substations over 240 V mains to home units. Trials involved 1,000 premises in London and Milton Keynes and allowed two-way communication with consumers for remote reading of gas, electricity and water meters. System also had load management features.

Credit and Load Management Systems (C.A.L.M.S.) developed by South Eastern Electricity Board and tested in 300 homes in South Eastern, East Midlands and Midlands Electricity Boards. A two-way communication path provided by ordinary subscriber telephone used "idle line" principle supplemented by facility to receive radio teleswitching signals. Each consumer had an electronic terminal including a microprocessor and facilities offered included information on tariffs, state of a consumer's account and circuit loading, remote meter reading and flexible tariff arrangements. Gas and water utilities also participated.

1984 *The last public DC supply shut down in February.* Associated Newspapers in Fleet Street were supplied from a motor converter and mercury-arc rectifier at the Dorset Rise Sub-station.

1984 C.E.G.B. completed on 4 April a *changeover in the control of the Grid system* from three tier with national control, area control and district control to two tier by merging the areas and the districts. The process had begun on 3 March 1980.

1984 *Legality of tariff increase* challenged by London Electricity Consultative Council. Legal advice received by L.E.C.C. indicated that two per cent increase in domestic electricity prices proposed by London Electricity Board from April to meet Government financial targets was ultra vires on grounds that it was not consistent with L.E.B.'s statutory powers. Legal advice obtained by L.E.B. indicated that the increase was legal. L.E.C.C. then made a statutory representation to the Electricity Council against the tariff increases, who found that there had been no defects in L.E.B.'s plans and arrangements.

1984 *Project Management Board* established under C.E.G.B. chairmanship for construction of the Sizewell "B" nuclear station, with directors from the National

Nuclear Corporation and C.E.G.B. Design, manufacture and construction of the station became responsibility of a Project Management Team based at N.N.C. with staff drawn from C.E.G.B. and N.N.C., and directed by P.M.B.

1984 *"European Community Coal Policy. Tenth Report from the Select Committee on the European Communities, Session 1983–84", H.M.S.O., H.L. 80.* Concluded that although E.E.C. coal demand was likely to appreciate considerably by year 2000, probably almost all the increase would be met from outside E.E.C. E.E.C. coal industries had to surmount difficulty of continued production at manifestly uneconomic pits. They could best help E.E.C. needs by modernising plant, closing uneconomic pits, introducing new economic capacity and achieving profitability. Government were urged to write off many of N.C.B.'s losses.

1984 *"A Guide to Questions of Law and Practice in Relation to Electricity Consumers in England and Wales"* (third edition) published by Electricity Consumers' Council.

1984 *C.E.G.B.'s Bulk Supply Tariff* for 1984/85 incorporated a new *System Service Charge* set to recover unavoidable costs of some £550M and additional unit rates to reflect larger cost differentials between weekdays and weekends and between summer and rest of the year.

1984 *"Development of Nuclear Power. Report by the Comptroller and Auditor General." H.C. 261.* Recommended that Department of Energy control would be improved if U.K.A.E.A.'s programmes and projects included milestones against which both expenditure and technical progress could be measured since absence of costed technical plans meant that monitoring arrangements lacked formal procedures to facilitate examination of technical progress against expenditure.

1984 Chapelcross "A" nuclear station successfully completed 25 years of service.

1984 *"Tackling Pollution—Experience and Prospects." Tenth Report of the Royal Commission on Environmental Pollution, Cmnd. 9149.*—emphasised importance of concept of 'best practicable environmental option', advocated a general right of access by the public to all data collected by pollution control authorities, recommended that level of advice on radioactive waste from sources independent of nuclear industry should be enhanced, C.E.G.B. should introduce abatement of SO_2 emission from power stations on a pilot basis, and highest priority should be given to appraisal of alternative energy scenarios.

1984 *"Electricity and Gas Prices. First Report from the Select Committee on Energy, Session 1983–84." H.C. 276–1*—they were not persuaded by Treasury case for a two per cent increase in domestic prices from 1 April either in terms of the need for E.S.I. to meet its financial target or on basis of the Government's policy for economic pricing for electricity. Concluded that only plausible motivation for large increase in E.S.I. repayment to Government imposed by Chancellor was to reduce Public Sector Borrowing Requirement.

1984 *Combined Heat and Power Inquiry Bureau* established by Electricity Council.

1984 *"South Wales Electricity Board—a Report on the Efficiency and Costs of the Board"*, Monopolies and Mergers Commission, Cmnd. 9165—observed that

controllable costs had been rising faster than rate of inflation. Made recommendations on planning and management aspects including tighter control through performance indicators and information systems. Future of appliance repair business should be considered if breakeven not achieved in 1984–85.

1984 *External Financing Limits* for 1984–85 set by Government for E.S.I.—a net reduction in debt of £746M for England and Wales and £2M for North of Scotland Hydro-electric Board; for the South of Scotland Electricity Boad a net borrowing of £261M.

1984 *First full-scale public drop of a Magnox modern fuel flask*—a 48 t flask of latest design with a wholly forged steel body was dropped from 30 ft. onto a totally unyielding 2,000 t 'anvil' at C.E.G.B.'s Structural Testing Centre, Cheddar, Somerset. The successful test was part of a £4M nuclear fuel flask development programme.

1984 *Formel NF—world's first totally non-flammable insulating and coolant transformer fluid* developed by the Electricity Council and I.S.C. Chemicals Ltd.—a blend of four short-chain aliphatic halocarbons which do not contain hydrogen.

1984 *"Report on Consulting Work in Connection with the Review of the Bulk Supply Tariff." Coopers and Lybrand Associates*—recommended that B.S.T. should be improved as a long-run marginal cost tariff. Two capacity charges were not justified, fuel cost adjustment was inappropriate for a marginal cost tariff, more complex kWh charges would provide Area Boards with information to improve their retail tariffs. Favoured a B.S.T. based on economic resource allocation, which would yield less than existing tariff because of C.E.G.B.'s excess capacity—but since nation had already paid for the capacity it was appropriate to set tariffs which encouraged its use. Economic objectives were in conflict with Government's financial objectives.

1984 *Coal miners' strike* against pit closures. From 5 March South Yorkshire Area of N.C.B. were on strike and by 15 March collieries in Scotland, North East, South Wales and Kent were on strike or picketed out. Ballots in ten N.C.B. Areas showed that six and Durham Enginemen were strongly against the strike, North West Lancashire were 59 per cent against, North Derbyshire evenly split. Nevertheless strike continued until 5 March 1985, but was not 'solid'—pits in Nottingham Area and some elsewhere remained open. Power supplies were maintained—power stations had nearly 12 Mt in stock at the end of strike. The cost of the strike to the C.E.G.B. was £2,020M. N.C.B. lost 61 coal faces plus equipment etc. Cost to the nation was a little over one per cent of GDP in 1984. C.E.G.B. met the highest ever maximum demand without load shedding.

1984 *Fast breeder reactors*—U.K., France, Germany, Italy and Belgium signed a Memorandum of Understanding establishing principles underlying collaboration in liquid-metal-cooled fast reactors. U.K. was represented by U.K.A.E.A. and National Nuclear Corporation; France by Commissariat a l'Energie Atomique and Novatome; Germany by Kernforschungszentrum, Karlsruhe and Interatom; Italy by Comitato Nazionale per la Ricerca e per lo Sviluppo dell'-Energia Nucleare e delle Energie Alternative and Nucleare Italiana Reattori Avanzati; Belgium by Centre d'Etude de l'Energie Nucleaire (C.E.N.) and Belgo nucleaire.

1984 *Secondary Legislation—"The electricity (conduct of proceedings for the determination of disputes) regulations 1984".* S.I. No. 135—prescribed the procedure when a dispute between an Electricity Board and a private generator or

supplier was referred under S. 9 of the Energy Act 1983 to the Secretary of State.
—*"The electricity (private generating stations and requests by private generators and suppliers regulations 1984"* S.I. No. 136—prescribed the notice and information to be given to an Electricity Board by a private generator or supplier proposing to construct generating capacity.

1984 *E.E.C. Directive 84/467/Euratom* set out the basic safety standard for protection against *ionising radiation.*

1984 *East Midlands Electricity Board reorganisation*—Districts were reduced from 18 to 15 on 1 April.

1984 *"Resale of Electricity by Landlords*—a Consultative Document", Consumer Affairs Division, Department of Trade and Industry, April 1984. Office of Fair Trading looked at problem of landlords charging more for electricity than maximum price specified by Electricity Boards; set out various solutions that had been suggested such as making overcharging a criminal offence, and invited views from interested parties. Major point was that consumers overcharged tended to be socially more vulnerable and therefore less likely to seek redress.

1984 *Japan—Takahama 3,* an 870 MW P.W.R. station of Kansai Electric Power Company, achieved criticality after only 39 months from pouring first concrete.

1984 *"The Case for an Inquiry into Hydro Electric Generation in the North of Scotland"*—study prepared for Federation of Civil Engineering Contractors, called for an expert committee to consider additional hydro-generation.

1984 *A separate financial target for appliance retailing and electrical contracting* agreed with Government by Electricity Council—an average of five per cent current cost pre-tax return on net assets between 1984–85 and 1987–88 for each activity.

1984 Electricity Council Research Centre (E.C.R.C.) developments—
high power channel induction furnace particularly suitable for aluminium melting was installed at Inductotherm Corp. at Fort Wayne foundry, U.S.A. With a unidirectional flow, channel kept free from erosion; and power density could be increased to produce rapid melting with high efficiency and low metal loss.
11 kV overhead line automatic sectionaliser was licensed to Brush Fusegear Limited for production and became commercially available. Worked in conjunction with multi-shot autoreclose circuit-breakers and could be fitted into existing expulsion fuse mounting. Operated only for the re-occurrence of permanent faults, thus improving security of supply in rural areas.

1984 *France*—EdF's *Paluel I* 1,300 MW P.W.R. commissioned, first of 20 of this size in French P.W.R. programme.
—Cour des Comptes (Comptroller and Auditor General) reported in June (ISBN 2-11-071392-5) that EdF's accumulated profit had reached Ffr 117M, but then drastically deteriorated so that net operating losses were recorded—Ffr 4·6G in 1981, Ffr 8·4G in 1982 and an estimated Ffr 5·4G in 1983. Self financing had fallen to 28 per cent in 1982, borrowings reached Ffr 32G in 1983 and absorbed ten per cent of French capital market even though 41 per cent of EdF's borrowings were from abroad. Reasons for deterioration were mainly large nuclear programme launched in 1974 which needed heavy investment and associated capital charges while an expected growth in consumption had not materialised. Meanwhile manpower increased by 12 per cent, other operating costs had increased, and a new tariff policy had pitched prices too low.

1984 *Japan*—first trials of *Com-fuel*, a mixture of oil and pulverised fuel, began at Vokosuka Power Station of Tokyo Electric Power.

1984 *Canada*—pilot tidal power scheme at Annapolis Royal in Bay of Fundy, Nova Scotia, commissioned. Employed a single 20 MW Straflo turbine.

1984 *Railway electrification*—East Coast line from London to Edinburgh via Newcastle agreed by Government, for completion in 1991, at a cost of £306M.

1984 "*Acid Rain*—Fourth Report from the Environment Committee Session 1983–84", H.M.S.O., Vol. I, Report etc., H.C. 446–1, Vol. II, Minutes of Evidence, H.C. 446–II, 446–i–x. C.E.G.B. witnesses stated that a combination of ozone and drought might account for German forest damage which first showed up on the silver fir. Emissions of nitrogen oxides and hydrocarbons together with sunlight were precursors of higher than natural ozone levels. E.E.C. Commission's Directive (*q.v.*) would have effect of increasing cost of generation at stations affected by about 9–10 per cent and raise total costs of generation by about 5–6 per cent in respect of SO_2 abatement.

1984 C.E.G.B. demonstrated *integrity of a 48 t nuclear fuel flask* by crashing a passenger train into it at 100 mph—at a cost of £1·6M. Flask had previously been dropped onto a prepared 'anvil' at Cheddar Tower Testing Station.

1984 "*Expenditure on Fuel 1982*"—report commissioned by Electricity Consumers' Council and National Gas Consumers' Council from Social Policy Research Unit at York University found that fuel accounted for a larger proportion of household budgets in 1982 than in 1980—pointing need for promotion of gas and electricity Easy Payment Schemes.

1984 E.E.C. Directive Com (83) 704 "*Limitation of Emissions of Pollutants into the Air from Large Combustion Plant*" included in Article 3 requirement by end of 1995 of a reduction on 1980 levels of 60 per cent in SO_2 emissions and 40 per cent in both nitrogen oxide and particulate emmissions.

1984 *Heysham I A.G.R. incident*—two alarms indicating higher than average temperatures in two fuel channels were missed. Half-an-hour later a computer-assisted survey of fuel channels spotted abnormal temperatures and reactor was tripped. Blanking plates used during pre-fuelling tests had been left in two fuel channels.

1984 *Acidity in the Environment*, H.M.S.O.,—study by Dr Deborah H. Buckley-Golder of Department of Energy's Energy Technology Support Unit concluded that SO_2 and NO_x emitted into the atmosphere from man-made sources may be redeposited in both dry and wet processes causing detectable damage, but in many cases such damage was difficult to quantify due to complexity of chemical and biological systems involved and the lack of background data for unpolluted atmospheres. Very difficult to estimate the degree of U.K. contribution to long-term sulphur deposition in other European countries because was not yet clear whether long-term or episodic deposition was more important nor how U.K. contributed to sulphur deposited. Many issues within the description of origin, transport, transformation, deposition and effects of environmental acidity and its precursors remained poorly understood.

1984 *German FR—Gersteinwerk Station* of Vereinigte Elektrizitatswerke Westfalen (V.E.W.) became *world's largest* operational *fully-fired combined cycle plant* with commissioning of a 750 MW unit comprising a 114 MW gas turbine fired with natural gas and a coal-fired Benson once-through boiler steaming a 656 MW reheat steam set. Total capacity was 2,350 MW and overall net efficiency 41 per cent after works load associated with flue gas desulphurisation.

1984 "*Air pollution*—22nd Report from House of Lords Select Committee on the European Communities, Session 1983–84" H.L. 265—included a memorandum by C.E.G.B. on financial implications of E.E.C.'s Proposal for a Directive Com (83) 704 on limiting emissions of pollutants (*q.v.*) On basis of Scenario C (one per cent p.a. average growth in U.K. G.D.P. to 2000) and medium nuclear

development (a nuclear station will commission in 1991 and further nuclear capacity up to 2000 will be limited to capacity needs) a 60 per cent reduction in sulphur emission by flue gas washing would involve capital expenditure at 1983 prices of £1,430M, plus £560M to replace loss of capacity of 663 MW. Annual costs would reach £350M after 1995. Total cost present valued to March 1983 would be £2,500M equivalent to £550/t of sulphur abated. 40 per cent reduction of nitrogen oxide emissions would involve replacing burners in boilers, if technically feasible, at a cost of not less than £225M. Reduction of 40 per cent in particulate emission might be achieved automatically by installation of flue gas desulphurisation plant, but if replacement of precipitators were necessary cost would be about £16M to £20M for each 2,000 MW station. The capital cost of monitoring equipment would be about £16M to £40M.

1984 *"Investigation of the Possible Increased Incidence of Cancer in West Cumbria"*: Report of the Independent Advisory Group, Chairman, Sir Douglas Black, H.M.S.O. Examined claims in a Yorkshire TV documentary regarding incidence of leukaemia in Seascale, near Sellafield. Recommended inter alia that "there should be a critical review of the necessity for discharges of alpha as well as beta/gamma emitters in discharges from B.N.F.L. Sellafield site to be significantly in excess of those from similar plants in other countries". Found no evidence of any general risk to health for population living near Sellafield when compared to the rest of Cumbria.

1984 *Japan—nuclear fuel cycling*—the nine power companies announced plans to build a uranium enrichment plant, a nuclear fuel reprocessing plant and a permanent storage facility for low-level radioactive waste at Rokkashomura in northern Japan.

1984 U.K.A.E.A.'s *Dounreay P.F.R.* synchronised with national grid at nearly 200 MW output (it reached full power, producing 250 MW(e), on 4 March 1985).

1984 Britain's *first national wind power test centre* on a moorland ridge about 8 km. south west of East Kilbride. Department of Trade and Industry and Scottish Development Agency contributed £750,000. Will test and accredit British built wind turbines under supervision of D.T.I.'s National Engineering Laboratory.

1984 Operating lifetime of C.E.G.B.'s eight *Magnox nuclear stations*, (3,445 MWso total capacity) extended from 25 to 30 years (20 to 30 years for Wylfa). Avoidance of more expensive coal and oil firing expected to save £1,000M to £1,500M. Savings on depreciation and decommissioning charges spread over a longer period, saved £126M in 1983/84. Important factors in decision were—greater ability to predict oxidation rates of components and to repair them, better knowledge of condition of pressure circuits and of radiolytic corrosion of graphite moderators.

1984 *Mont Louis* sank off Belgian coast with cargo of 225 t of uranium hexafluoride (UF_6) that was to be enriched in U.S.S.R.

1984 *Kielder Reservoir Hydro Station* commissioned—6 MW joint venture by Northumbria Water Authority and C.E.G.B. based on Europe's largest man-made lake. Larger releases of water passed through a Kaplan turbine to drive a 5·5 MW set. At times of low water, releases of water to satisfy river ecology powered a Francis turbine to drive a 500 kW alternator.

1984 *B.N.F.L. committed for trial 4 October*—on five summonses under Nuclear Installations Act 1965 and Radioactive Substances Act, 1965 arising from the contamination by radioactive wastes of beaches near its Sellafield plant. On 23 July 1985 after a seven-week trial, found guilty on four charges and fined £10,000.

1984 *First electronic solid state single-phase domestic meters in U.K.*—possibly first in the world—installed by East Midlands Electricity Board, the S.A.N.G.A.M.O. model 720.

1984 Ranks Hovis McDougall closed Europe's largest *eel breeding centre* at Drax power station because flow of warm water was reduced due to miners' strike.

1984 *Financial targets* for E.S.I. in England and Wales: *External Financing Limit*—repayment of £1,130M of borrowings in 1985/86; *Return on Assets*—2·75 per cent during 1985/86 to 1987/88 inclusive; *Performance Aim*—reduction in controllable unit costs of 6·1 per cent end 1987/88 cf. 1983/84.

1984 *France—EdF's planned exports*—25 TWh in 1984 rising to 30–35 TWh a year by 1990.

1984 Improved *Codes of Practice covering repair and servicing of domestic electrical appliances* introduced jointly by A.M.D.E.A., Electricity Council, and Scottish Electricity Boards—provided for minimum charges to be notified to customers before first visit, normally within three working days, and where subsequent visit is made repair should be completed in 15 working days; and written quotations to be provided on request. Guarantee period on repair work of larger appliances covering both parts and labour to be twelve months, compared with three-month guarantee on smaller appliances.

1984 *Acid rain*—C.E.G.B. sponsored a £5M five-year research programme conducted by Royal Society, London, Swedish Royal Academy of Sciences, and Norwegian Academy of Science and Letters, to investigate causes of acidification of Norwegian and Swedish surface waters. C.E.G.B. had already spent £8M on acid rain studies, including tracking emissions from Eggborough coal-fired station. Over three years it planned to spend over £20M investigating sulphur reduction in coal, desulphurising flue gas, fluidised-bed combustors, furnace burners with reduced outputs of oxides of nitrogen, and coal gasifiers with reduced emissions.

1984 "*Acid rain: the Government's Reply to the Fourth Report from the Environment Committee* Session 1983–84, H.C. 446–I", H.M.S.O., Cmnd. 9397. Government aimed to achieve 30 per cent reduction on 1980 levels of SO_2 and NO_x emissions by end of 1990s, although very substantial expenditure required to install flue gas desulphurisation plant at existing power stations could not be justified while scientific knowledge was developing and environmental benefits remained uncertain.

1984 *South Africa—De Villiers Commission* on Electricity Supply recommended a new Electricity Council with enhanced powers of control.

1984 *Fast Reactor Technology Ltd.* (F.A.S.T.E.C.) formed by National Nuclear Corporaton (51 per cent shareholding) and U.K.A.E.A. (49 per cent shareholding) to manage the commercial use of technology generated by them on research, design and development of fast reactors. F.A.S.T.E.C. negotiated an agreement with Societe Européène pour la Promotion des Systemes des Reacteurs Rapides au Sodium (S.E.R.E.N.A.) which managed commercial use of technology of other countries in the European fast reactor collaboration.

1984 *France*—EdF agreed with Government that over four years it would reduce production costs by three per cent a year and increase electricity sales to industry. Tariff increases would be one percentage point below rate of inflation, sufficient to bring EdF out of the red. Self financing in 1984 was expected to reach 64 per cent.

1984 *Brazil*—first of 18 × 700 MW generators commissioned at Itaipu on Brazilian/Paraguay border—*world's largest hydro-electric project.* First phase of

world's largest DC link also commissioned—±600 kV DC, capacity 6,300 MW, from Itaipu to Sao Paula.

1984 *"Report of the Independent Review of Disposal of Radioactive Waste in the North-East Atlantic"*, H.M.S.O.—by independent scientists under Professor Fred Holliday, commissioned by Government and T.U.C. Found that British scientific work in radioactive waste disposal at sea was of highest quality. There was no evidence of harm to man or environment. Because of uncertainties about long-term natural processes involved, recommended that disposal at sea of low-level and intermediate-level radioactive wastes, suspended in 1983, should not be resumed until completion of current international reviews.

1984 *Sweden*—Electrolux took over Italy's Zanussi creating *world's largest household appliances manufacturer.*

1984 *Canada*—Phase I of Hydro-Quebec's *James Bay hydro project* was completed with commissioning of LG-4 power station—providing total capacity of 10,269 MW from La Grande River stations LG.2, 3 and 4. Potential capacity from all rivers flowing into James Bay could amount to 25,000 MW.

1984 *"Disposal Facilities on Land for Low and Intermediate-Level Radioactive Wastes: Principles for the Protection of the Human Environment"*, Department of Environment et al, H.M.S.O., December 1984—included objective that radiation exposure of individuals and collective dose to the population from radioactive waste should be as low as reasonably achievable—not more than 5 mSv in any one year. National Radiological Protection Board believed that the average dose to a critical group could be less than 1 mSv a year from all sources of radiation and lifetime effective dose equivalent to a member of the public would not exceed 70 mSv. After several hundred years, when on-site supervision no longer required, appropriate target applicable to a single repository was a risk to an individual of no more than 0·1 mSv a year, a risk of death from radiation exposure of one chance in a million.

1984 *"Nationalised Industries Legislation—Consultation Proposals"*—note sent by Chief Secretary to the Treasury to Nationalised Industries Chairmens' Group, set out proposals to update nationalising statutes so that they conformed to a common set of statutory provisions. New legislation would include provisions covering borrowings and guarantees, accounts, reports and audits, financial targets, terms of appointments to boards, formation of companies and privatisation. The proposals were strenuously resisted by ni's and shelved.

1984 First U.S. commercial integrated coal gasification combined cycle (I.G.C.C.) plant commissioned at the Cool Water Station in Southern California. SO_2 and NO_x emissions from the 100 MW plant were only a tenth of legal maximum.

1985 *East Midlands Electricity Board*—new domestic *Appliance Repair Guarantee.* Labour charges are cancelled if a customer's call is not attended within three working days.
—'Metermate' energy monitoring system installed in premises of 17 large customers. They had the advantage of special tariffs matching periods of maximum use with cheap rates and meter-reading costs were reduced.

1985 *Eastern Electricity Board* used *optical fibres* within earth conductors of overhead lines in Norwich to save renting telephone circuits from British Telecom. Expected to reduce annual costs by half.

1985 *Heber* 45 MW *prototype geothermal station* commissioned by E.P.R.I. in Imperial Valley, California. Moderate-temperature brines were utilised by means of a binary cycle based on a low boiling point hydrocarbon fluid, thus extending the scope for geothermal generation.

1985 *"H.M. Treasury's Consultation Proposals for Legislation in Respect of the Nationalised Industries."* Sixth Report from the Energy Committee, Session 1984–85, H.C. 302. Included the proposals made on 20 December 1984 (*q.v.*) and the comments of B.G.C., the Electricity Council, N.C.B. and Scottish electricity boards.

1985 First of two 600 MW reactor units commissioned at *Dungeness "B" (Kent) A.G.R. nuclear station* at interim rating of 450 MWso. Work on site started in 1966.

1985 B.N.F.L. commissioned their *Site Ion Exchange Effluent Plant (S.I.X.E.P.)* to enhance the purification of water discharged from Sellafield. The zeolite, clinoptilolite, was used to remove caesium and strontium in two ion-exchange columns.

1985 South Western Electricity Board—£3M mains distribution system installed on the *Scilly Isles.* Consumers on islands of St Agnes, Bryher, Tresco and St Martins, who had relied on private generation were now supplied by the 3·5 MW diesel station on St Mary's via submarine cables. For environmental reasons much of the 9 km of standard 50 mm, three-core 6,350/11,000 V aluminium cable network was installed underground with additional cost borne by Duchy of Cornwall and Countryside Commission.

1985 London E.B. began trials of *'pay-as-you-go' meters*—two hundred *token meters,* operated by electronically coded plastic tokens worth £1 of electricity, and one hundred key-operated devices using special keys charged with as much credit as the customer wants. Both can be programmed to give emergency credit and collect arrears.

1985 Merseyside and North Wales E.B.—first to use *electronic metering* of *industrial customers* on maximum demand tariffs as standard practice.

1985 Northern Ireland—A four-year project to convert the 600 MW Kilroot power station from oil to coal expected to cut fuel costs by £30M a year.

1985 *"Metering Survey",* Jeannette Atton, Electricity Consumers' Council, Research Report 13—into consumer attitudes to metering, billing and other related topics.

1985 *The Future of the Electricity Supply Industry. A Discussion Conference.* Centre for Energy Studies, Polytechnic of the South Bank 25–27 June 1985. Papers considered inter alia privatisation (decentralisation) options and included one on economic pricing by R. W. Orson.

1985 *Debt collection, disconnections and electricity consumers: Report on the operation of the Code of Practice.* Electricity Consumers' Council Discussion Paper 14. Assessed the situation since the 1982 revision. Main recommendation was that there should be a survey to obtain systematic information about the circumstances of consumers whose supply has been disconnected.

1985 *Jersey—started to import electricity* from France in May via a £12·7M underwater link—suffered three island-wide power failures in the first month—two due to faults on French HV lines. Tariffs were reduced by approximately 24 per cent for domestic customers down to 5·8 pence/kWh.

1985 *Guernsey*—Government voted to spend £100,000 to survey a possible cable link with France. Imports would cost about one-third of present oil-fired generation.

1985 *Medical Research Council Study—on the Mortality of Employees of the U.K.A.E.A. 1946–1979,* Beral et al, British Medical Journal, 17 August 1985 pp 440–447. Among the U.K.A.E.A. employees monitored for exposure to low dose ionizing radiation under an M.R.C. contract with U.K.A.E.A., for an average of 16 years between 1946 and 1979, the only condition significantly

related to cumulative radiation exposure was prostatic cancer, showing a clearly increased mortality relative to national rates. The reason could not be determined and further investigation was required. The collective recorded exposure of employees monitored was 660 Sv (65,954 rem).

1985 Swedish Government decided to phase out nuclear generation by 2010—the 45 per cent of national generation will be replaced by hydro-power, wind power, domestic peat, combined heat and power and, as a very last resort, oil or coal-fired plant.

1985 S.S.E.B.'s *Hunterston* Magnox and A.G.R. reactors achieved *79·45 per cent average load factor*—the world's best.

1985 U.S. Nuclear Regulatory Commission cleared the way for the reopening of an undamaged reactor at *Three Mile Island* power station.

1985 CEGB Energy Information Centre opened at Hartlepool AGR station, attracting over 1,000 visitors a month. Six others were planned at power stations.

1985 *"Resale of Electricity by Landlords"*—report by the Director General of Fair Trading, recommended that new legislation should be introduced which would create an offence of charging more for electricity, resold for domestic use, than the maximum charge published by the appropriate electricity board. The legislation should also require those who resell electricity, when demanding payment, to give the consumer an itemised bill. A statutory duty to enforce the new provisions should be placed on local weights and measures authorities. Electricity Boards should give increased publicity to maximum resale prices.

1985 *First commercial air radio frequency assisted (A.R.F.A.) drying* installed by Avalon, Leatherhead, with the result that the drying rate for leatherboard improved by 300 per cent. The electrical technique of radio frequency with air impingement was developed by the Electricity Council Research Centre at Capenhurst and manufactured by Greenbank Darwen Engineering of Blackburn.

1985 Commissariat à l'Energie Atomique closed their 70 MW CO_2 *gas-cooled heavy-water* (D_2O) moderated *reactor at Monts d'Arree*, Brittany—the last of its kind. Fuel was slightly enriched UO_2 clad in CuZr—it commissioned in 1971.

1985 *"The Ionising Radiations Regulations 1985"*, S.I. No. 1333 covered dose limitation, regulation of work involving radiation, dose measurement, medical surveillance, control of radioactive substances and monitoring radiation.

1985 *"North of Scotland Hydro-Electric Board. A report on the efficiency and costs of the Board."* Monopolies and Mergers Commission Cmnd. 9628. Principal criticisms were a failure to appreciate in good time the need to refurbish the distribution system and a lack of manpower planning. Part-time members should be more involved in corporate strategy.

1985 *Electricity boards appliance repairs*—Following Monopolies and Mergers Commission report on South Wales EB, Electricity Council decided that boards' published accounts would include key indicators of performance in this activity: figures for turnover, operating profit or loss, average net current cost capital employed and percentage return on that capital. Council also indicated that boards would aim to run this business on a profitable basis. (House of Commons Official Report 27 November, Written Answers col. 566).

1985 *Roads and the Utilities Review of the Public Utilities Street Works Act 1950* Report to the Secretary of State for Transport the Rt. Hon. Nicholas Ridley MP, of a Committee chaired by Professor Michael R. Horne, Department of Transport, November 1985. Reviewed all aspects of P.U.S.W.A. and the 1974 Model Agreement and specifications in the light of present-day circumstances and

recommended that utilities should become responsible for all the excavation and reinstatement work associated with their activity in the highway. This would include responsibility for meeting the full cost of both excavation and reinstatement and the highway authority should be able to charge to the utility its reasonable costs for making temporary traffic orders and signposting diversions. A broader and more powerful range of measures to be provided to allow the highway authorities to deal with poor reinstatements which would provide "an unambiguous incentive to the management of the utilities to achieve good reinstatements of the highway".

1985 At *Hinkley Point "B" A.G.R.* station 8 tons of CO_2 escaped from Reactor 3 on 29 November while the station was off-load during maintenance work on a gas circulator. There was no increase in radiation levels.

1985 *First generation by large-scale* high temperature gas-cooled reactor *(H.T.G.R.)*—from the 300 MW THTR 300 in Hamm-Uentrop, owned by Hochtemperatur-Kernkraftwerk, an association of German FR regional and local electric utilities. This commercial prototype operated at temperatures up to about 1,000°C by avoiding the metal cladding of fuel elements, using an inert gas instead of CO_2 as the coolant, and maximising the heat transfer capabilities of material in the core. Its 240,000 spherical fuel elements, in a pebble bed arrangement of uranium-thorium oxide were 60 mm. in diameter and coated with pyrolitic carbon to retain the fission products, the graphite acting as both moderator and cladding. The large surface to volume area of the fuel facilitated heat transfer to the coolant which, with the use of high refractory graphite in the core structure, enabled high-thermal densities to be obtained. Because of the high operating temperature of the fuel element surfaces a chemically inert coolant gas was necessary. Helium was selected on grounds of cost, availability, heat transfer properties, low neutron absorption, suitability for purification and stability when irradiated. The reactor fuel comprised a highly enriched uranium fissile component and a thorium fertile component.

1985 *First wave power station* commissioned—at Toftestallen near Bergen, Norway—of tapered channel design (Tapchan). Waves entering the channel grow in height as they travel through a narrowing cross section of the channel. Ultimately they overflow the channel's wall into a "high basin" then flow through a conventional low head Kaplan turbine back into the sea. Installed capacity was 350 kW, generating costs 4p/kWh. A second 500 kW prototype on the same site—of the oscillating water column design developed at Queen's University, Belfast was also completed in 1985.

1985 *External Financing Limit* set for E.S.I. in England and Wales was a repayment of £1,128M during 1986/7.

1985 *Oil prices plummet*—from December the price of oil fell as O.P.E.C. countries endeavoured to increase free market share—from $25/bbl in December, it was below $10/bbl by the spring of 1986. At dollar price of about $17/bbl and below, oil firing for generation was cheaper than that using British coal.

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OERSTED
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Plate 1 In 1600 William Gilbert published the results of his elegant experiments on lodestone magnetism (De Magnete, Magneticisque corporibus et de Magno Magnete Tellure, Physiologia Nova) and was able to establish the fundamentals that opposite poles attract and like poles repel. Luigi Galvani noted that a violent twitching occured in the leg of a frog when a copper wire was connected to a leg muscle and a silver or iron wire to the corresponding nerve and the free ends of the two wires were joined. His results were published in 1791 (De Viribus Electricitatis in Motu Musculari Commentarius) and investigated by Alessandro Volta who after eight years of research assembled in 1800 a "pile" of pairs of silver and zinc plates separated by moist paste board obtained an electric shock by touching the first silver plate and the last zinc plate. His primary battery provided the first continuous current and in April 1820 Hans Christian Oersted found that a pivoted magnetic needle tended to move in the presence of a "live" conductor–news of his discovery reached England in October 1820. Michael Faraday thought that it ought to be possible to observe similar motion in a freely mounted conductor when it was brought into the field of a fixed magnet and was able to demonstrate this in September 1821. If electricity could be converted into mechanical energy then it should be possible to convert mechanical energy into electricity and in 1831 Faraday showed that a changing magnetic intensity produced an electric current in a conductor and an electric current was produced in a conductor that is moved across the lines of force of a magnet.
(I.E.E. Journal, November 1931)

Plate 2 Frictional electrical machine used by Sir Humphry Davy.
(Courtesy The Royal Institution of Great Britain)

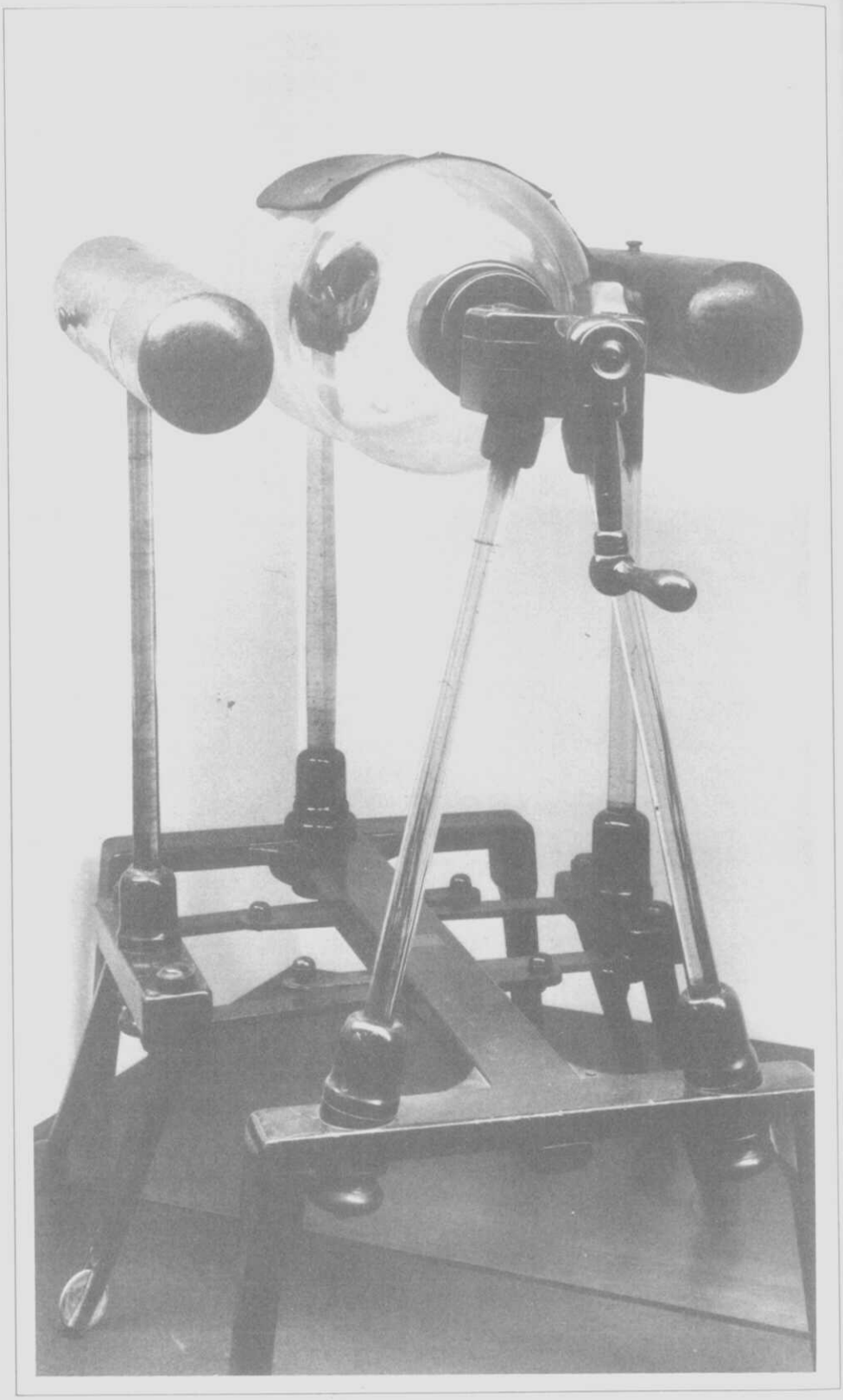


Plate 3 *Westminster Bridge lighted by the new lime light* ("The Illustrated London News", 19 May 1860)

A contemporary account in "The Illustrated London News" of 10 May 1860

"For the past few weeks the completed portion of the new Westminster-bridge has been lighted by the new lime light, and has presented a brilliant appearance. There are ten lights on the bridge—about one-third of the number of the old gas-lights. The light is of a pure white colour and of dazzling brilliancy, making all the old gas-burners in the proximity appear as dull as though they were burning in the bright sunlight. . . . A single jet of the lime light of medium size is equivalent to 40 argand, or 80 fish-tail gas-burners, or to 400 wax candles; and its intensity and brilliancy may be increased by augmenting the quantity of gases supplied. As compared with the illuminating power of common gas, a single jet, consuming four cubic feet of the mixed gases of hydrogen and oxygen, is said to be equal in illuminating power to that obtained from 400 ft. of ordinary gas. The mode in which the light is produced is by the combustion of lime under the great heat caused by the flame of the mixed gases. A stream of common gas, which is used instead of pure hydrogen, is conducted through one pipe, and a supply of oxygen is sent through a second one, each being attached to separate gasholders. These pipes terminate near the lamp in one single tube, where the gases are allowed to mix on their way through a curved jet to what may be called the wick of the lamp, which is simply a lump of lime held in close proximity to the mouth of the curved tube by a piece of metal. In lighting the lamp the first step is to direct the stream of hydrogen upon the lime; it is lighted and gives forth a small flame of pale yellow colour. In a few seconds after this pale colour gives place to a deep red, caused by the combustion of the metal calcium in the lime under the great heat of the hydrogen flame. When the lime is in this state the oxygen is turned on, and instantly the bright white light is produced, which will continue as long as the 'wick' remains unconsumed. The supply of lime is kept up by the action of simple clockwork machinery, which raises the material as it burns down at a rate of speed varying according to the progress of the combustion. There is nothing of an expensive character about the light, and with ordinary care it may be used with perfect safety. At present the oxygen gas is conveyed in bags to the pipes, as the gasholders provided are not sufficiently large to contain the quantity required for the night's consumption."

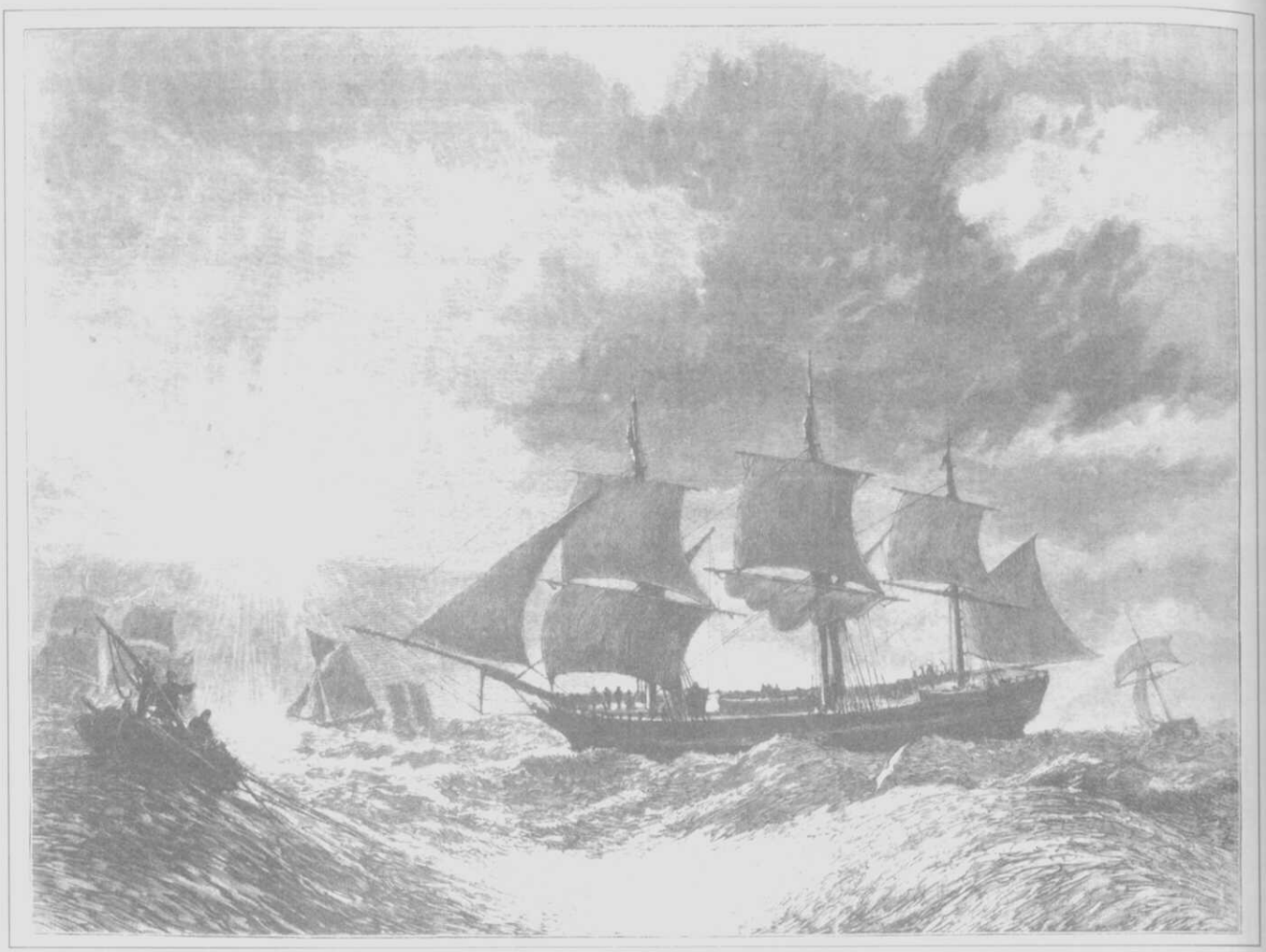


Plate 4 *The electric light at the South Foreland lighthouse* provided by a steam-driven magneto-electric generator– from "The Graphic", 3 February 1872.

La Societé Générale de L'Electricité of Paris was founded in 1853 to develop Professor Nollet's machine to generate current for the electrolysis of water in order to produce hydrogen and oxygen for making lime light. The project was not successful, but the machine was enormously developed by Professor Frederick Hale Holmes and he tried one out in the lighthouse at Blackwall in 1857, and another at South Foreland lighthouse at the end of 1858, at which time the early arc lamps were three times as expensive as oil. Holmes' machines saw service between 1870 and 1900. They weighed three tons and their output was less than 2 kV–but by 1879, at the Lizard lighthouse the cost of electricity was only ½ of the cost of oil. The generators consisted of seven groups of eight fixed compound magnets, between the poles of which rotated six discs, each carrying 16 bobbins equally spaced around the periphery of the disc. Commutators were not fitted and the alternators thus delivered their output in a series of pulses. They were driven by 32 hp Allen engines and provided a light of 1,520 cp. Lighthouses, with their requirement for very powerful lights, provided the best application for arc lighting.

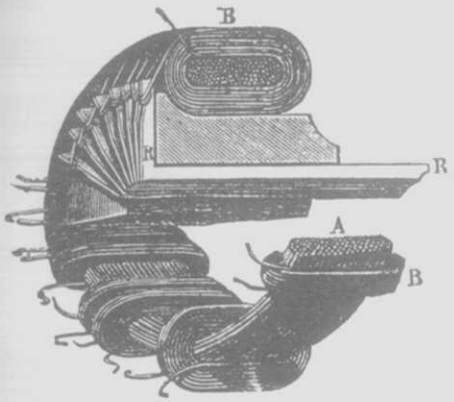
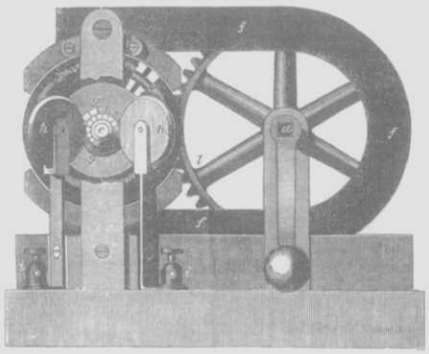


Fig. 1

Fig. 2



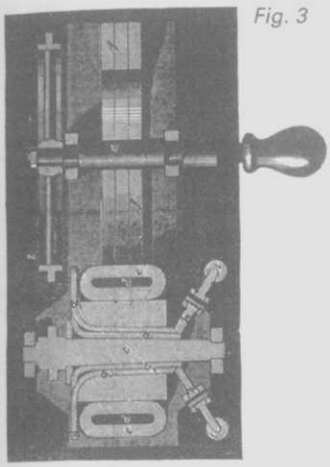


Fig. 3

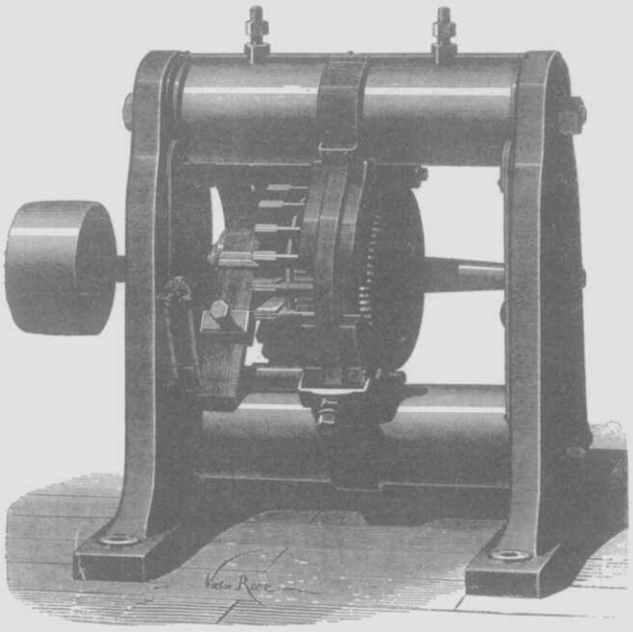


Fig. 4

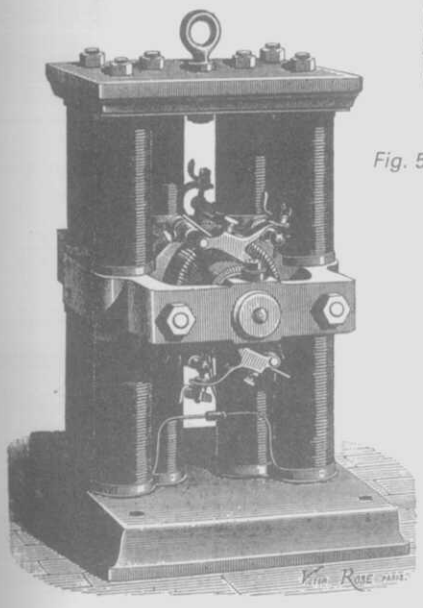


Fig. 5

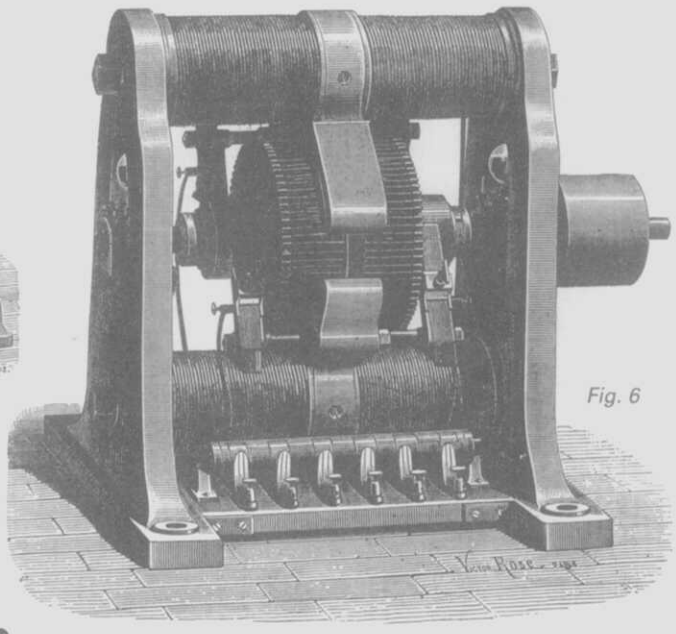


Fig. 6

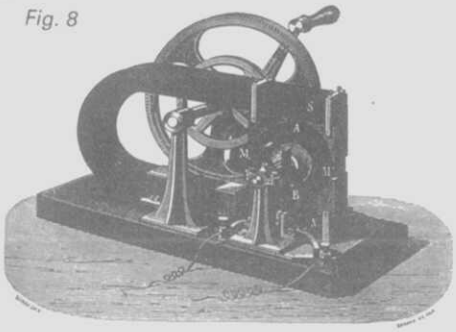


Fig. 8

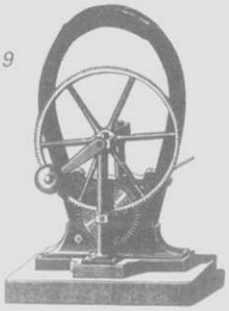


Fig. 9

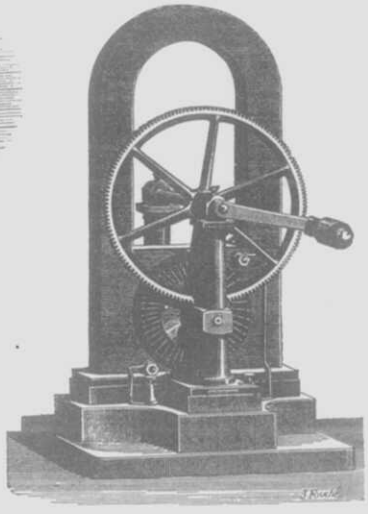
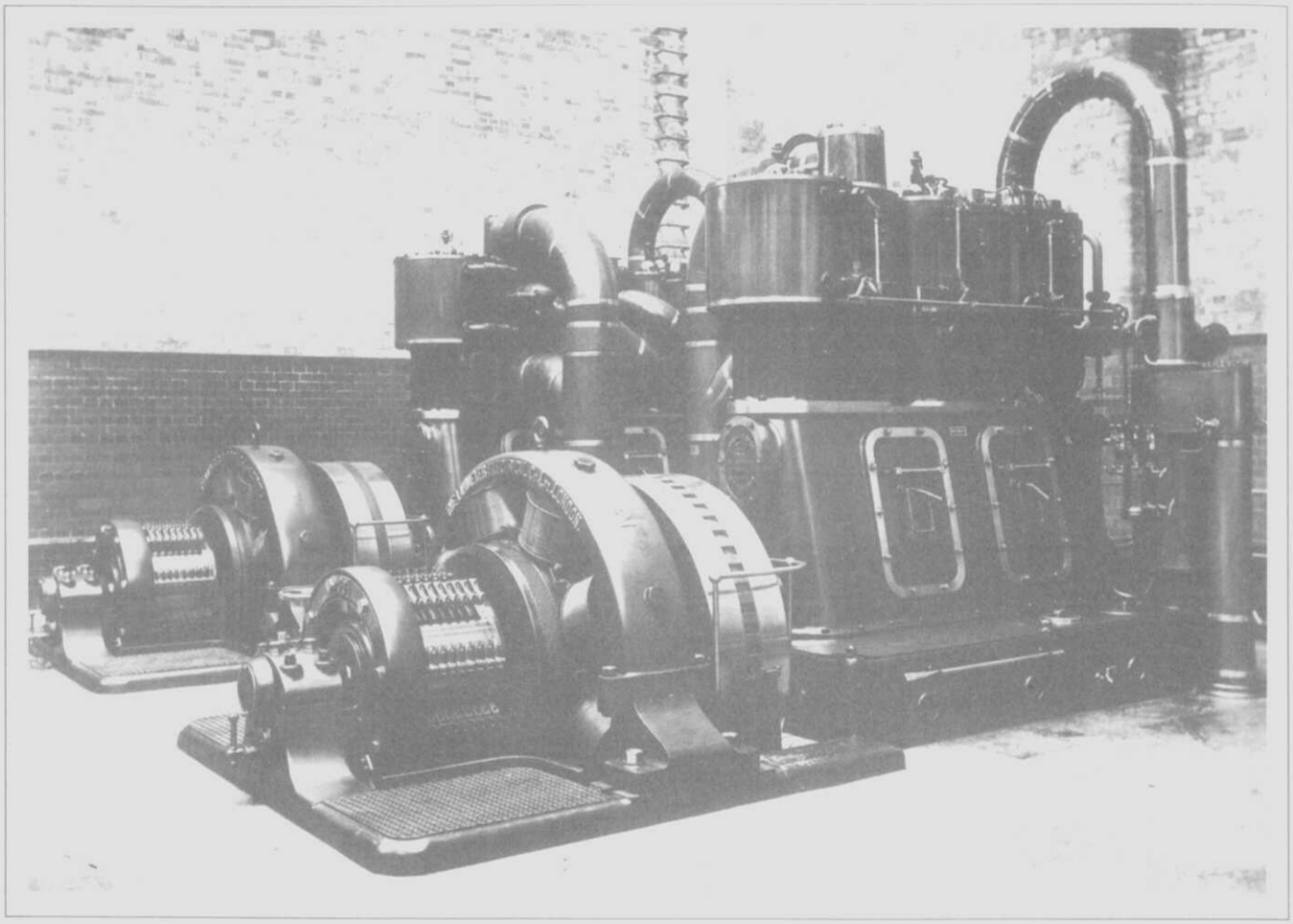


Fig. 7

Plate 5 *Gramme's ring.* Generators of Pixii (1832) and others, such as Nollet's by 1870, obtained induced currents of only very short duration. It was appreciated that if a magnet were moved at constant speed along a lengthy coil encompassing a bar of soft iron (armature) the induced current would last during the whole time of the movement and would preserve a constant intensity. Gramme achieved this by giving the armature a circular form (fig. 1). His machine of 1871 (figs. 2 & 3) rotated the ring on a horizontal spindle between field magnet poles above and below. When the machine was driven by two men a platinum wire 19½ in. long and nearly 0·04 in. in diameter could be heated to incandescence. The rotating armature was divided into three–one part used for supplying an electromagnet. In 1873 Gramme supplied a machine for public trial in the clock tower at Westminster over several months for lighting arc lamps. Sparking at the contact of the metallic brushes and increases in temperature in the ring or in the electromagnets were drawbacks. These problems were overcome in his machine of 1874 which had a single armature and the electromagnet formed part of the circuit. Figure 4 shows a machine constructed for electrotyping–used by printers to reproduce engravings by means of copper blocks. Figure 5 is a 1874 machine for supplying arc lamps, reduced in size with electro-magnets in the form of a triangle instead of a straight line. It produced a normal intensity of 500 Carcel burners. Figure 6 is a later design–the longtitudinal cylinder at the base enabled two distinct currents to be connected together for either quantity or tension and prevented sparking at the collectors. At 900 rpm the light produced was equal to 200 Carcels. Small machines for laboratory and lecture tables had permanent magnets–in fig. 7 horizontal and in fig. 8 vertical. Figure 9 employed an improved magnet by Janim.



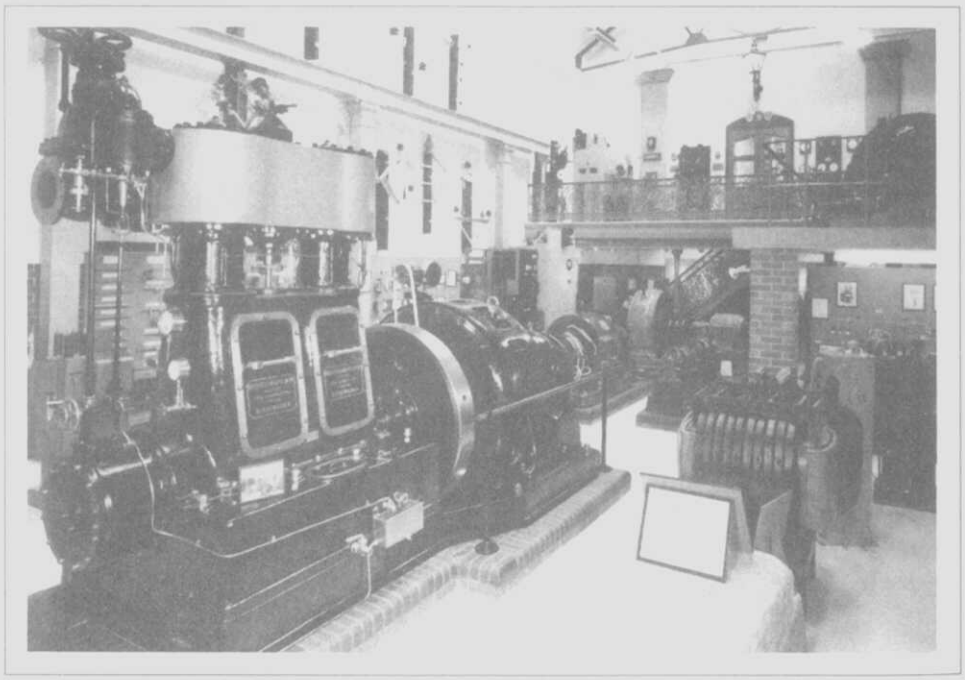
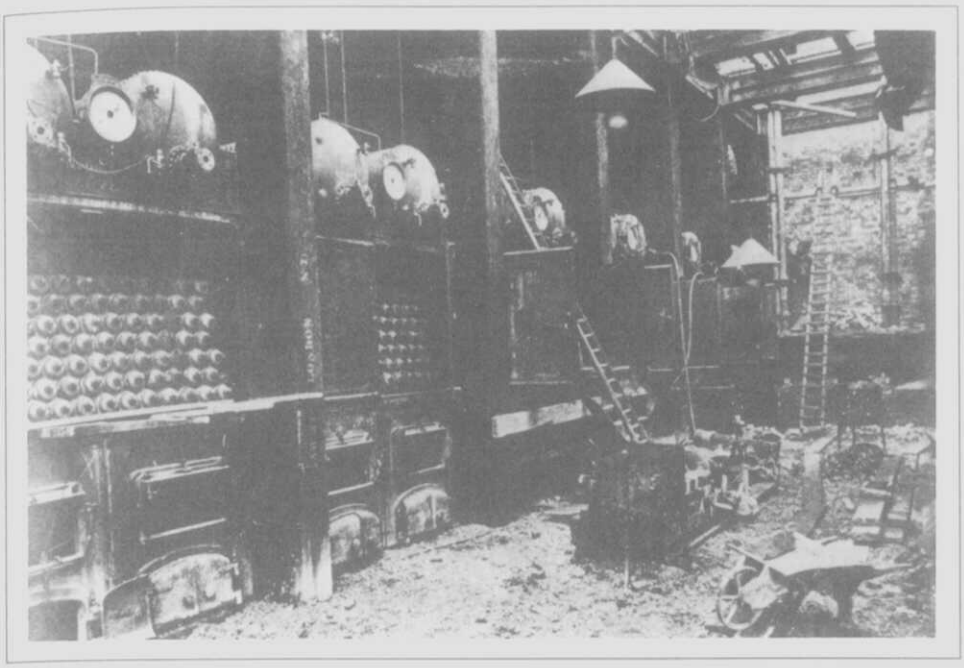


Plate 6 Top–Willans central valve reciprocating engine introduced in the 1880's. Its high rotational characteristics made it particularly suitable for the direct driving of generators, avoiding rope-drive, and this combined with the reliability due to its mechanical perfection, soon gained for it an overwhelming predominance in power station work. For several years it had no real competitor until the Bellis high-speed engine with its advantages of double-acting cylinders and forced lubrication, entered the same field. These engines were not suited for outputs much in excess of 1·5 MW and the demand for larger powers was satisfied by the introduction of the Parsons steam turbine from 1889.
(E.C. Archives)

Right–Bellis and Morcom 300 hp engine driving a G.E.C. 200 kW generating set (c. 1913). Now restored and located in the lower gallery at the Southern Electricity Museum, Bargate, Dorset.
(Courtesy Southern Electricity Museum)



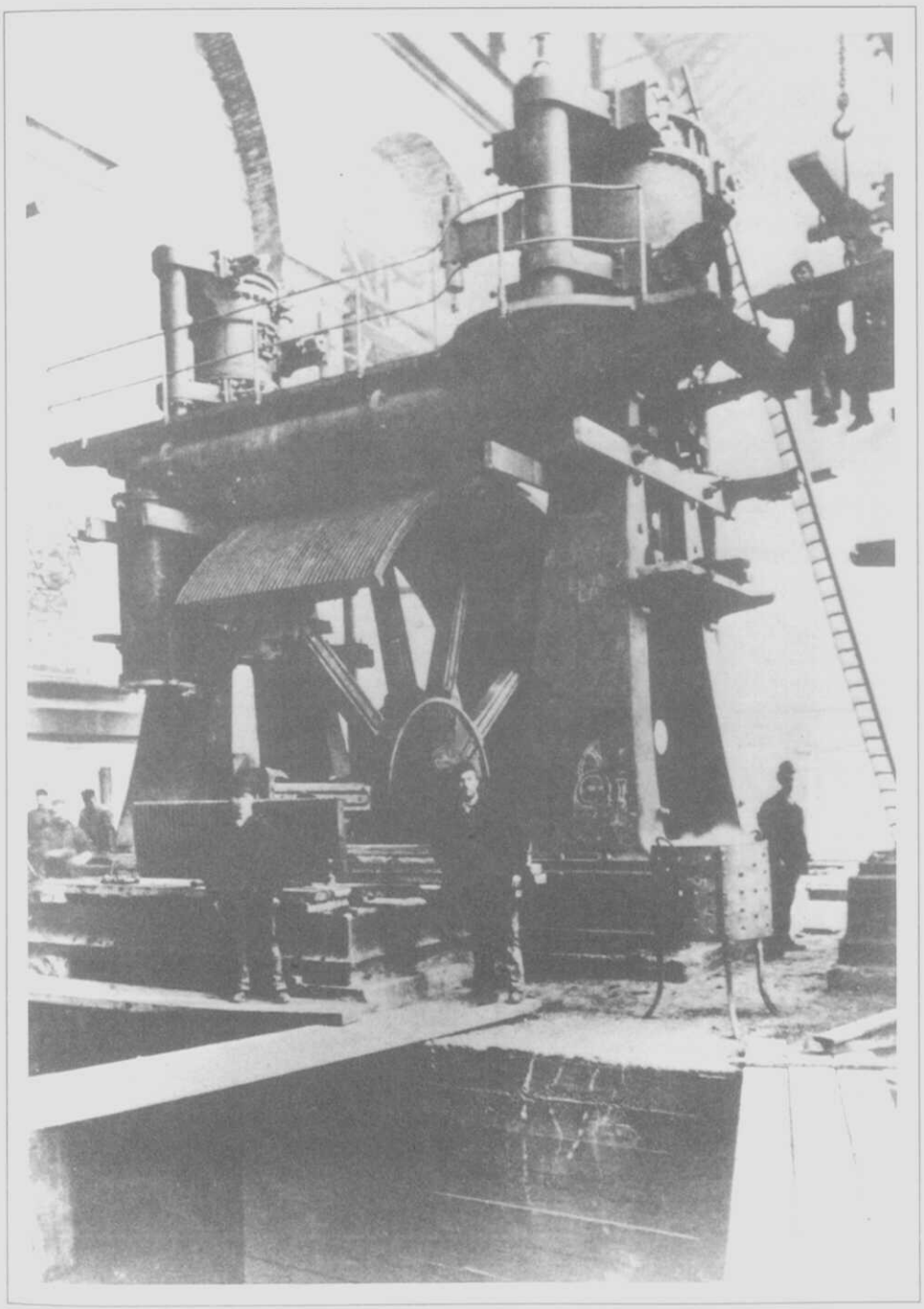


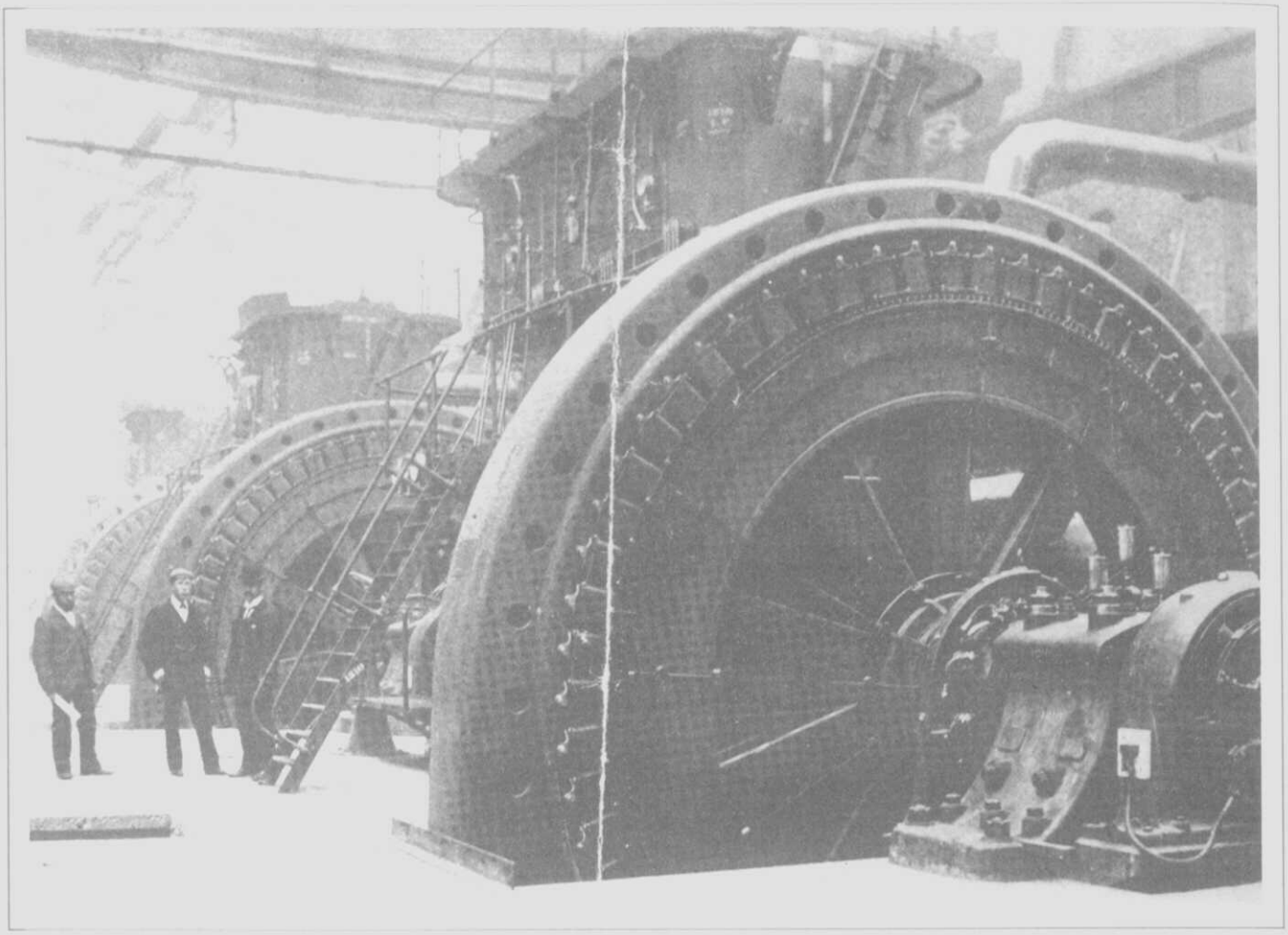
Plate 7 *Deptford Power Station under construction 1889.* Work on site commenced April 1888 and carried on night and day—by midsummer 1889, 24 Babcock and Wilcox boilers with a total steaming capacity of 414 k lb/h had been installed.

Left—B. & W. hand-fired boilers of type W.I.F. (wrought iron front). Power stations needed high pressure and rapid steaming capacity—requirements which the water-tube type successfully met. By October 1889 engines and alternators of 3,000 hp were operating and the provision of regular supplies began on 16 February 1891.

Below—Compound vertical inverted 1,500 hp Corliss marine-type engine by Hick Hargreaves. Diameters of cylinders were 28 in. and 56 in., and the stroke 4 ft. Running speed was 78 rpm with drive by means of 40 × 5 in. cotton ropes fitted to the drum/flywheel of each machine—22 ft. in diameter and weighing 60 tons.
(E.C. Archives)

Plate 8 Single phase "hedgehog" transformer c. 1891. This open core design sparked off a "battle" of transformer design, "closed" v "open".
(Courtesy Crompton Parkinson Archives)

Plate 9 Cable laying in The Strand by St Clement Danes, 1895.
(Courtesy B.I.C.C.)



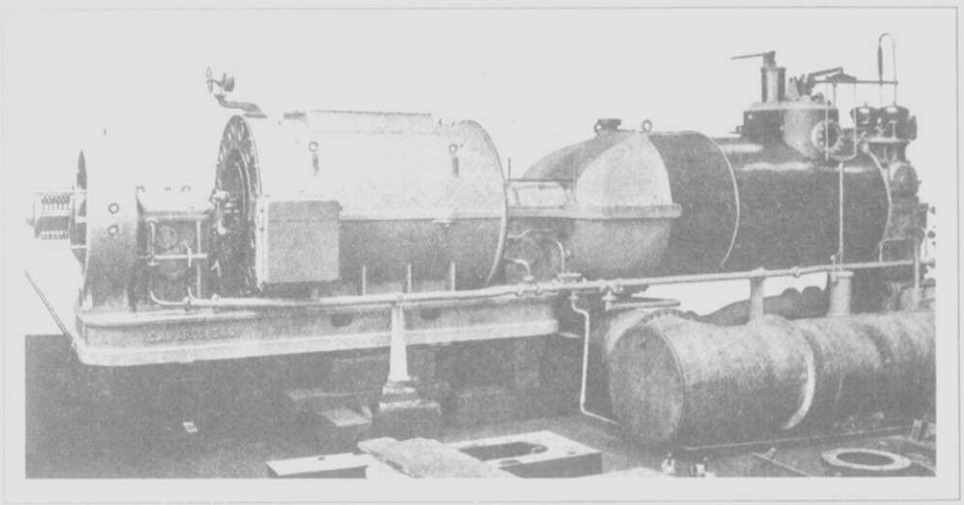
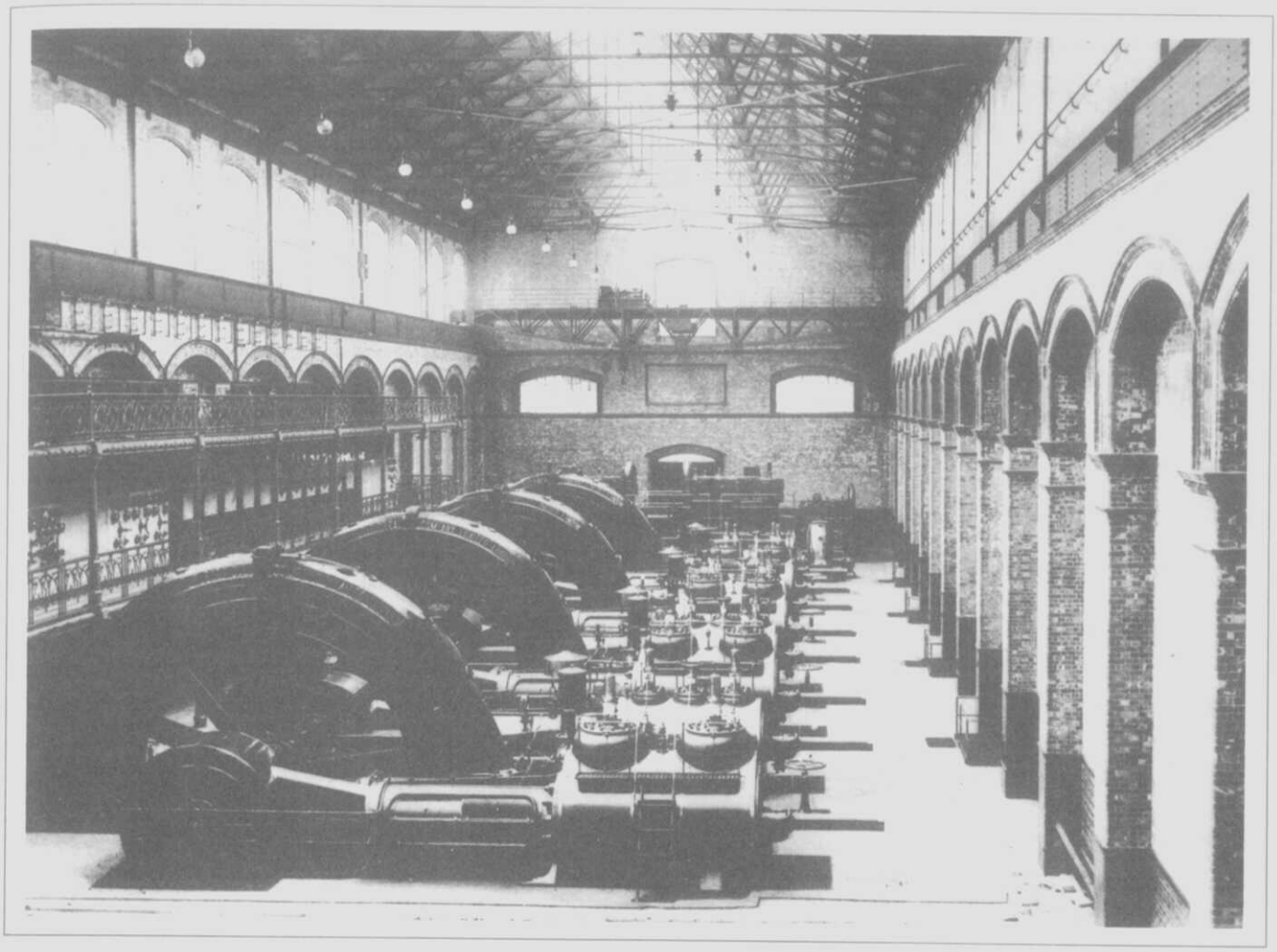


Plate 10 Above: *Willesden (Acton Lane) Electricity Works of the Metropolitan Electric Supply Company*—engine house at 9 October 1899. The station replaced the Manchester Square, Sardinia Street, Amberley Road, Rathbone Place and Whitehall Court stations. Transmission was over five miles at 10 kV two-phase, 60 Hz, each phase carried by a separate two-core concentric cable having the outer conductor earthed at the power station. The three Westinghouse engines were of the enclosed compound vertical marine type, with cylinders 36 in. and 55 in. diameters by 36 in. stroke, running at 120 rpm and each powered a 1·5 MW Westinghouse alternator. (E.C. Archives)

Right—A 2 MW Parsons turbo-alternator set (1904) installed at the *Carville "A" station, Wallsend, of the Newcastle-upon-Tyne Electricity Supply Company Ltd.* It generated at 6·6 kV, three-phase, 40 Hz at 1,200 rpm. Steam conditions at the turbine stop valve were 440 F and 200 lb/in². The set had previously been at Neptune Bank before it was shut down, and moved from Carville to the Philadelphia Station to make way for Parsons sets of 3·5 MW. Carville was designed by Merz and McLellan and was an important breakthrough in station design, with a capital cost of £15/kW compared with the average figure of £40/kW. ("The steam turbine as applied to electrical engineering" by Parsons, Stoney and Martin, I.E.E. Journal Vol. 33, No. 167, 1904)



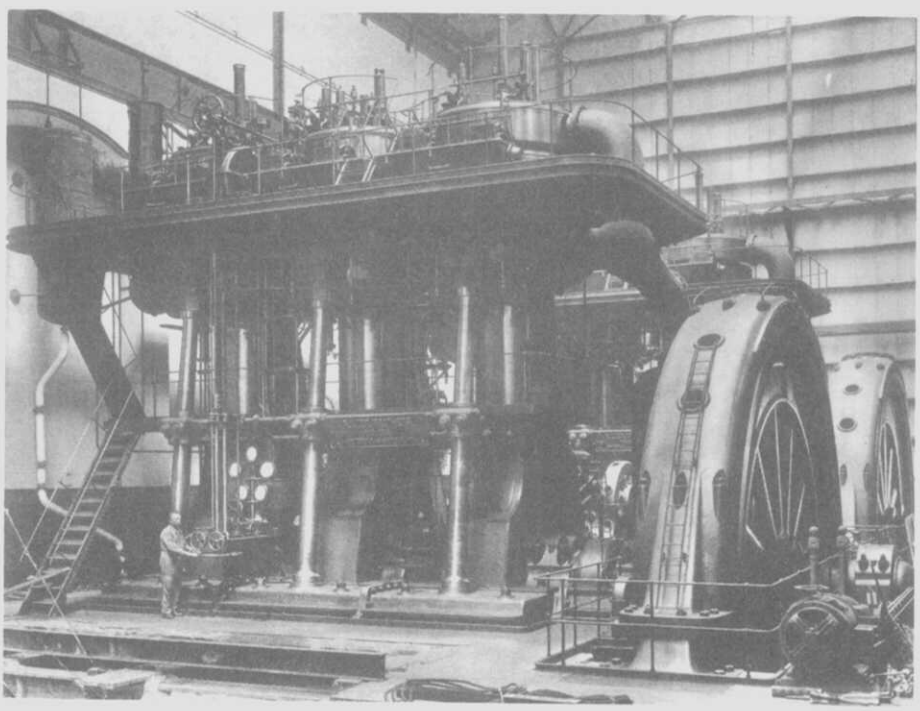


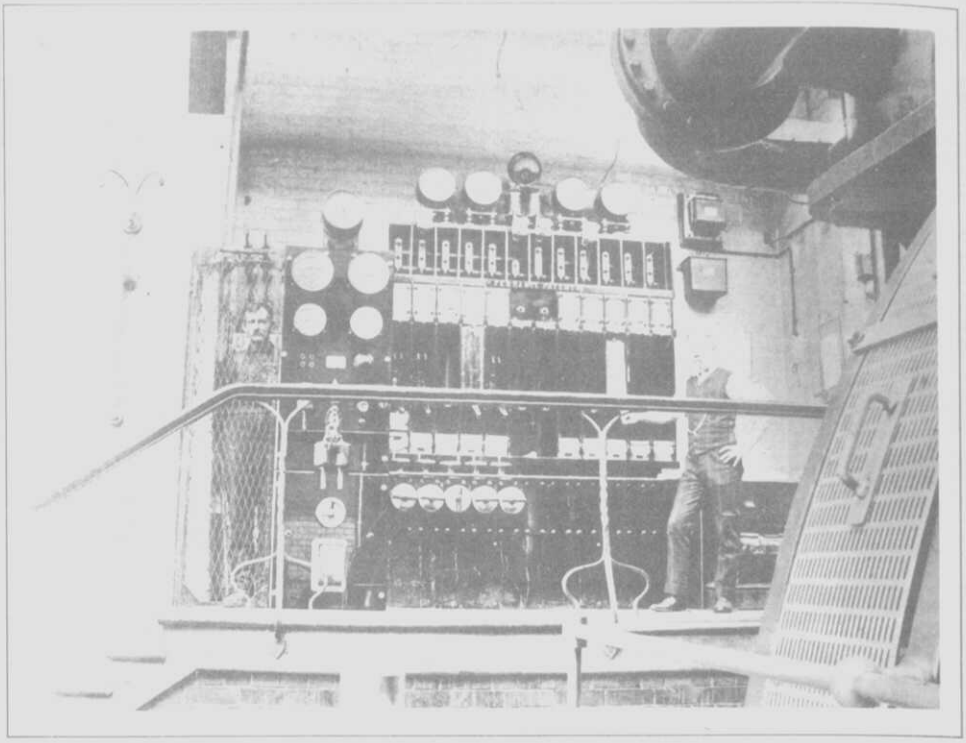
Plate 11 *Bow generating station* of the Charing Cross and Strand Electricity Supply Corporation Ltd.–engine room 1905.

Above–four 1·6 MW (2,500 hp) horizontal cross-compound Sulzer engines with Lahmeyer flywheel alternators on the centre of the crankshaft.

Left–a pair of 4 MW vertical three-crank compound Sulzer engines driving Lahmeyer alterntors from the end of their crankshafts which were completed in 1904 and 1905. An HP cylinder 50¼ in. in diameter was located between two LP cylinders 70⅞ in. in diameter, all with a stroke of 51¼ in. The engines reached 33 ft. 4 in. above floor level and weighed 450 tons each without the alternator. The plant ran at 83·3 rpm.
(E.C. Archives)

Plate 12 Right–Switchboard for 330 kW PS at Watford 1897. Plant comprised three Raworth universal engines coupled direct to Mordey inductor alternators.

Below–Nos. 5 & 6 boilers at Walthamstow showing bunker-fed travelling grates c. 1925. Seven Babcock & Wilcox boilers steamed 14·1 MW of plant in nine sets–the largest 5 MW. (E.C. Archives)



* First Position.

* Second Position.

Plate 13 Left–some of the earliest official illustrations dealing with treatment for electric shock from a Second Interim Report of the Department Committee appointed to inquire into and report upon "Certain Miscellaneous Dangerous Trades: Electrical Generating Works" H.M.S.O. C-8522, 1897. (E.C. Archives)

CURATIVE ELECTRICITY.

TO THE EDITOR OF THE ELECTRICIAN.

SIR: I was very pleased to find in last week's *Electrician* a reply to your article on the above subject. I should have replied myself, only I felt sure some one better known and more able to discuss the subject would take up the cudgels.

I have for five years used electricity as a curative agent—with success—in cases of paralysis, dipsomania, neuralgia, and many other complaints, also for the extraction of lead and mercury.

I quite agree with Drs. Stone and Kilner that the magnetic belts are valueless.—Yours, &c.,

ARCHIBALD REYNALDS.

"The Electrician" April, 1882

Mr. J. Lovell
c/o Mr. Scholes

104 Bradford Rd.
Dewsbury
May 26th, 04

Dear Sir

Will you please send me a character for the time I was with you. I am making application for another situation, this place is a proper deathtrap. Trusting you will oblige I remain yours

I remain
Yours J. Lovell

P.S. I hope you are getting on all right with your new Driver.

Left–A letter dated 24 May, 1904 from Mr L. Lovell to J. P. Crowther, Resident Engineer, Electric Light Works, Worksop District Council (Notts) Lighting. The works had three Scott & Mountain vertical high-speed compound enclosed engines, coupled direct to three Scott & Mountain multipolar dynamos. Steam was provided from two Danks Lancashire boilers. (E.C. Archives)

"Dear Sir
Will you please send me a character for the time I was with you. I am making application for another situation, this place is a proper deathtrap. Trusting you will oblige I remain yours . . .
P.S. I hope you are getting on all right with your new Driver."

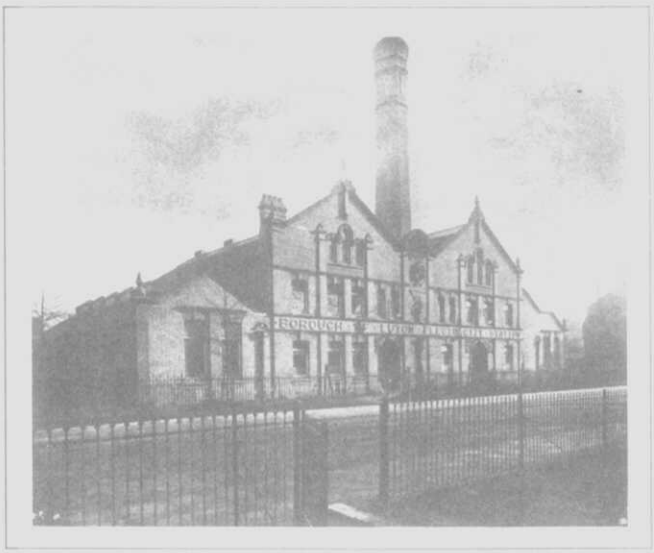


Plate 14 Top–Opening of Borough of Luton Electricity Station 1900. Seated Lord Kelvin. Cecil Rhodes is fifth from left in platform front row. Above left–station exterior. Above right–the engine room showing three Allen engines coupled direct to Allen dynamos and a 45 kW steam balancer. Total capacity was 300 kW steamed by two Lancashire boilers.

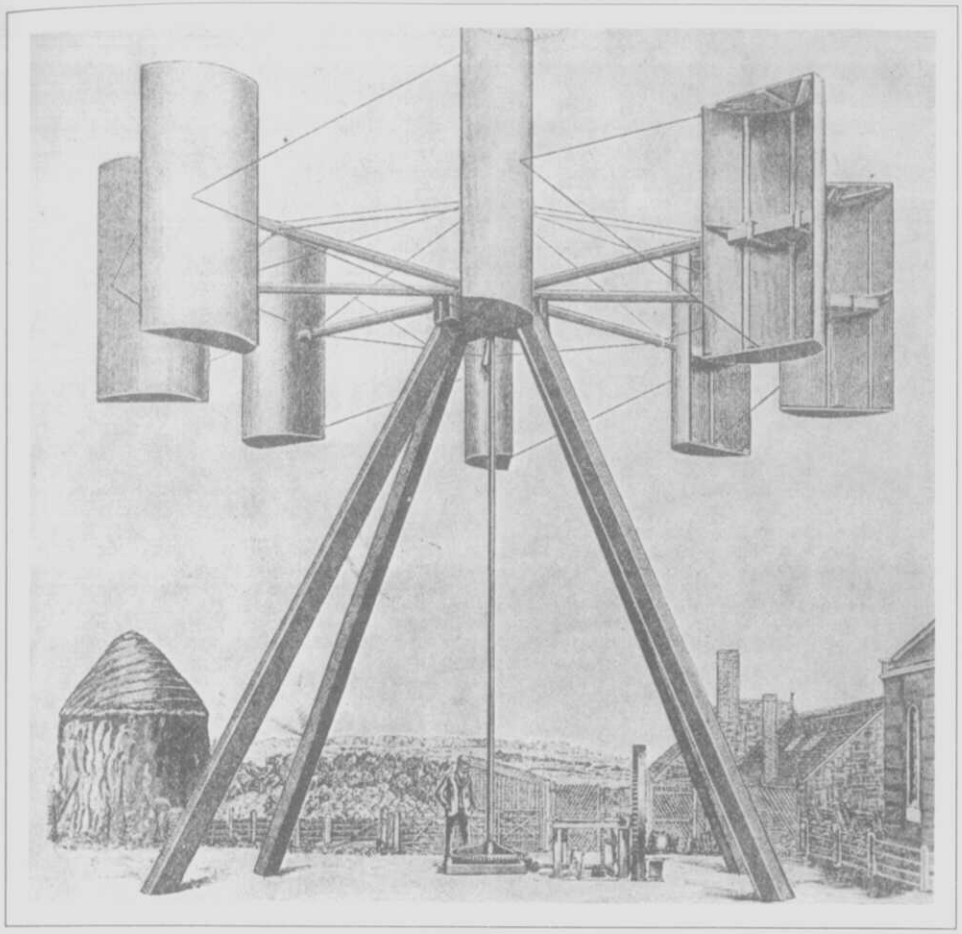
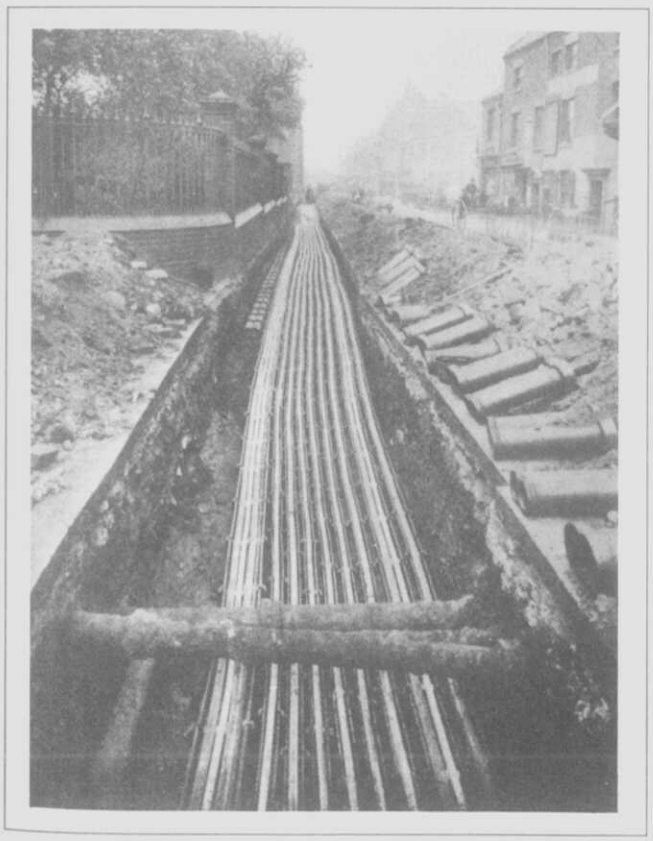


Plate 15 Left – Wind generator constructed by Professor Blyth of Glasgow c. 1900 – adapted from the Robinson anemometer. (From "Electrical Installation of Electric Lighting, Power, Traction and Industrial Electrical Machinery" by Rankin Kennedy, London, The Caxton Publishing Co., 1902).

Below – Underground cable work by Messrs. Callender's Cables and Construction Co. Ltd., for Birmingham Corporation Electric Supply Department 1906. View showing underground cables for lighting and tramway supply laid in earthenware troughs. Left – Ready for running in solid with bitumen. Right – After being run in solid with bitumen and covered with bricks for protection, ready for ground to be filled in and made good.
(From "Souvenir of opening of Summer Lane Generating Station". E.C. Archives)



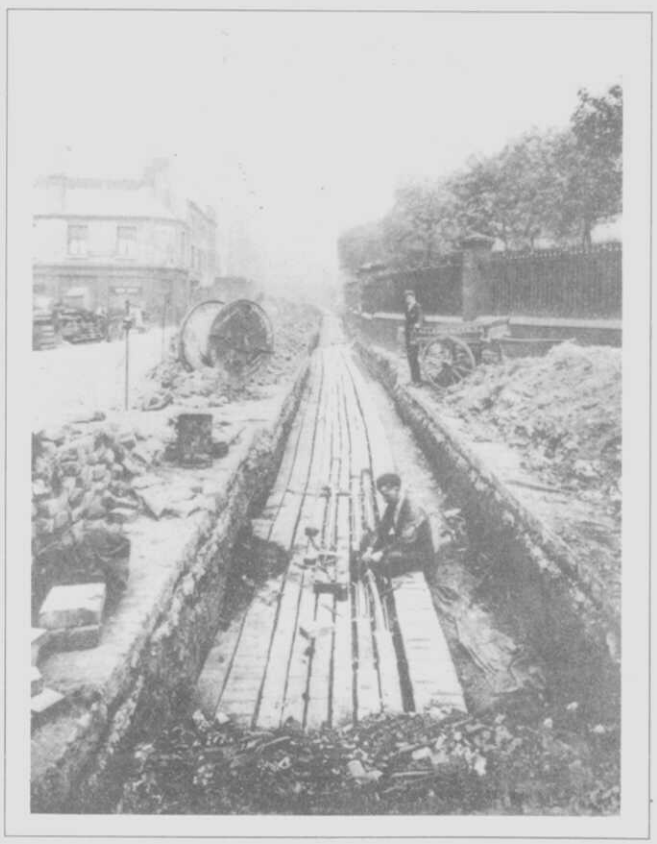
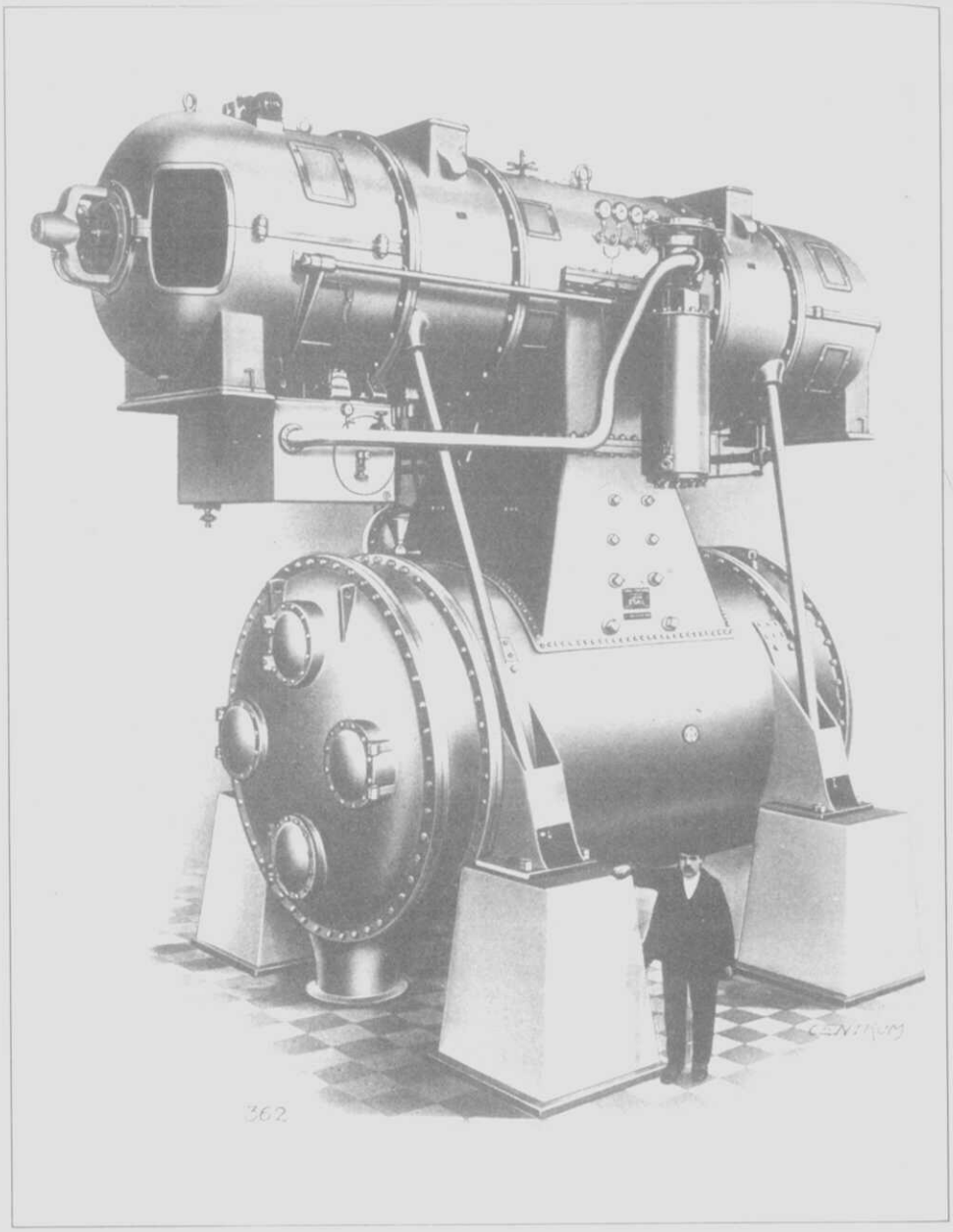
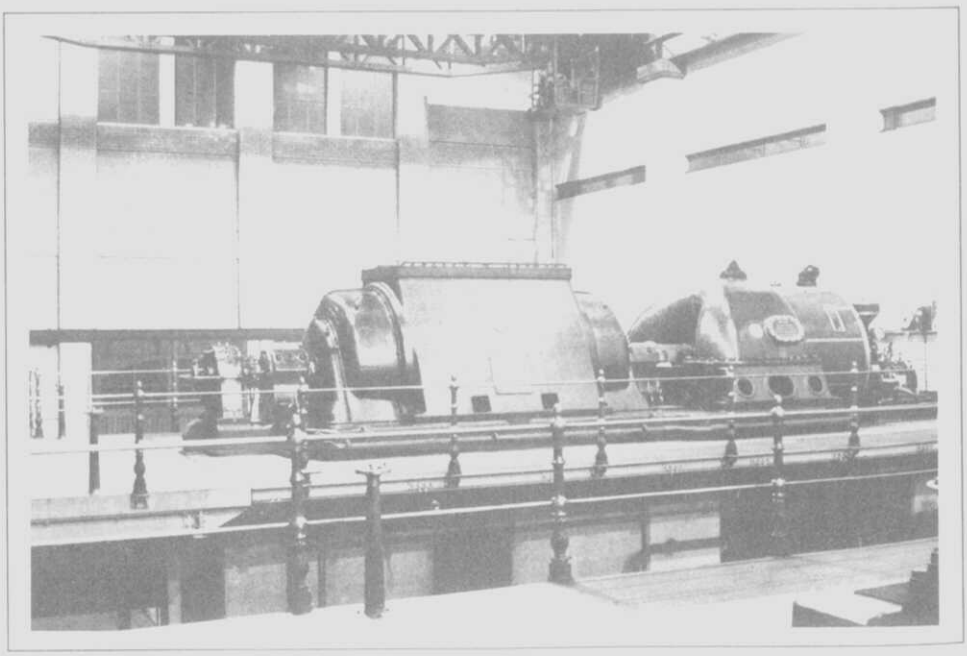


Plate 16 Right–Brush-Ljungstrom 5 MW turbo-alternator installed at the Willesden (Taylors Lane) power house of the North Metropoliton Electric Power Supply Co. in 1917. It was capable of producing 7 MW. In this double rotation radial flow turbine, what is the fixed blading in the Parsons turbine is rotated in the opposite direction to the moving blading at the same rotational speed. The two uncoupled shafts were kept uniform in speed by their generators at either end being in parallel and mutually balancing. Ljungstrom developed the concept and completed his first turbine in 1910 and a 1 MW version was installed at Willesden in 1915. The sets were manufactured in Britain by the Brush Electrical Engineering Co. Ltd. and the largest made was 50 MW which comissioned at Brighton "A" in December 1947; its steam conditions were 650 lb/in^2 and 850°F. The last to commission was in 1956–a 30 MW set at Doncaster. The design was not capable of meeting the requirements for very large sets up to 660 MW.

Below–No. 6 set at Back o' th' Bank station of Bolton Corporation Electric Supply as at 23 April 1938. This 12·5 MW English Electric Co. set commissioned in October 1923 and was in service until March 1979. Steam conditions were 200 lb/in^2, 538°F. It is being preserved in the Electricity Gallery at the Greater Manchester Museum of Science and Industry which is located on the historic Liverpool Road Station site, Liverpool Road, Castlefield, Manchester.
(E.C. Archives)





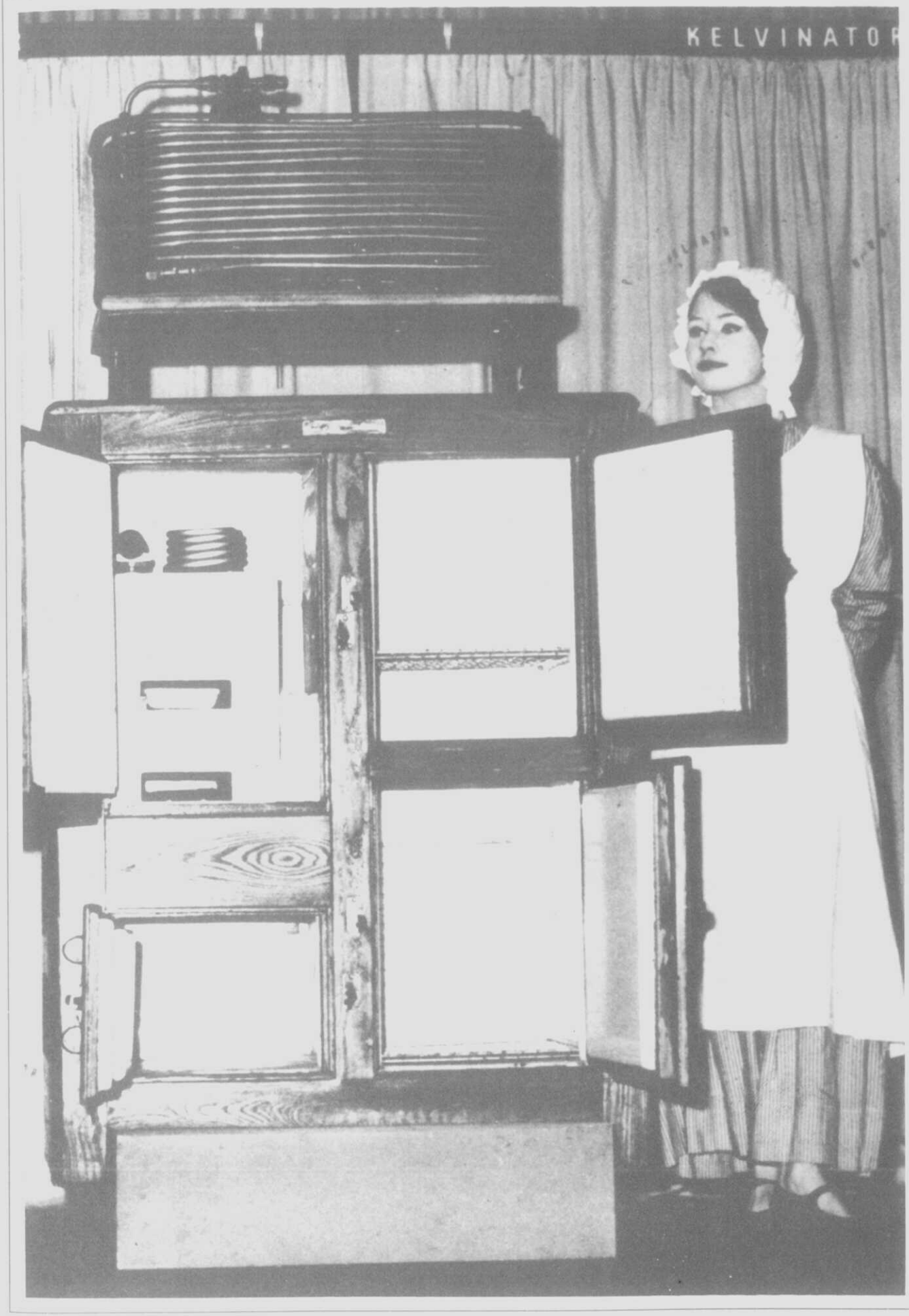


Plate 17 1914 Domestic refrigerator.
(Courtesy Electrical Association for Women)

Plate 18 British Electrical Development Association (E.D.A.) promotional publicity c. 1919–1922. Foot of page–Extract from published transcript of a speech by Hugo Hirst on Marconi's 2LO station. (E.C. Archives)

Everything electrical will make a house a home
Leaving restless husbands little wish at nights to roam.
Electric lights with pretty shades improve a wifey's looks.
Cooking is an art which she no longer learns from books.
Touch a little button and the dinner soon is done
Roasting things electricly is really lots of fun
If laundry prices make you frown, a cure you can rely on is
Consists of nothing more than this—your own electric iron.
If the day is damp and dreary and your nerves begin to twitch
Then hurry to the ideal home, that little house in which
You can "keep the home fires burning" by just turning on a switch!


The LAND of BEAUTIFUL REALITY

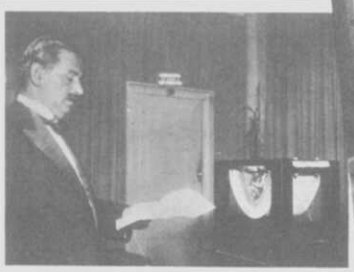
TIRED and worn out, small wonder that so soon as *his* meal was over, she fell fast asleep in the chair. It had been a hard day for Barbara.

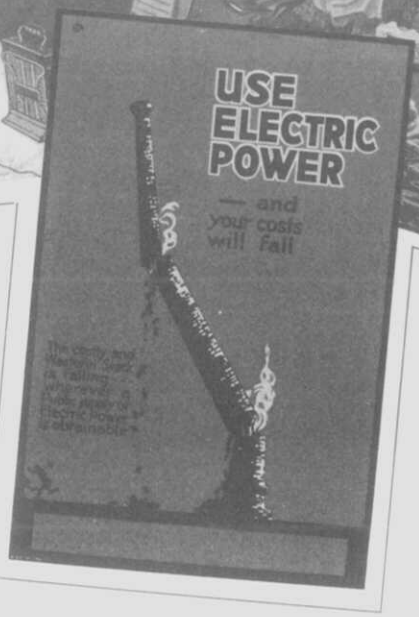
Her wonderful little maid-of-all-work, a gem of a girl that made life possible, had gone away to keep her own home tidy—to cook meals for *her* master.

Barbara slept a sleep borne of fatigue. The grates to clean, the fires to light, the meals to cook, more coal and more coal—it had been a day of endless drudgery.

But, not long after, that one time happy housewife was to arrive in the land of beautiful reality.

It was her birthday. And that adorable man of hers had arranged for a most practical gift. By the aid of *Electricity* he had had all those wearisome grates replaced by handsome fires. Fires that gave heat and good cheer with the turn of a switch. Even the hungry coal-range





A
Broadcast Story
of the
Electrical Industry

by
Mr. Hugo Hirst
(Chairman of the General Electric Co., Ltd.)

I have lately read of an attempt to train domestic servants for their calling. I know of no better course for your servants wishing to be trained than a short engineering course to make them fit for the electric home.

Plate 19 E.D.A. promotional publicity c. 1920's. Bottom left extracted from City of Manchester Electricity Supply Dept. booklet "Domestic Electrical Service". (E.C. Archives)

The Reflection of a Housewif

With an ELECTRIC IRON

The job is done quicker and the clothes last longer

EDA

NO LONGER *tied down by housework*

AT A TOUCH OF THE SWITCH

Spring-clean with **ELECTRICITY**

Fan the flies away in Summer time

E.D.A. 33

You push it along

The Power Station keeps it hot

TAKE the "fag" out of Tuesdays. Don't bend over an ironing table or carry irons to and fro from the kitchen range. Keep fresh instead of getting tired. Sit down to iron—the electric way. With an electric iron you merely push the iron along—the electricity keeps it hot.

HOT WATER WHEN AND WHERE YOU WANT IT

In the bedroom, or bath room, on tea or breakfast table an electric kettle will quickly boil water when ve you need it. Fill the kettle, connect to your nearest lampholder pendant—switch on. That's all—perfectly easy, simple, and clean. Use electricity, the modern means of eliminating work and dirt.

E.D.A. 262

THE ELECTRIC HOUSE

Is an actual home, being occupied by a member of the Corporation Staff and his wife: this lady, a diplômé in Domestic Economy, will be pleased to receive visitors (by appointment—permits issued at St Ann Street Showrooms) on Wednesday and Thursday afternoons between

Electric Table Cookery.

Sunrise in your Bedroom

MAIDS MUST BE INSTRUCTED.

An ordinary sized electric range has, as a rule, three or four rings, an oven, a plate-heater which utilises all waste heat from the oven, and a "broiler" underneath the oven for grilling. It has been claimed that in an average household, cooking practically entirely by electricity, and where care is taken, the usual consumption works out at about one unit per day per person. This, of course, means that servants must be properly instructed in the art of electric cooking. There is a great tendency, for instance, to leave switches on when they are not wanted, and to leave "full" when "low" heat is quite sufficient, merely because there is no indication of flame to remind the careless cook.

Washing Day in the Old Days.

SULKY COPPERS.
GUNPOWDER.
BAD TEMPER.
RUBBING.
SCRUBBING.
-UNCH: HALFWAY THROUGH THE "WASH."
P.M.: STILL WORKING.
P.M.: FATHER COMES HOME.
P.M.: TIRED OUT.

or alternatively

LAUNDRY BILLS

large enough to break the family bank.

Washing Day in the New Day

Thousands of American women (92 per cent. live without servants,) are playing tennis at ten o'clock on washing day. . . . Think! English women, too, who have discovered Electric Washing, lunch at their favourite restaurant at noon. Think again!!

You must see an Electric Washer and convince yourself. It actually does the washing in one-fifth of the time occupied by the old fashioned methods, and at one-tenth of the cost of laundry charges.

Can you really afford to be old fashioned?

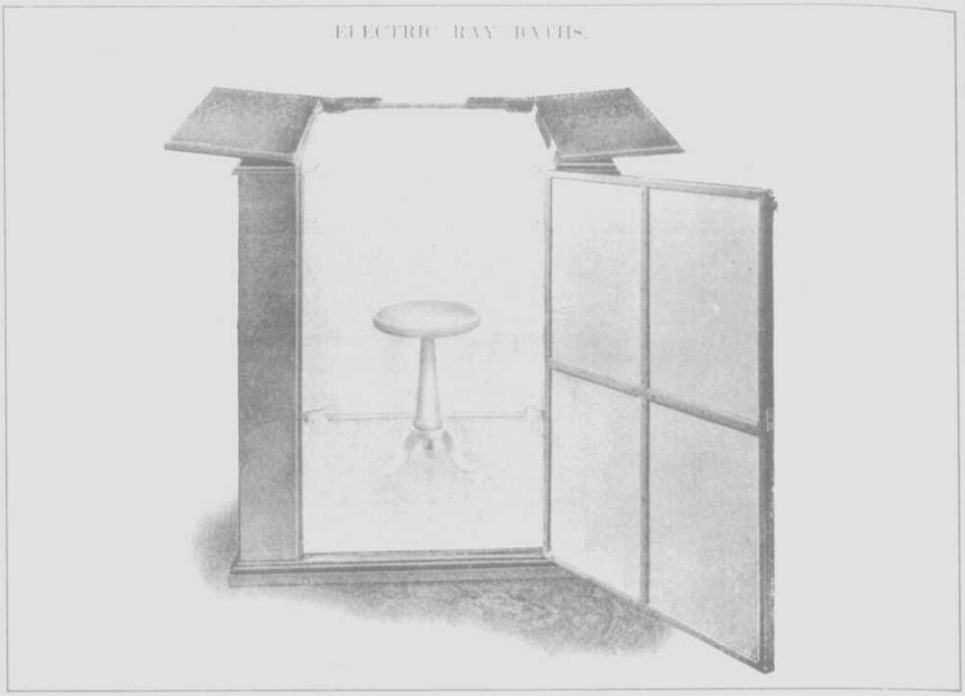
With the Electric Washer no laborious rubbing and soaping is necessary, while a power driven mangle attached to the machine does the wringing.

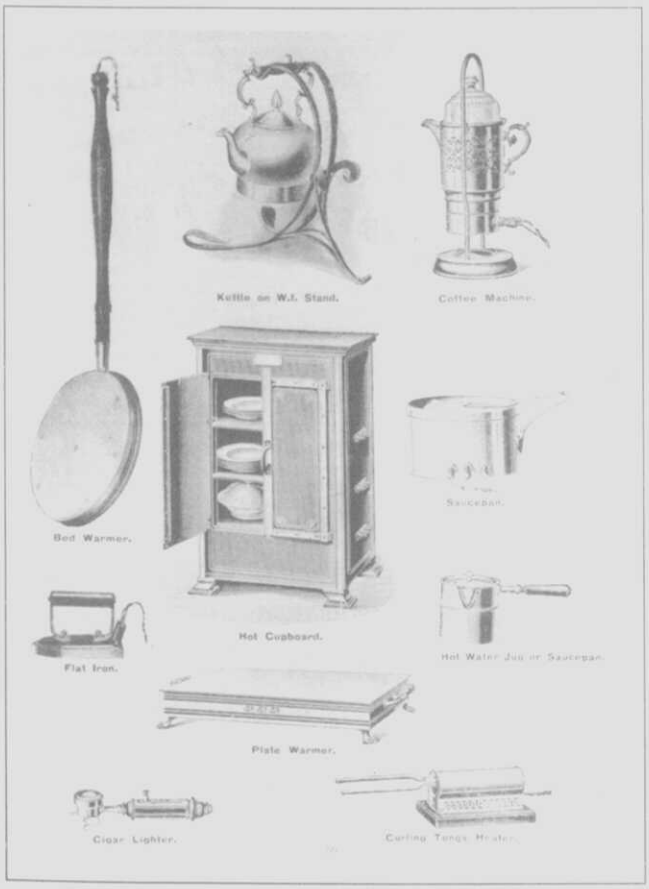
Electric Washing saves time, trouble and money. See "what it costs" on the next page.

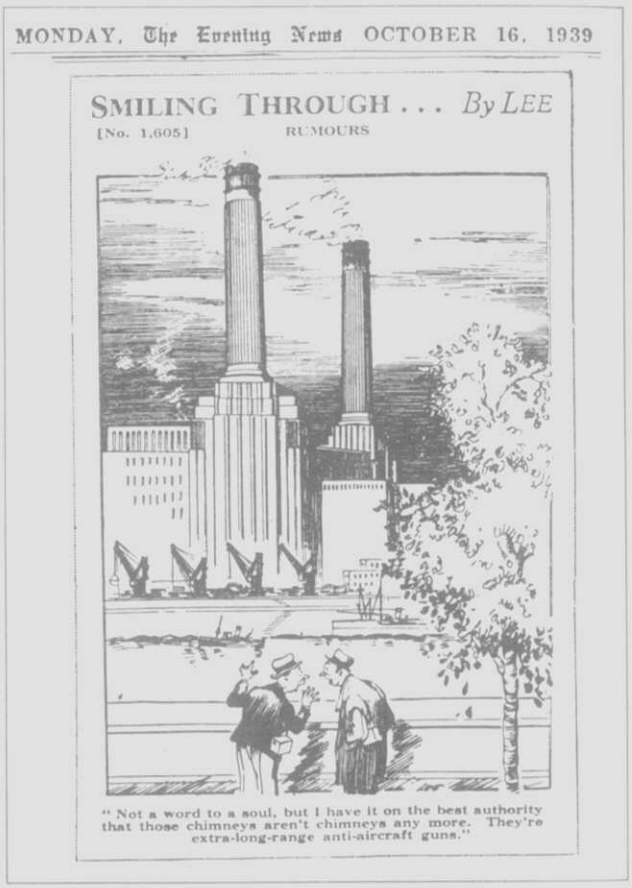
Plate 20 Right–Electric ray bath of 1910 which "can safely be used without the necessity for medical aid, and are especially refreshing after a hard day's hunting".

Below left–Some 1910 electrical appliances. ("Electricity Applied to Light and Power: a treatise on the application of electric current to every phase of country house and estate requirements", by Drake & Gorham Ltd., c. 1910)

Below right–Cartoon by LEE (Courtesy Mail Newspapers plc).







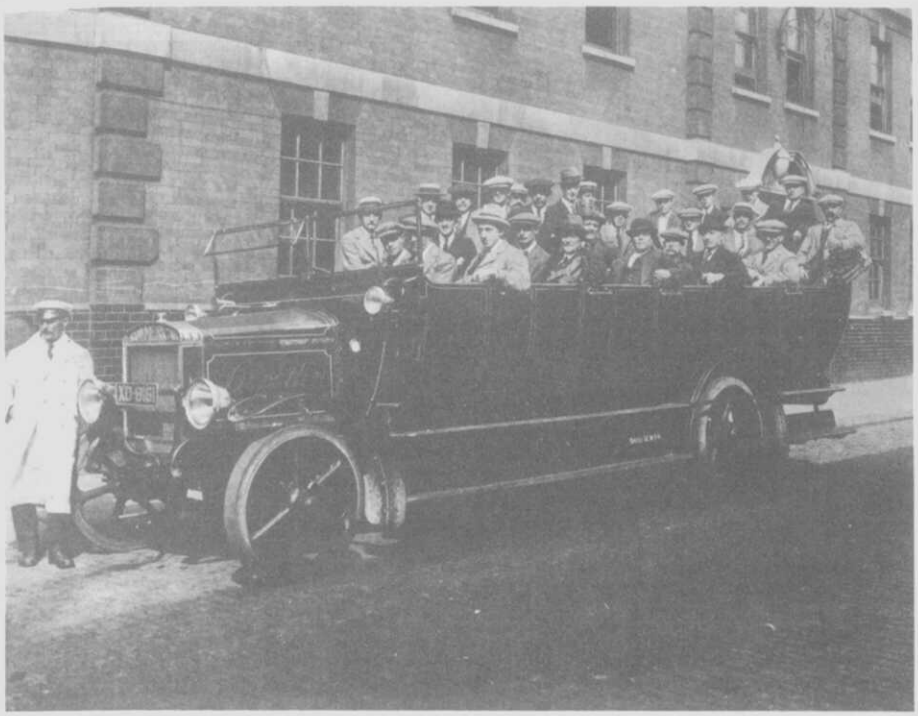


Plate 21 Staff "Annual Beanos". Left–Penrose Street Power Station of Southwark (Metropolitan Borough) Electricity Supply 1926.

Below–Hackney Metropolitan Borough Electric Supply c. 1930.
(E.C Archives)

Plate 22 Appliance design and showroom layout.

Right–Electricity showroom of Sheffield Corporation Lighting 1908.

Below–Edwardes Lane showrooms of Stoke Newington Borough Council Electric Supply 1931. (E.C. Archives)

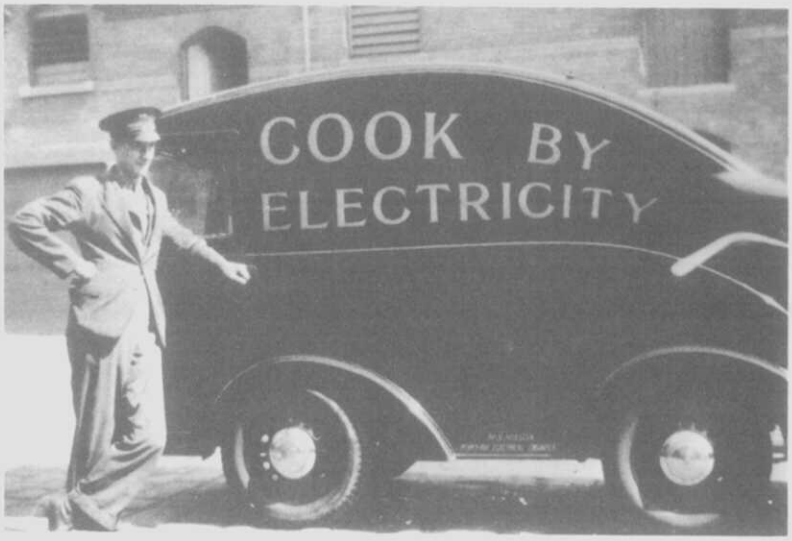
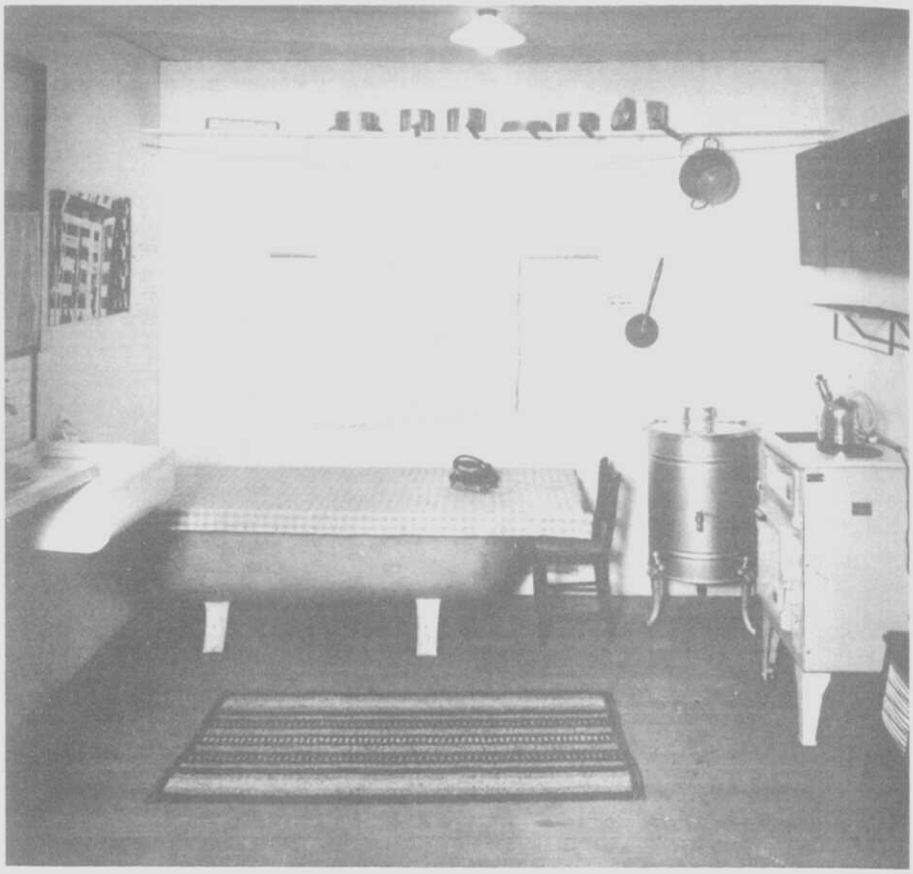


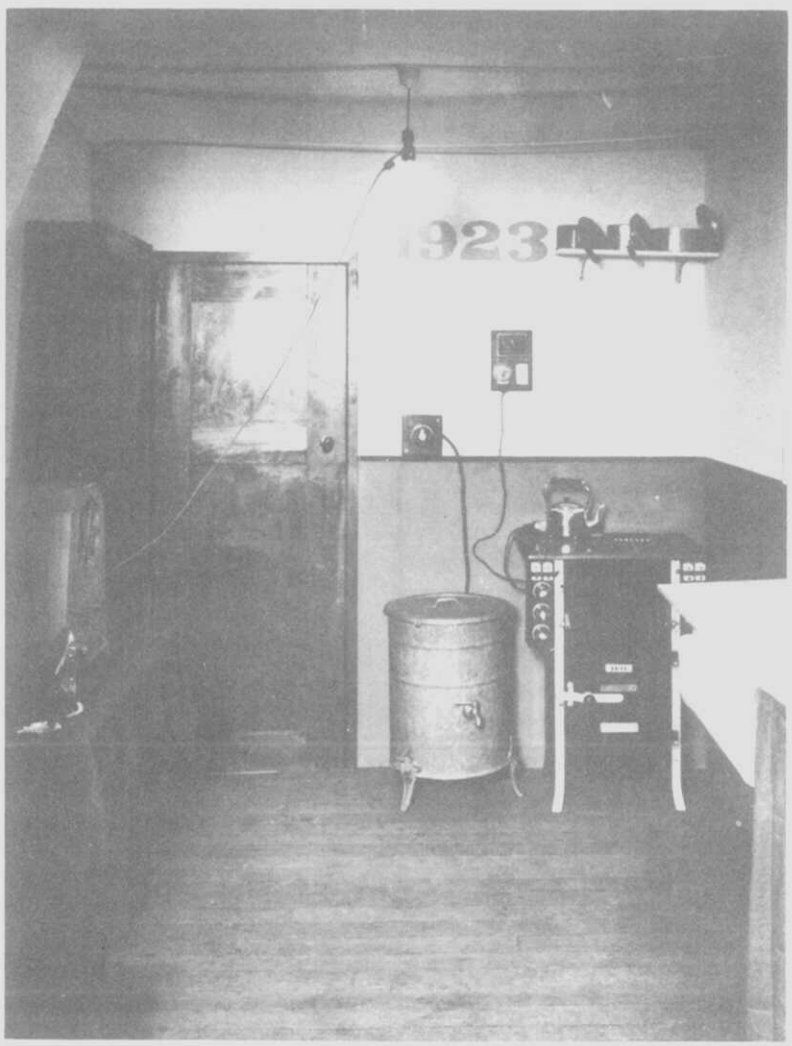
Plate 23 Transport– Wolverhampton Corporation Electric Supply first street lighting ladder; West Ham County Borough undertaking delivering cookers c. early 1930's; Worksop Corporation cooker promotion; Sheffield Corporation early transport arrangements; and early lamp promotion.
(E.C. Archives)

Plate 24 E.A.W. All-electric Working Class Housing Exhibition–December 1934.

Right–kitchen/bathroom on the L.C.C.'s Ossulston Estate, St Pancras. The water is pumped from the wash boiler into the bath.

Below–an all electric kitchen in a block of flats erected in 1923 by the Hackney Disabled Sailors and Soldiers Foundation. (Courtesy Electrical Association for Women)





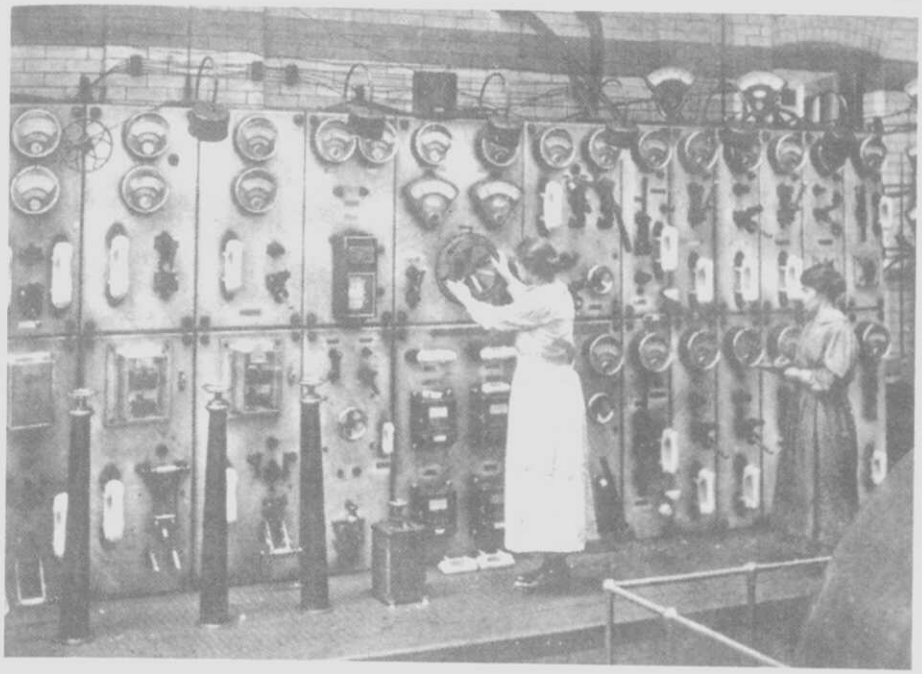


Plate 25 Left–Women operating attendants at switchboard, Burstem Works of City of Stoke-on-Trent Electrical Engineer's Department 1915–18.

Below–Fulham girls on loan to Metropolitan-Vickers Trafford Park Works for taping coils in a stator under construction for Fulham power station to expedite plant delivery. (E.C. Archives)

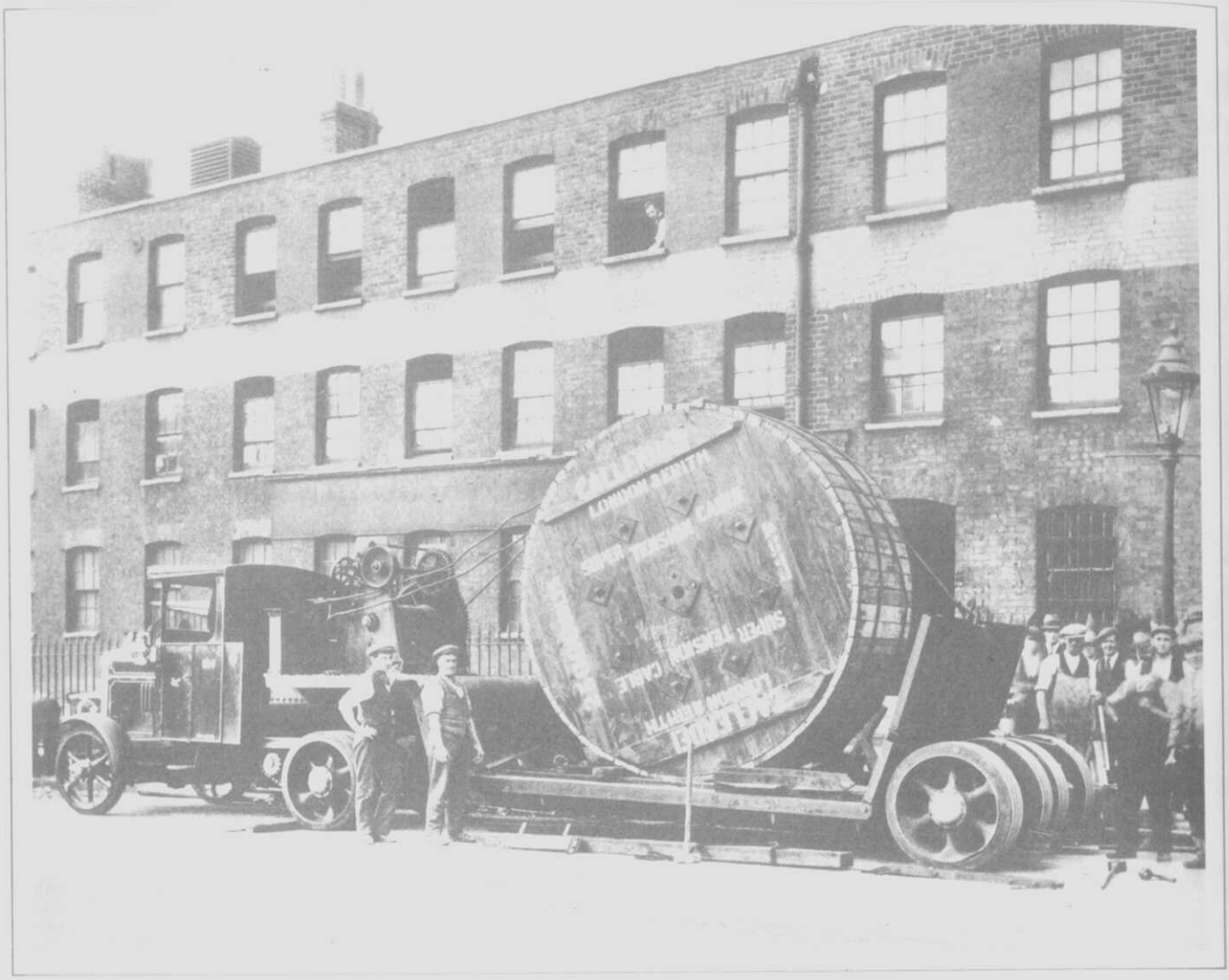
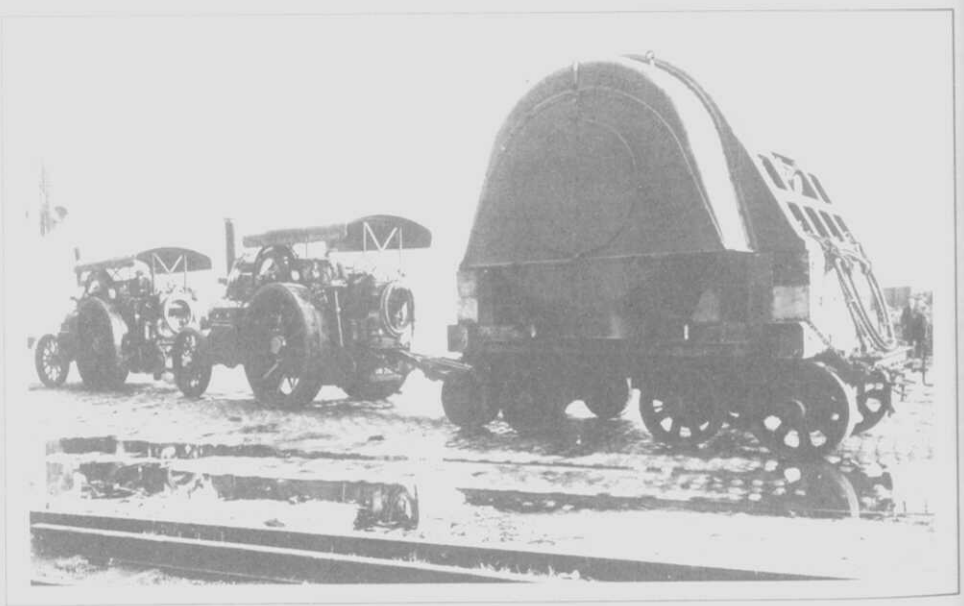
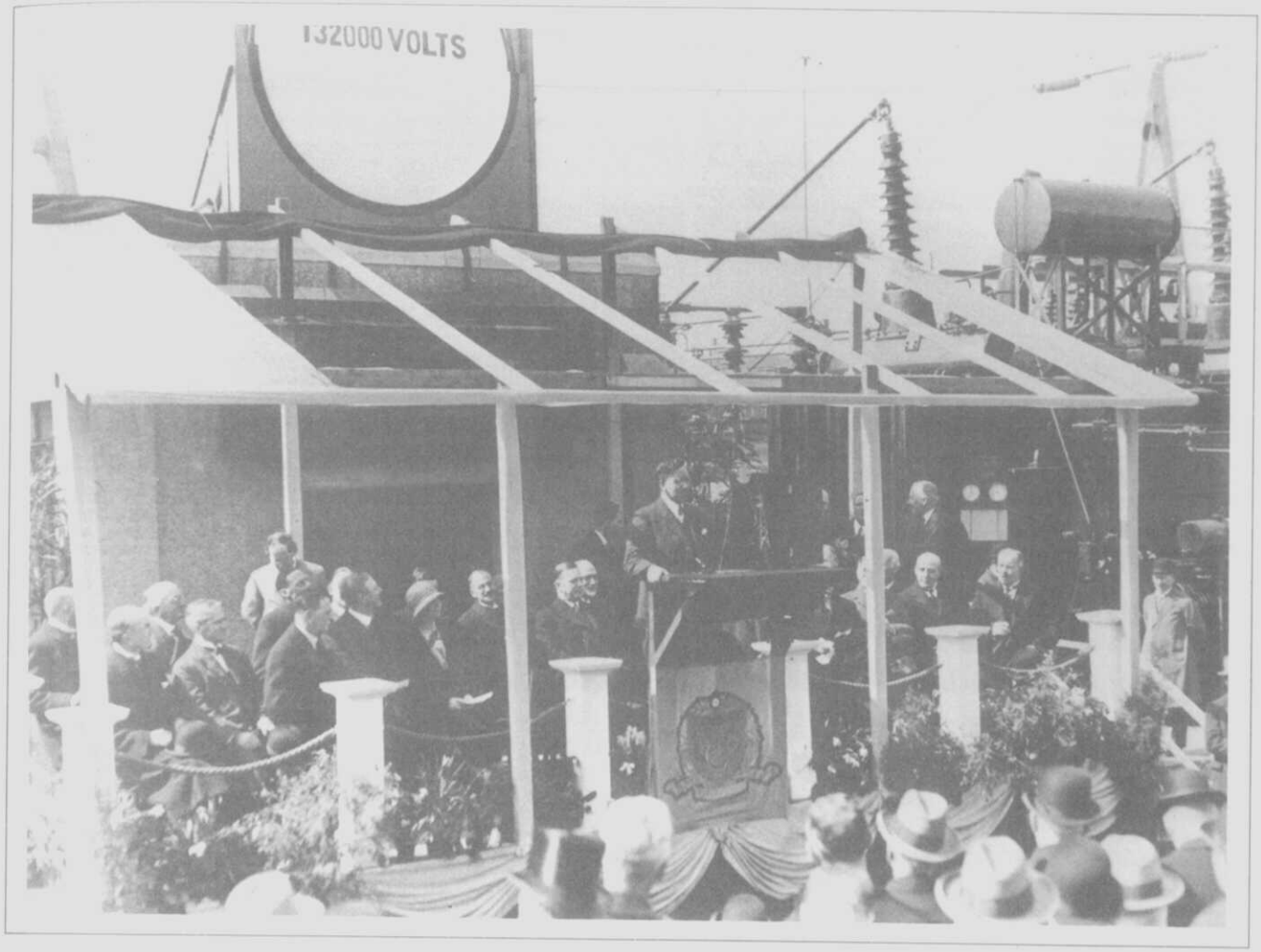


Plate 26 Above—Cable work in progress on Southwark Bridge in the City of London, 28 September 1928. (Courtesy B.T.C.C.)

Right—The Stator of a 23·4 MVA set en route for the Dalmarnock Station which was selected to generate for the C.E.B.'s Central Scotland Grid Scheme. This set was a new extension which commissioned in 1938. (Courtesy C.E.G.B.)





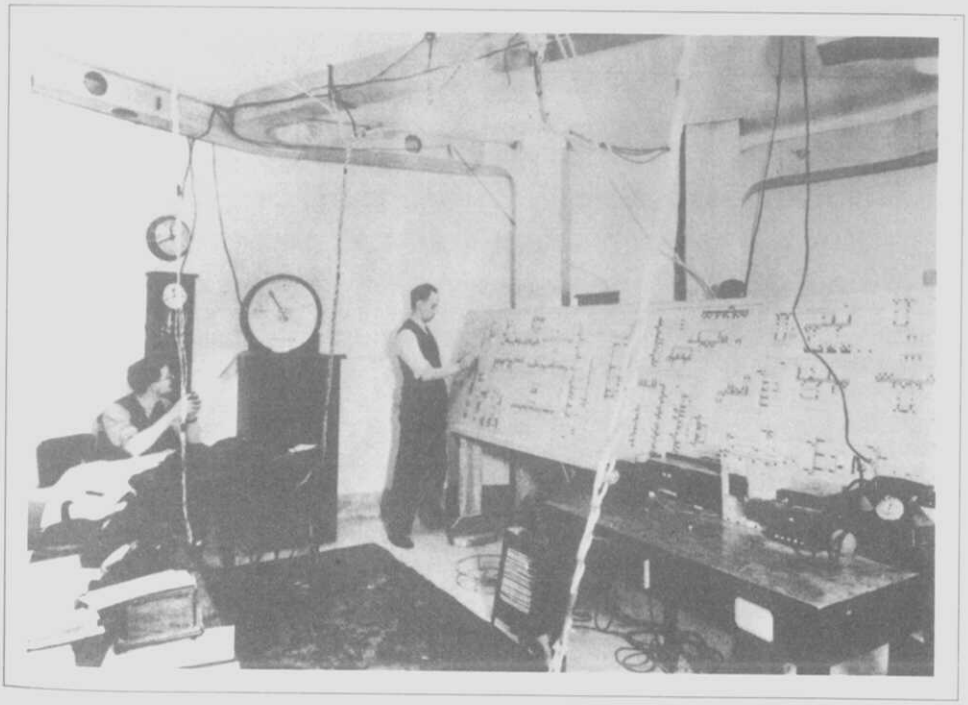


Plate 27 Above–The Central Scotland Electricity Scheme adopted by the Central Electricity Board on 29 June 1927 was the first part of the Grid to commission. It was officially inaugurated on 30 April 1930 by Herbert Morrison, Minister of Transport, switching Edinburgh Corporation's Portobello Power Station onto the 132 kV system through the C.E.B.'s Portobello sub-station by closing a 132 kV oil break switch.
(E.C. Archives)

Left–Early construction view taken while the Grid's wartime national control room was being set up in "The Hole" under the Post Office tube station at Paternoster Square near St Paul's Cathedral. Two disused lift shafts at the tube station were leased from the London Passenger Transport Board and converted into bomb-proof control premises.
(Courtesy C.E.G.B.)

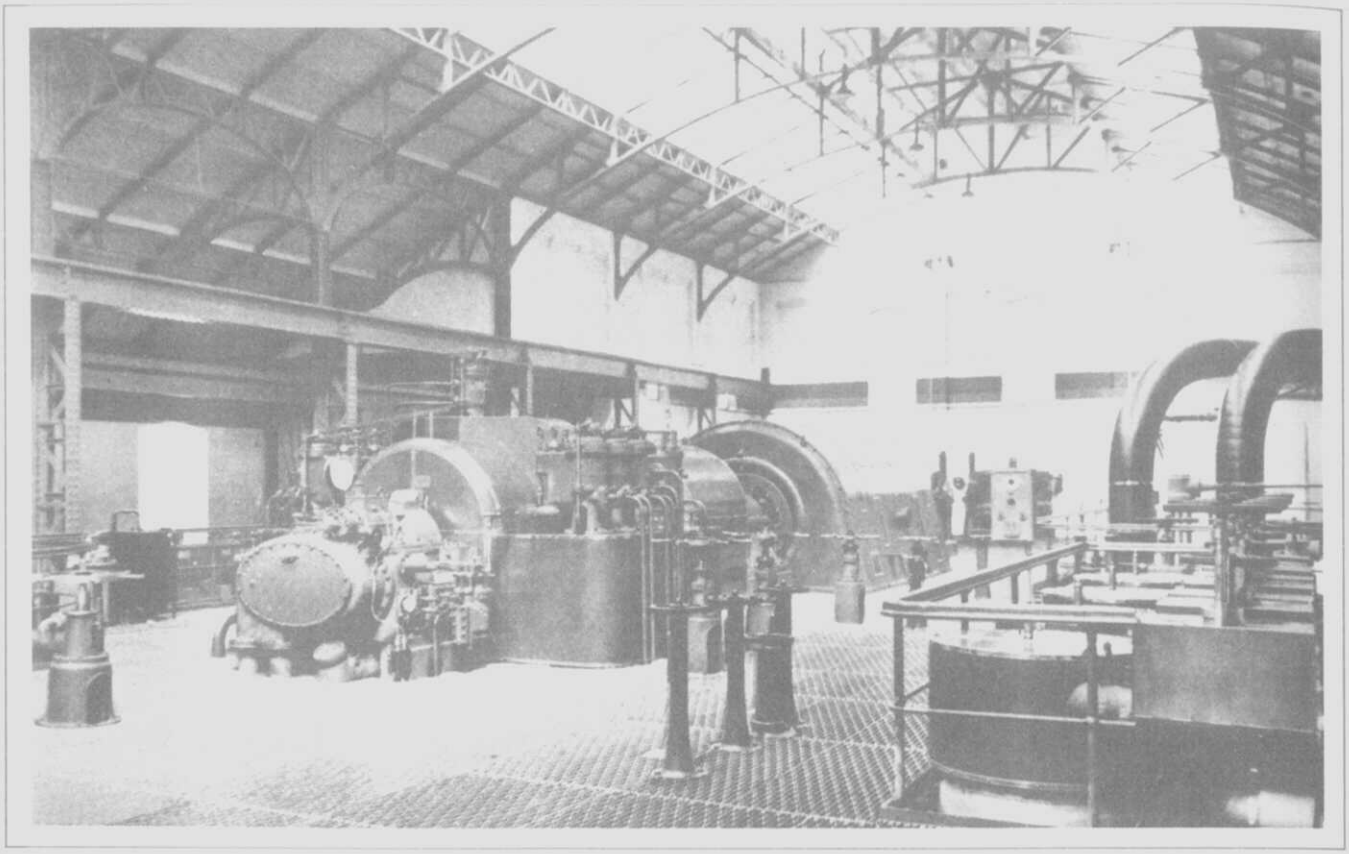
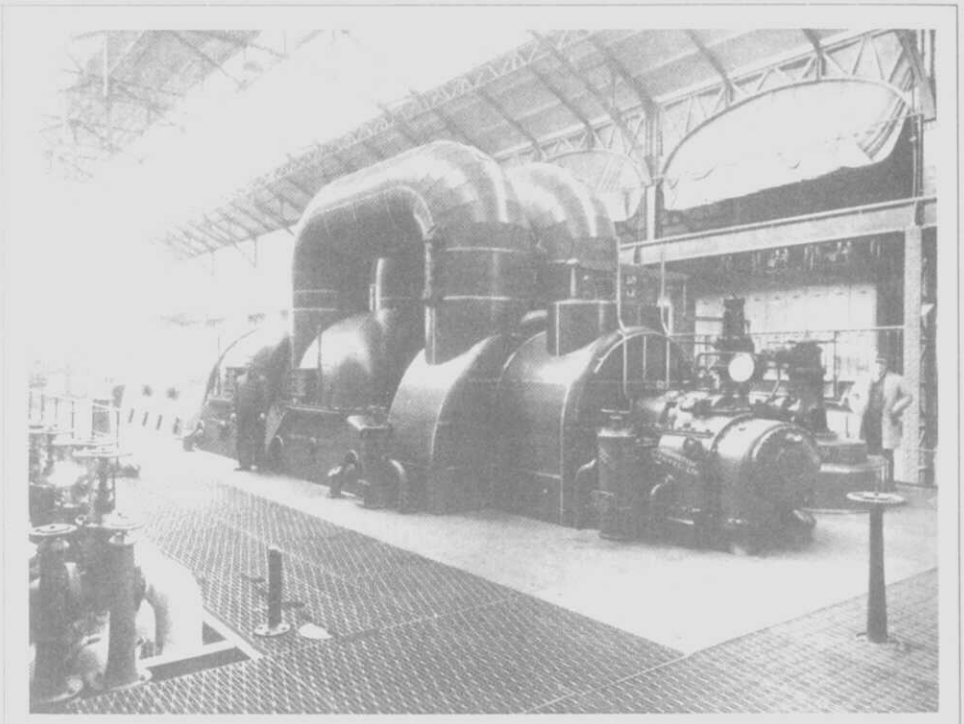
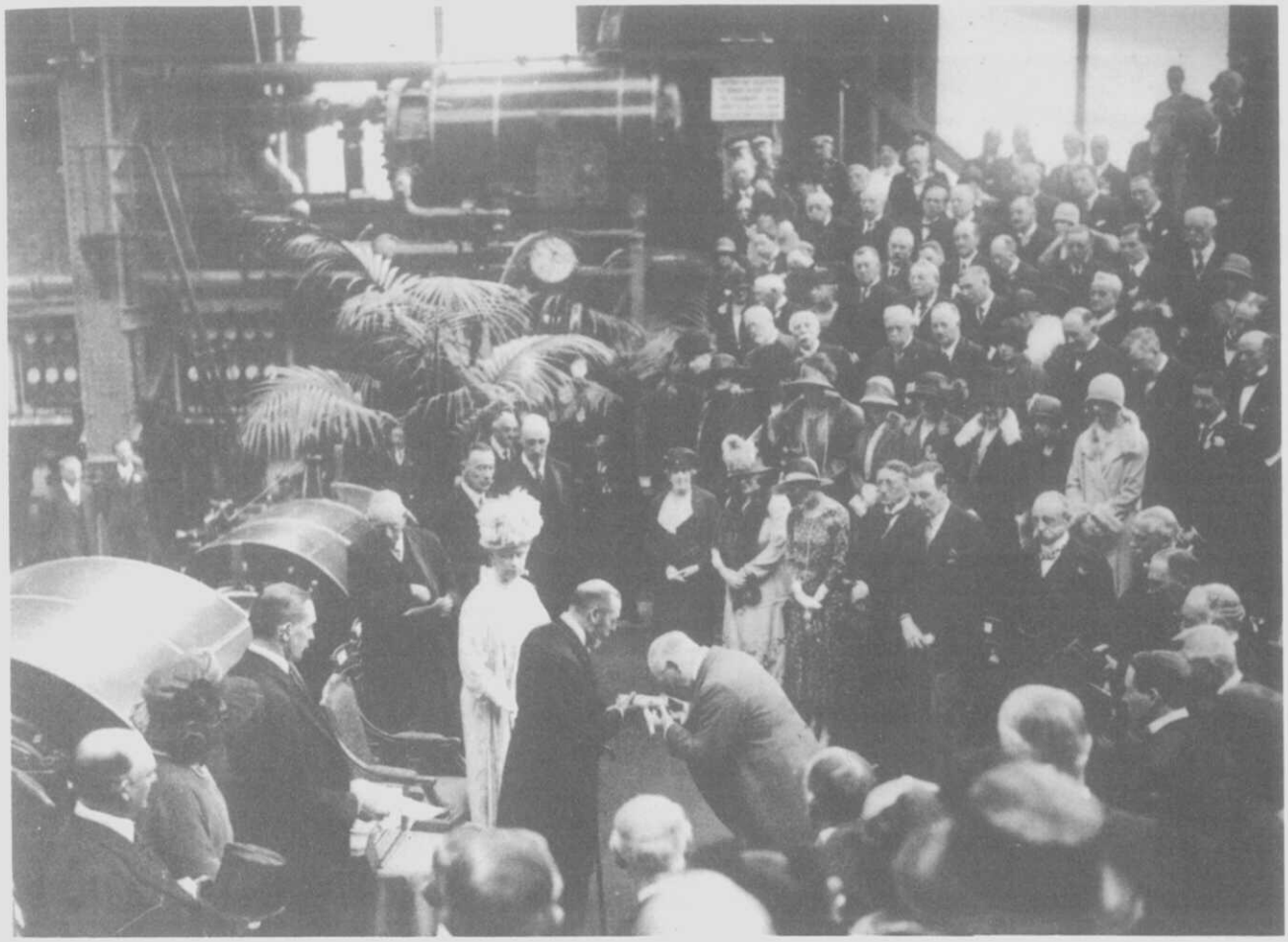


Plate 28 The Brimsdown "A" and "B" stations of the Northmet Power Co. embodied generating plant unique in its time and of high efficiency. A 53 MW cross-compound set by Metropolitan-Vickers of very advanced steam conditions commissioned at the "A" station in 1938.

Above – The 19 MW primary HP set and right the 34 MW condensing LP set. Both sets generated at 33 kV direct to busbars. Stop valve steam conditions were 1,900 lb/in² at 930° F with reheat at 160 lb/in² to 810° F. Steam was provided by two 210 klb/h Loeffler boilers manufactured by Mitchell.
("Engineering" May 26 & June 2 & 9, 1939)





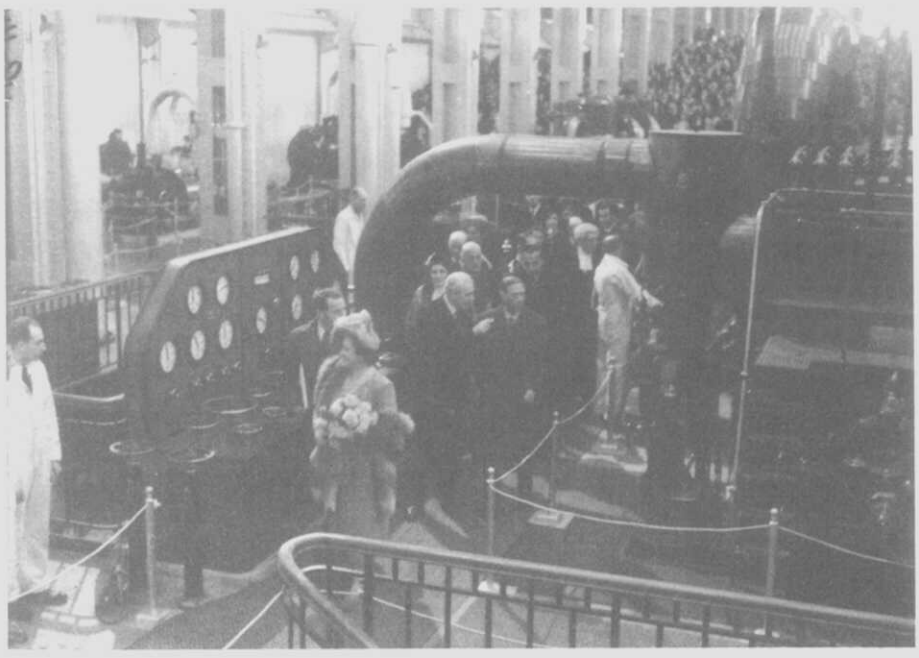


Plate 29 Above–Barking "A" official opening by King George V and Queen Mary on 29 May 1925 with Sir Harry Renwick, Chairman of the County of London Electric Supply Co., presenting his address in casket. The 240 MW station comprised 4 × 40 MW and 4 × 20 MW Parsons sets with steam conditions 350 lb/in^2, 700°F. Set no. 1 had reheat at 40 lb/in^2 to 700°F. (E.C. Archives)

Left–Kingston "B" official opening by King George VI and Queen Elizabeth on 27 October 1949–the first new station to commission after nationalisation on 1 April 1948. When completed in 1950 the station had 4 × 30 MW sets by British Thomson-Houston with steam conditions 600 lb/in^2 at 825°F.
(E.C. Archives)

Plate 30 Above–Electrical Association for Women's 21st Birthday exhibition at Dorland Hall 11–25 October 1945–Queen Mary examining demonstration model of an electric cooker.

Right–the first Women's Electrical Exhibition arranged by the British Electrical Development Association–L.A.C.W. Kathleen Cook, Petty Officer Nancy Taylor and Junior Commander J. Allen examining the Bendix Automatic Home Laundry. (E.C. Archives)

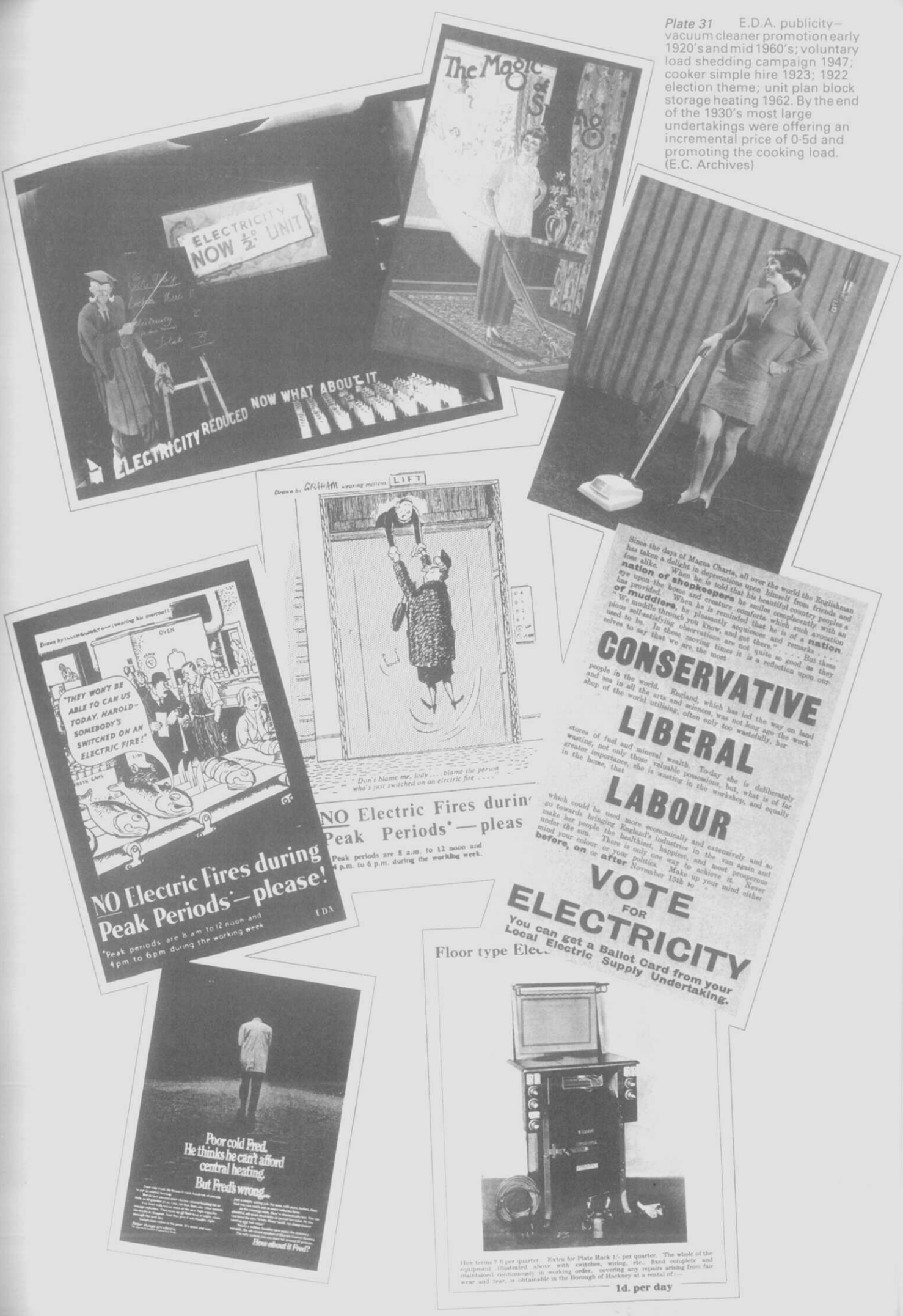


Plate 31 E.D.A. publicity– vacuum cleaner promotion early 1920's and mid 1960's; voluntary load shedding campaign 1947; cooker simple hire 1923; 1922 election theme; unit plan block storage heating 1962. By the end of the 1930's most large undertakings were offering an incremental price of 0·5d and promoting the cooking load. (E.C. Archives)

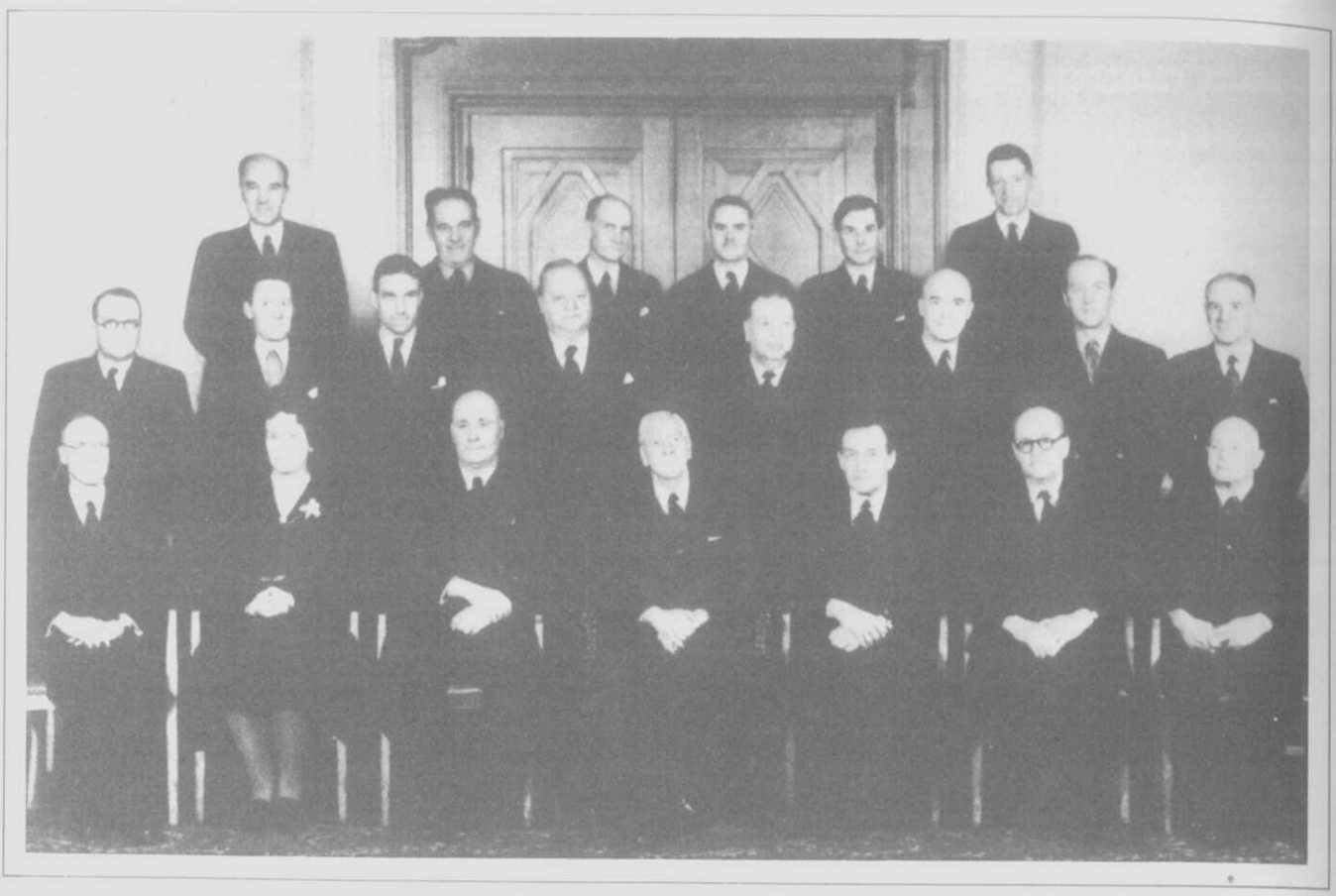


Plate 32 First meeting of British Electricity Authority's Central Authority with the Area Board Chairmen 26 November 1947.
Left to right: Front row–Col. Woodward (part-time), Dame Caroline Haslett (part-time), Sir Henry Self (Deputy Chairman (Administration)), Lord Citrine (Chairman), Sir John Hacking (Deputy Chairman (Operations)), E. W. Bussey (Member for Labour Relations and Welfare), Sir William Walker (part-time).
Middle row–W. S. Lewis (Midlands), S. F. Steward (South Western), N. Elliott (South Eastern), G. Gibson (North Western), L. Howles (South Wales), C. T. Melling (Eastern), H. J. Randall (London), J. S. Pickles (SW Scotland).
Back row–J. Eccles (Merseyside & North Wales), C. R. King (East Midlands), H. Nimmo (Southern), W. M. Lapper (Yorkshire), H. H. Mullens (North Eastern), Sir Norman Duke (SE Scotland).
("Electrical Review" 26 November 1947)

Index

Note
This index is alphabetised letter-by-letter. References are made not to page numbers but to years. If an item is mentioned more than once under the same year the number of occurrences is given in brackets. For English language references the definite article has been ignored.

Abbreviations
EB: Electricity Board
ESI: electricity supply industry
ps: power station(s)

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B

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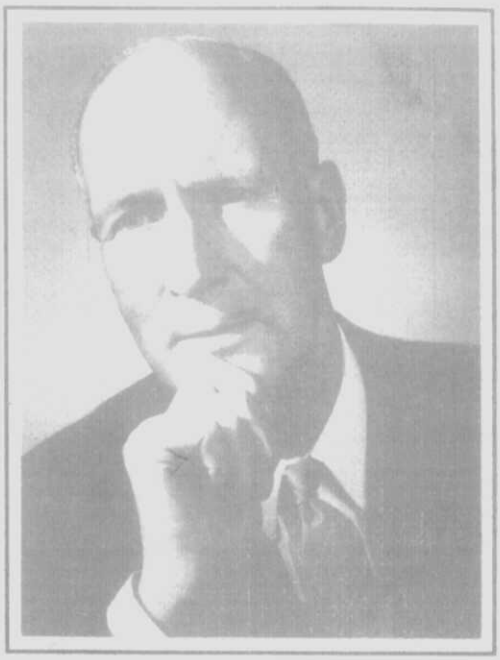

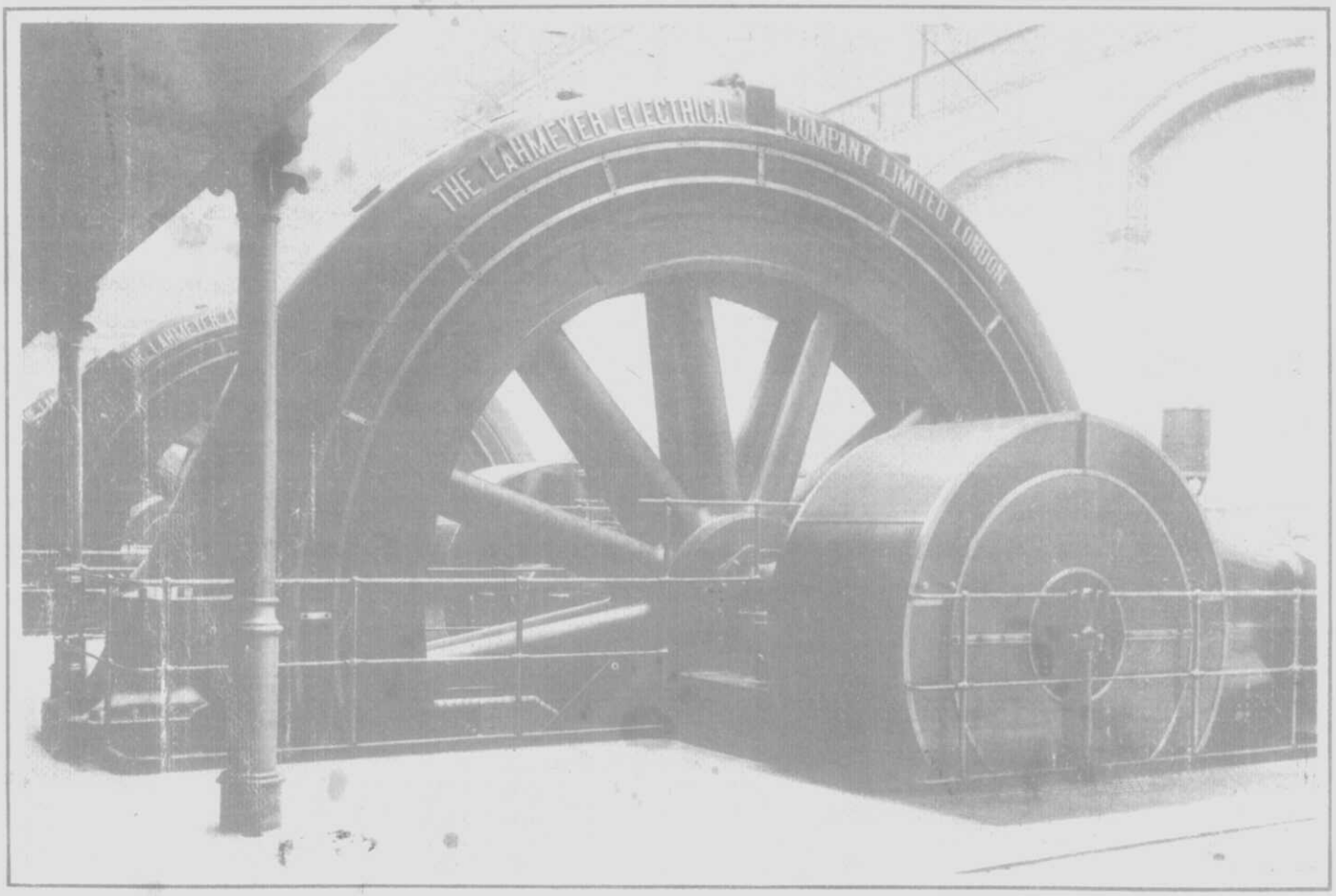
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