SHORT STORIES OF GREAT INVENTIONS.

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18. THE ELECTRIC FURNACE. Electric heating dates from the time of Volta and Davy, but the first experiment in electrometallurgy was the production of cementation steel by William Pepys (Eng.) about 1815. It was not until 1853 that attempts at electric furnaces were made, one in England by J. H. Johnson, another in France by Pichou. These were commercial failures. The first furnace attracting public attention was that of William Siemens in 1878, where the molten metal formed one electrode. The Cowles Brothers (Eng.) in 1884 and 1885 finally succeeded in the production of aluminum alloys, and aluminum itself was made (by a combination of the electrolytic and heating effects) by Hall in America and Heroult in France, in 1886 or 1887. Elihu Thomson patented a resistance furnace in 1886, Borchers (Ger.) produced a successful one in 1891, and DeLaval made an attempt in 1892. In 1892 also, Moissan, using an arc furnace and employing the marvelous nonconducting properties of quicklime, produced calcium carbide; while Acheson, using a resistance furnace, discovered the well-known abrasive carborundum. This was followed by the commercial production of calcium carbide (whence the making of acetylene gas) by Willson in 1895.

A new type, the induction furnace, useful where iron free from carbon is desired, was invented by Ferranti in Italy and Colby in America in 1897. Work along similar lines was done by Stassano (It.), 1898; Kjellin (Swedish), 1900; Hjorth (Swedish), 1904; Frick (Eng.), 1904; and Girod (Fr.), about 1905.

Electric welding, forging, etc., are very nearly related to work with furnaces. The first electric welding of which we have record is that of a bundle of iron wires by Joule in 1856. The use of the arc for cutting and welding (where the material is one electrode) dates back to 1881 when De Meretens did "lead burning" with it. A more general use was made by the Russian Bernardos about 1901. The deflected-arc process began with Wederman in 1874, who used an air blast; the use of a magnet for deflecting the arc was by Zerener about 1881. A very novel and spectacular method is that of the "water-pail forge," introduced by LaGrange and Höho (Belgians) in 1892.

Lastly, one of the most important welding processes is that of Elihu Thomson (1889), employing the heat from the resistance (at the points of contact) to the heavy current from the secondary of a special step-down transformer.

19. THE WHEATSTONE BRIDGE, the great fundamental measuring instrument for all ordinary resistances, was brought to public attention by Wheatstone in 1845, but this was, as Wheatstone himself states, invented by Christie in 1833.

We are more or less familiar with its variations in construction (slide wire, "Post Office," dial decade, etc.), but some neglect the importance of a sensitive galvanometer and an accurate resistance box. The latter is the invention of Werner Siemens, but the "rheostat" is credited to Wheatstone.

The story of the search for a suitable resistance material (before manganin, platinoid, etc., were selected) is interesting, as is also that of the "aging" of the wire, the difficulty of determining its exact temperature at the time of measurement, and other refinements, as the use of the ice bath or motor-stirred oil immersion. The names of Carey Foster, Lord Kelvin, and Varley should also be put down for their share in the development of the bridge.

20. GALVANOMETERS. The "frog's leg" experiment of about 1780 furnished the first means of detecting an electric current, but the electromagnetic type began with Oersted's great discovery (Denmark) in 1819. That the magnetic needle could be used to detect very small currents followed immediately upon Schweigger's discovery (Germany, 1822) of the use of a coil of many turns of wire, and such "moving-needle" instruments have reached marvelous perfection and have taken many shapes.

The "moving-coil" instruments, now becoming widely used, are frequently called "D'Arsonval galvanometers," but D'Arsonval (1882) merely put into commercial form the instrument used by Sturgeon (one of the inventors of the electromagnet) in 1836. Lord Kelvin's submarine cable "siphon recorder" is of this variety.

Most of the other prominent types, as the solenoid and plunger, the ballistic, etc., are electromagnetic in action, with the exception of a few of the "hot-wire" or expansion type.

21. ELECTROMAGNETISM began with Oersted in 1819; and his work was at once added to by Ampere and by Arago (in France), who in 1820 discovered that iron filings cling to a copper wire

bearing current, that steel could be magnetized, etc.

In 1825 Sturgeon (Eng.) constructed the first practical electro-magnet, and in 1829 Joseph Henry, working independently, improved it so much that its commercial development may be dated from that time. This definite combination of a coil of wire with soft iron (only in a few cases, as the telephone receiver, the polarized relay, etc., is the core of steel) became a necessary part of dynamos, motors, bells, telegraph sounders and relays, galvanometers and most measuring instruments, annunciators, switches, and other remote control apparatus.

22. THE REVERSIBILITY OF THE DYNAMO. The fact is that every dynamo can be made to run as a motor. Faraday's discovery (1831), that a conductor moved in a magnetic field has a current induced in it, was the reverse of his experiment (1821) where a magnet rotated about a wire carrying current; but Lenz (1838) seems to have been the first to recognize that fact. The real reversibility of an actual dynamo was shown by Jacobi in 1850. This did not become generally known, and it was independently discovered by Pacinotti (1864) and by Rowland in America. Another story has it that it was stumbled upon at the Vienna Exposition of 1873 by a workman who connected two leads (not knowing them to be alive) to a dynamo, which at once ran as a motor. By some, the discovery is credited to Fontaine & Gramme at this same date.

23. THE TRANSFORMER was really discovered by Faraday in 1831, but it did not become of industrial value until 1882, when Gaulard & Gibbs began to make transformers in England. In this long period, men had not been idle, however, work having been done by C. F. Varley, Jablochhoff, Ferranti, Zipernowski, and others..

The first transformer in the United States is claimed to have been that of William Stanley at Great Barrington, Mass., in 1885. At about the same time, the far-seeing George Westinghouse acquired the Gaulard & Gibbs rights for America and began their manufacture here.

The columns of the electrical journals now note casually the construction of transformers of 5800 K. V. A. capacity (5,800,000 watts at unity power-factor) to operate at 150,000 volts. These high voltage transformers, representing marvelous engineering skill in methods of cooling, good insulation, bracing of coils against possible distortion, overcoming magnetic leakage, avoiding "aging" of the iron or steel core, etc., have efficiencies

of over ninety-eight per cent. And how difficult it is for the observer to grasp what is going on within the smooth shell of one of these almost silent monsters!

The gradual increase in the voltages used is paralleled by the improvement in insulators, culminating in the suspension type. This kind handles any increase in voltage by simply adding more units to the "string," the limit being the point at which "corona" makes its appearance on the wire.

24. THE WIRELESS TELEPHONE. A hissing condition of the electric arc was noticed by De La Rive (Swiss) in 1849, a musical arc by Lecher in 1888, another form by our own Elihu Thomson in 1892, and one by Blondel in 1893. As it was recognized that the arc was the seat of high-frequency oscillating or regularly pulsating currents, inventors were stimulated in the hope of its use for telephonic transmission (using the wireless ether waves). While one patent (Marconi, 1895) is recorded of an effort to use a high-frequency alternator for wireless transmission, the experiments of most of the workers were along the line of musical arcs.

Simon (1898) is regarded as the real inventor of the "singing arc," and his work was followed by that of Blondel, Collins, and Duddell in 1900, Szczepanik in 1901, Fessenden and Poulsen (the latter using hydrogen gas and cooled metal electrodes) in 1902, Ruhmer, Pierce, and Majorana in 1904, Fessenden, Ruhmer, and M'Carty (a San Francisco boy) in 1906. Lee de Forest in 1907 transmitted music a few blocks.

When well adjusted, the perfected apparatus gives marvelous results, more awe-inspiring than those of the ordinary telephone; but it is subject to many interferences, requires careful adjustment, and at present can compare with wireless telegraphy for long distance work, only on rare occasions.

25. OHM'S LAW. The law now known to the world as Ohm's law was discovered away back in 1800 by Cavendish in England. But that austere and self-effacing scientist published not one word of many discoveries, this one included, and it remained unknown until Ohm's experimental paper came out in 1826. (His book containing the theoretical deduction came out in the following year.) He was at this time a hard-worked teacher in the gymnasium at Cologne, and lacked appliances and good books; but with the skill obtained when a boy from his father, a locksmith, he constructed most of the apparatus (including the thermopile used as a source of current) for his investigations.

He was ambitious to become a professor in a university, but the tardiness of recognition should be noted; he taught in Berlin for six years, in Nurnberg for thirteen years, and finally in 1849 was appointed extraordinary professor at the University of Munich. He became full professor in 1852, and enjoyed the fruition of his life's hopes for two years only, dying in 1854.

26. THE VOLTAIC CELL. Galvani (of Bologna) discovered in 1780 that frogs' legs would twitch when they were touched to two different (connected) metals. His theory of "animal electricity" was disputed by Volta (of Pavia) who had been working with static electricity for some time (he had invented the electrophorous in 1775). It is recorded that Volta had noticed the peculiar "taste" produced by holding a gold and a silver coin in the mouth in about 1790 (anticipated in this by Johan Sulzer, in Germany); and his experiments on the chemical nature of the source of these electric currents culminated in the construction of the voltaic pile (zinc, copper, cloth moistened with vinegar) and the "crown of cups" (simple cells in series) in 1800.

From that date to the present, the efforts of inventors to overcome polarization, to produce low internal resistance or high electromotive force with economy of materials, to develop cells for continuous or for intermittent use, or for standard electromotive force, resulted in numberless varieties of cells.

Among the best known are the following: Grove, Bunsen (or Poggendorff), Grenet, Daniell (and gravity), Fuller, Leclanche (and "dry"), silver chloridé, Edison-Lalande, Clark and Weston.

It is interesting to compare the progress made in the world's knowledge of electricity for almost two thousand years with that made in the one hundred years following Volta's capital discovery.

27. THE STORAGE CELL. It is stated that Gautherot, one year after the publication of Volta's discovery, found that platinum or silver electrodes would give a current of short duration after the electrolysis of water. In 1803 Ritter noted the same thing (using gold wires), and constructed the first secondary battery, plates of gold and discs of cloth moistened with ammonia.

Some knowledge of the subject was contributed by Volta himself, by Davy and by Marianini, and in 1837 Schoenbein used "suboxide of lead." Work with oxides of lead was done by Grove, Wheatstone, Siemens, and Faraday, and in 1842 Grove attracted attention to his "gas battery" of fifty cells, which was powerful enough to produce an arc light.

The commercial development of the storage cell dates from 1860 in the work of Planté who used the lead, lead oxide, sulphuric acid combination. Others have tried lead-copper, lead-zinc, and copper-iron (alkaline zincate solution), but the only important improvement in the lead cell since the time of Planté was that of "pasting" (which now means shortening the time of "forming" the plates by having pellets of lead salts forced into holes in the plates, sometimes by a hydraulic press). This was made a commercial success by Faure in 1879, but the process had been invented by Metzger previously. It was invented independently in this country, and the U. S. courts gave the decision for priority to Brush.

The only radical change since then has been the development (about 1905) of the nickel-iron cell by Edison. (The solids are nickel oxide and iron, the liquid is a solution of caustic potash containing a little lithium hydrate.) Its advantages are that it is much lighter, will stand a high charging rate, and is not injured by lying idle when discharged. One disadvantage is its high cost; another, for some kinds of work, is that its e. m. f. discharge curve is not so "flat" as that of the lead cell.

28. ROENTGEN OR X-RAYS. This series of stories of great inventions may well close with that of the most mysterious of them all. How commonplace now is the news that some friend has had "an X-ray photograph," or that a bullet can be located exactly by the fluoroscope with a stereoscopic attachment.

The discovery of these wonderful rays is a recent one (1895), and most of us remember the sensation created by the publication of Roentgen's modest paper, in which he referred to them as X-rays, but which the world rightly calls by his name.

His discovery followed the invention of the Crookes tube and some experiments by Lenard and Hittorf. The fact that an exhausted bulb having electrodes connected to the secondary of an induction coil has a peculiar set of rays from its cathode was known; Roentgen found that the other electrode, the anode, was the source of a "new kind of light" which would penetrate substances opaque to ordinary light, exciting fluorescence in substances like barium platinocyanide and affecting a sensitive plate.

Edison constructed the useful fluoroscope in 1896 (also claimed for Professor Salvioni) which at once made it possible for the surgeon to locate any body denser than human flesh by "seeing" its shadow on the screen of the instrument.