

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, Feb. 28, 1902.

The 162d meeting of the INSTITUTE was held this evening, President Steinmetz calling the meeting to order.

SECRETARY POPE:—Mr. President, at the meeting of the Executive Committee and Board of Directors this afternoon, the following associates were elected:

Name.	Address.	Endorsed by
AYRES, ALBERT DOANE, Salesman, Westinghouse, E. & Mfg. Co.;	residence, 3808 Grand Boulevard, Chicago, Ill.	C. F. Scott. Arthur Hartwell. W. K. Dunlap.
BURTON, CHARLES GILLETTE, Salesman, Westinghouse E. & Mfg. Co.;	residence, 6328 Greenwood Ave., Chicago, Ill.	C. F. Scott. Arthur Hartwell. N. W. Storer.
CHESTER, M. E., Telephone Engineer, Western Electric Co., 463 West St.;	residence, 296 Manhattan Ave., New York City.	G. F. Atwood. O. A. Bell. G. A. Hamilton.
CHUBBUCK, LEONARD BURROWS, Checker in draughting room, Westinghouse & Mfg. Co.;	residence, (Homewood) 535 Clawson St., Pittsburg, Pa.	C. E. Skinner. E. H. P. Davis. T. R. Rosebrugh.
COOPER, WILLIAM, General Superintendent, Bullock Electric Mfg. Co., Cincinnati, Ohio.		R. T. E. Lozier. B. A. Behrend. L. E. Bogen.
COWEN, JULIAN BETTY, Manager of Export Department, General Incandescent Arc Light Co., 572 First Ave.;	residence, 204 W. 119th St., New York City.	Samuel Insull. M. J. Insull. H. P. Ball.
DRYER, ERWIN, Salesman and Engineer, Westinghouse E. & Mfg. Co.;	residence, 171 La Salle St., Chicago, Ill.	C. F. Scott. Arthur Hartwell. N. W. Storer.
ELEY, JOSIAH NORFLEET, Electrician and Operating Engineer, Georgia Electric Light Co., 198 S. Prior St., Atlanta, Ga.		C. N. Black. W. E. Moore. J. P. Edwards.

- FERRIS, ROBERT MURRAY, JR., Engineering Department, The N. Y. & N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y.; residence, 239 West 103d St., New York City. J. C. Reilly.
J. J. Carty.
B. Gherardi, Jr.
- FULLER, EDWIN ERNEST, Representative Engineer for Scotland for The British Thomson, Houston Co.; residence, Abbottsford, St. Andrews St., Ayr, N. B., England. W. J. Clark.
A. Churchill.
H. S. Meyer.
- GAYLORD, TRUMAN PENFIELD, Engineer, Westinghouse Mfg. Co.; residence, 610 Dearborn Ave., Chicago, Ill. C. F. Scott.
Arthur Hartwell.
N. W. Storee.
- GIBSON, JOHN JAMESON, Salesman Westinghouse E. & Mfg. Co.; residence, 171 La Salle St., Chicago, Ill. C. F. Scott.
Calvert Townley.
F. A. Pickernell.
- GREEN, CHARLES MAXWELL, Engineer on Brush Arc Dynamos, General Electric Co.; residence, 85 N. Common St., Lynn, Mass. E. Thomson.
C. P. Steinmetz.
P. G. Gossler.
- KINTNER, CHARLES JACOB, Solicitor of Patents and Expert, 45 Broadway, residence, 36 E. 29th St., New York City. R. W. Pope.
C. W. Price.
T. C. Martin.
- KINTNER, SAMUEL MONTGOMERY, Professor of Electrical Engineering, Western University of Pa.; residence, 1916 Perrysville Ave., Allegheny, Pa. C. F. Scott.
R. A. Fessenden.
H. W. Fisher.
- LLOYD, EDWARD WILLIAM, Assistant Superintendent of Construction, Chicago Edison Co., 139 Adams St., Chicago. L. A. Ferguson.
James Lyman.
W. G. Carlton.
- MILLER, GEORGE E., Assistant to Fourth Vice-President, Westinghouse E. & M. Co.; residence, 4911 Centre Ave., Pittsburg, Pa. R. W. Pope.
H. B. Shaw.
C. F. Scott.
- MORRILL, EDWARD FRANCIS, Engineering Department, The New York and New Jersey Telephone Co., 81 Willoughby St.; residence, 18 Willoughby Ave., Brooklyn, N. Y. B. Gherardi, Jr.
F. H. Dassori.
Samuel Sheldon.
- MULLIGAN, WALTER LYON, Assistant Manager, United Electric Light Co., Box 812 Springfield, Mass. Joseph Sachs.
R. W. Pope.
G. W. Blodgett.
- LOWSON, DAVID, Electrical Inspector, Department of Electricity, 1721 Park Row Building; residence, 35 W. 132d St., New York City. A. A. Nimis.
Joseph Sachs.
R. W. Pope.
- MARBURY, LOUIS C., Electrical Engineer, General Electric Co., Schenectady, N. Y. C. P. Steinmetz.
W. R. Whitney.
A. H. Armstrong.
- TER MEER, HENRY CHARLES, Tester in Meter Department, Brooklyn Edison Co.; residence, 990 Hudson St., Hoboken, N. J. F. B. Crocker.
M. I. Pupin.
G. F. Sever.

- NICHOLS, LOUIS CHARLES, Electrical Engineer, The H. B. Smith.
Converse Transformer Co.; V. G. Converse.
residence, 602 Shady Ave., A. L. Rohrer.
Pittsburg, Pa.
- PRICE, NORMAN I., Sibley College, Cornell University; G. L. Hoxie.
residence, 209 Huestis St., H. J. Ryan.
Ithaca, N. Y. E. L. Nichols.
- REMSCHEL, CESAR WILHELM AUGUST G. P. O., San C. O. Poole.
Francisco, Cal. F. E. Smith.
C. W. Waller.
- RUFFER, CHARLES SHUMWAY, Electrician, The Tellur-H. B. Shaw.
ide Power Co., Telluride; P. N. Nunn. [ger
residence, Vance Junction, W.K.Freudenber-
Col.
- SAWYER, WILLITS HERBERT, Engineer, Railway Engi- C. P. Steinmetz.
neering Department, General W. B. Potter.
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4 Gillespie St., Schenectady,
N. Y.
- SHARP, CLAYTON HALSEY, Test Officer, Lamp Testing W. S. Howell.
Bureau, 14 Jay St., New A. E. Kennelly.
York City; residence, 722 C. W. Rice.
Highland Ave., Newark, N. J.
- SLOAN, JAMES RICHARD, Electrical Engineer, The W. M. Stine.
Pullman Co., P. R. R. W. L. Bliss.
Depot, Jersey City, N. J.; A. W. Berresford.
residence, 607 West 61st
Place, Chicago, Ill.
- THOMAS, ALFRED CLARENCE, Engineer, The New J. C. Reilly.
York and New Jersey Tele- J. J. Carty.
phone Co., 81 Willoughby B. Gherardi, Jr.
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- WAGONER, PHILIP DAKIN, Commercial Department, C. P. Steinmetz.
General Electric Co., Box W. C. Woodward.
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- WILKINSON, JAMES, Chief Engineer Birmingham Rail- G. H. Harris.
way, Light and Power Co.; F. E. Kinsman.
residence, 1212 North 17th R. W. Pope.
St., Birmingham, Ala.
- WOODFIELD, SYDNEY, Assistant Engineer, Electrical C. W. G. Little.
Power Distribution Co., R. W. Pope.
York House, Norfolk St.; F. E. Kinsman.
residence, 24 Sinclair Gar-
dens, Kensington, London,
England.
- Total, 33.

The following associates were transferred to full membership:

- HOWARD S. WILSON, Superintendent, Puebla Electric Light Co., Puebla,
Mex.
- CHRISTOPHER M. GODDARD, Secretary, Underwriters' National Electric
Association, Boston, Mass.
- BYRON T. BURT, Superintendent, Chattanooga Electric Light and
Power Co., Chattanooga, Tenn.
- LEWIS A. HOWLAND, Engineering Department, Canadian General Elec-
tric Co., Montreal, P. Q.

THE ELECTROCHEMICAL INDUSTRIES.

BY SAMUEL SHELDON.

Introduction.—In this paper an attempt is made to give a general view of the present condition of the electrochemical industries. The subject of storage and primary batteries is so large and is so clearly differentiated from the other electrochemical industries that it is not touched upon. Neither is the subject of electrotyping considered. The carrying on of the other industries requires over 200,000 horse-power. Of this about 90 per cent. is obtained from water power. The cost of electrical power, obtained from water power, varies much in different parts of the world. Swan gives the limits per horse-power year as \$5 and \$50. At Niagara the price to large consumers is about \$17. This power is delivered in Buffalo for about \$30.

ELECTRO-DEPOSITION OF METALS.

Electro-Plating.—The methods of plating employed in establishments in the vicinity of New York do not differ to any extent from the methods well-known in the art. The average practice may be described as follows:

Gold.—There are three solutions in common use to give the three colors of deposit known as "California gold," "green gold," and "red gold." The salts to form the solutions are prepared by dissolving, in nitro-hydrochloric acid, the following alloys: For California gold, an alloy of 22 parts gold and 2 parts silver; for green gold, an alloy of 16 parts gold and 8 parts silver; and for red gold, an alloy of 16 parts gold and 8 parts copper. Upon evaporation the chlorides of these metals

remain. They are dissolved in a solution of potassium cyanide to form the plating solution. Double cyanides are thus formed. A freshly prepared solution contains a pennyweight of gold to the gallon. The anodes are of pure gold. The articles to be gilded form the cathodes. The rate of solution of the anodes is not as great as the rate of deposition on the cathode. Therefore the solution has to be enriched by frequent addition of the salts. The current density is adjusted by varying the depth of submergence of the anode, the baths being supplied with five volts at constant potential. The correctness of the current density which is being employed is determined by the eye and the experience of the attendant. There is no circulation of the electrolyte.

Silver.—The solution consists of a double cyanide of potassium and silver, the concentration being two ounces of silver per gallon of solution. The anodes are of pure silver. Owing to the tendency of silver to deposit in arborescent crystals, the articles which are being plated are moved backward and forward in the bath in a plane parallel with the anode surface. The path of movement is about two inches and the time required to traverse it about three seconds. The proper current density rests with the judgment of the attendant. Too great a density or an impoverished solution is indicated by a violet tinge imparted to the deposit. Silver-plated articles to have a polished finish require burnishing with steel or blood-stone burnishers moistened with a solution of soap and distilled water.

Nickel.—The solution universally employed is one of nickel-ammonium sulphate. The proper concentration results from dissolving eight pounds of the salt in a gallon of water. The solution should be kept neutral by the addition of either ammonia or sulphuric acid. The proper current density is from 0.5 to 1.5 amperes per square decimetre of cathode surface. Nitric acid should not be present in any form in the solution.

Brass.—Much house or builders hardware consists of brass-plated steel or iron. Many solutions are used. The best, perhaps, contains equal quantities of zinc and copper cyanides or carbonates dissolved in ammonium carbonate. The color of the deposit may be varied by changing the relative amounts of the copper and zinc salts.

Critical Current Density.—In the electro-deposition of metals from a salt solution the rate of deposition, which may be used, is limited. If a proper current density at the cathode be em-

ployed, an adherent reguline deposit will result. If the current density be increased, a limit is reached, when, if exceeded, the character of the deposit will change, becoming pulverulent and non-adherent. This limit is termed the *critical current density*. As an increase of the permissible current density allows of a smaller plant for the same output and shortens the time that the metal in the solution is idle, a consideration of the factors which determine the value of the critical current density is pertinent. Consider a cubic centimetre of metallic salt solution at rest, and directly in front of a cathode. It contains a certain weight of the metal. This weight is dependent upon the concentration of the solution and can be calculated from its specific gravity. A certain percentage of this metal, dependent on the temperature and concentration of the solution, is dissociated and takes part in the electrolytic conduction. If an attempt be made so to adjust the current flowing through this cubic centimetre, that by Faraday's laws the rate of deposition is such that all the dissociated metal ions must be deposited in one second, then, it is evident, the velocity of movement, or migration of the ions, would be one centimetre per second. Such a rate of deposition of ordinary metals from a stationary solution is impossible. The maximum velocity of migration is rather to be reckoned in thousandths of a centimetre per second. If the deposit is to remain reguline, the ions must not be expected to migrate faster. It is possible, however, to adjust the circuit for any current density. As soon as the rate of deposit exceeds the ability of the metal ions to supply it, hydrogen of the solvent appears to take part in the conduction and a pulverulent deposit results, which contain some hydrogen and is said by some to be a hydride of the metal. The critical current density may be increased by increasing the concentration of the solution, by raising its temperature, or by *circulating the electrolyte toward the cathode*.

Circulation.—Circulation of the electrolyte has three functions. It permits of a higher rate of deposition, as mentioned above; it replenishes the part of the electrolyte next to the cathode which has been deprived of its metal; and it prevents, to a certain extent, the deposit from assuming a nodular or aborescent form. When deposition is taking place at moderately large current densities, accidental differences of concentration occur in the vicinity of the cathode. Places on the cathode which can be reached by current flowing through the more concentrated portions of the electrolyte will receive a heavier deposit than

other places. As a result they will protrude slightly from the cathode. These unevennesses are multiplied and magnified as the deposition continues.

Dissociants.—The water of an ordinary electrolyte performs two duties. First, it acts as a solvent, whereby it allows and facilitates the uniform distribution of the dissolved substance throughout the solution, subdivision of the substance being carried to a condition of a molecular fineness. Secondly, it acts as a dissociant whereby some of the molecules of the dissolved substance are split up and dissociated into their component ions. Without dissociation there can be no electrolytic conduction of the current. Besides water the following substances are common solvents and dissociants: liquid ammonia, ethyl alcohol, methyl alcohol, glacial acetic acid, and pyridin. The last-named contains no oxygen, and it has been recently shown by Dr. Kahlenberg that from a solution of lithium chloride in it, pure metallic lithium may be electrolytically deposited.

Copper Refining.—Refined copper constitutes the most valuable product of all the electrochemical industries. The processes of producing the refined copper from its alloys have been well described by Badt in the ninth volume of the INSTITUTE'S published TRANSACTIONS. The copper alloy, or blister copper, is cast into slabs which are used as anodes in a bath containing a slightly acidulated solution of copper sulphate. This electrolyte is kept in continuous circulation. Pure copper is deposited from the solution upon pure copper cathodes at a current density of from 15 to 25 amperes per square foot. Copper is simultaneously dissolved at the anode, and the alloyed gold, silver, and other metals drop, as slime, to the bottom of the cell to be parted and recovered later. After deposition the cathodes are melted up, poled, and cast into wire-bars or other suitable forms. The "poling" of copper consists in stirring the molten metal with a pine stick. The stick carbonizes, and, as a result, reduces cuprous oxide which is present in the molten copper. Upon cooling, cuprous oxide gives up its oxygen to metallic impurities which may be present in the copper. As the mechanical and electrical properties of copper are better when impurities exist in the form of oxides rather than as metals, the proper amount of poling is when just sufficient cuprous oxide is left to oxidize the impurities. Overpoled or underpoled copper is brittle and of inferior conductivity.

Parting of Gold and Silver.—This is accomplished by means

of electrolysis very satisfactorily in the following manner. The alloy of the two metals constitutes the anode, and is placed in a linen bag. The cathode is a thin sheet of pure silver. The electrolyte is at first a one-tenth per cent. solution of nitric acid, which ultimately becomes a dilute solution of silver nitrate. With a current density of 33 amperes per square foot, silver 999.5 per mil fine is deposited on the cathode in the form of beautiful crystals. These are mechanically scraped off and allowed to drop to the bottom of the cell. Gold, in the form of mud, containing some silver, collects in the anode bags. The silver is removed from it by dissolving in nitric acid, leaving the gold in a very pure condition.

Extraction of Gold.—The process of Siemens and Halske, which is in use in South Africa, consists in dissolving the gold from the crushed ore in a solution of cyanide of potash and then subjecting the solution to electrolysis with iron anodes and thin sheet lead cathodes. The anodes are dissolved. Dr. Keith improves upon this process by adding a small amount of soluble mercury salt to the cyanide solution. It increases the rapidity of solution, and mercury is deposited alongside the gold on amalgamated copper cathode plates. The amalgam is scraped from these plates and the gold and mercury separated by "retorting."

Extraction of Nickel.—By the Hoepfner process the nickel ores are first roasted, crushed, and leached in a mixed solution of cuprous chloride and calcium chloride. By electrolysis with carbon electrodes the copper is removed from the solution. The lead and iron are removed by chemical means. There then remains a solution of nickel chloride. This is electrolyzed, and the nickel deposited upon a nickel cathode.

INORGANIC PRODUCTS.

Alkalies and Bleach.—The power employed in the electrolytic preparation of these substances amounts to more than 50,000 horse-power. There are many different processes employed, some of which are secret. The electrolyte is always common salt, either in water solution or in a fused condition. Upon passage of a current, using a carbon anode, chlorine is developed in the gaseous form at the anode and is led to chambers containing lime with which it forms bleaching powder. Metallic sodium appears at the cathode. If the cathode be mercury, as in the Castner process, a sodium amalgam is formed, which, upon wash-

ing with water, yields caustic soda and returns the mercury. If the cathode be iron in a water solution, caustic soda is developed by secondary reaction. In the Acker process the electrolyte is fused salt and the cathode is molten lead.

Sodium.—This is manufactured on a commercial scale at Niagara by the electrolysis of fused caustic soda. The electrolyte is maintained in a fused condition by the current which passes through it. An iron containing-vessel constitutes the cathode, and the anode consists of rods which dip into the electrolyte. The sodium after deposition rises to the top of the electrolyte, and floats upon its surface. As it accumulates it is removed by small iron dippers. The sodium, after its reduction, is used in the manufacture of sodium dioxide. This is done by spreading the metallic sodium on trays, which are placed in tubes, supplied with air and dried over calcium chloride. The sodium peroxide is then used for producing peroxide of hydrogen. For this purpose it is mixed with sulphuric acid, and during the mixing the temperature is maintained near zero by melting ice. This is necessary because of the unstable character of the peroxide of hydrogen.

Aluminium.—This metal is reduced electrically from alumina by the Pittsburg Reduction Co. at Niagara Falls in America, and at Shawinigan Falls, in Canada, and by six other concerns in Europe. The annual product in America is about 3,000 tons. Kershaw estimates the total output for 1901 as 7,500 tons. The double fluoride of aluminium and calcium, in a fused state, is used as a solvent and dissociant. The heat developed by the passage of the electrolyzing current maintains the solvent in a fused state. The electrolyte is contained in large cavities made in carbon slabs. The carbon constitutes the cathode, and groups of large carbon rods, dipping into the fused electrolyte, constitute the anodes. The metal is drawn off once a day through taps leading to the bottom of the cavities. As the electrolyte is deprived of its metal its resistance rises. This fact is utilized to give warning to attendants. An incandescent lamp is shunted between the electrodes and, as the resistance of the electrolyte rises, the brilliancy with which the lamp burns increases. The attendant then introduces fresh alumina to the fused electrolyte. The process is thus continuous and uninterrupted.

Sponge Lead.—This is produced from litharge by placing it in contact with a sheet lead cathode in an electrolytic cell having a lead anode and dilute sulphuric acid as the electrolyte. The

deposited hydrogen reduces the litharge, leaving a lead sponge of fine quality. This process is employed by the National Battery Co. at Buffalo. The Electric Lead Reduction Co. of Niagara Falls is also producing sponge lead by subjecting galena to electrolysis.

Potassium Chlorate.—This is manufactured in considerable quantities by the National Electrolytic Co. at Niagara Falls by the electrolysis of a solution of potassium chloride. The process is not ideal as compared with many other electrolytic processes and the yield is not as great as could be desired for the electrical energy which is employed. The yield is increased by introducing a small quantity of potassium chromate into the electrolyte, as shown by Muller, and the introduction of a little alumina neutralizes the potassium hydrate as it forms at the cathode. The cathodes, as used at Niagara, are of wire gauze covered with cuprous or cupric oxide. The reduction of the oxides by the liberated hydrogen develops sufficient heat to maintain the temperature of the electrolyte at 50°C. The electrolyzed solution is led into refrigerating tanks, where the chlorate is made to crystallize by lowering its temperature.

Ozone.—This gas is a modified form of oxygen. It is generally stated that a molecule of ozone contains three atoms of oxygen while a molecule of gaseous oxygen contains but two atoms. This, however, is uncertain. Ozone differs from ordinary oxygen in being a much more powerful oxidizer at ordinary temperatures. It very quickly oxidizes organic substances. Ordinary rubber becomes brittle and crumbles after an immersion for a short time in the gas.

There are many forms of apparatus devised for the electrolytic production of ozone. The general principle underlying the construction of all of them is to pass a stream of dry oxygen or air between two conducting surfaces which are close to each other. The conductors are subjected to differences of potential which are rapidly varied in amount over wide limits. The high tensions of electrostatic machines, induction coils, or transformers are used. Disruptive discharges may be employed for producing the rapid change of potential difference. One company is using an alternator which gives 10,000 cycles per second. The issuing gas is said to be ozonized. At best it contains but little above one per cent. of ozone. A molecule of oxygen, consisting of two atoms, each bearing an electric charge, when subjected to the sudden variations in the electrostatic field between the con-

ductors, may in some or many cases be torn apart. The constituent parts may join with other molecules of oxygen to form ozone molecules.

Ozone is used on a commercial scale in yielding organic oxidation products, in sterilizing water for potable purposes, and in bleaching fabrics. Among its proposed uses may be mentioned the decoloration and defecation of syrup in sugar manufacturies, the aging of wines, and the aging of woods for the construction of musical instruments such as violins.

Nitric Acid.—One firm which is interested in electrochemistry, has perfected a method for the electrolytic production of nitric acid, the nitrogen being recovered from the atmosphere. The electrical process very materially reduces the cost of production. The importance of such a process may be very great in the future. Nitrogen is essential in the diet of all the higher forms of animal life. Soils are deprived of their nitrates by the crops which are grown. The supply is replenished to some extent by parasites which grow in nodules on the roots of leguminous plants. These parasites are capable of taking nitrogen from the atmosphere and oxidizing it. And yet fertilizers containing nitrates have to be applied to the soils to maintain their productiveness.

ORGANIC PRODUCTS.

Several hundred organic substances have been prepared in the laboratory by means of electrolysis. Most of them remain as laboratory preparations, but some have come upon the market, being manufactured on a commercial scale. All these organic products may be arranged in four classes, depending upon the ultimate constitution of the substance yielded as compared with the composition previous to electrolysis. Without considering the actual electrolytic process, the effective process is either one of oxidation, of reduction, of concentration, or of substitution or addition. These processes, like all electrical processes, are especially valuable because of the extreme delicacy of regulation which is possible. The efficiency of the process as regards yield is thereby increased.

Electrolytic methods constitute a valuable addition to the facilities at the disposal of the organic chemist. In carrying on experimental work attention should always be given to the temperature, to the concentration, and to the current density which is being employed.

Iodoform.—This is prepared by the electrolysis of ethyl alcohol in a solution of sodium or potassium iodide. The anode is of platinum and is placed in a solution made of 15 parts of potassium iodide, 100 parts water, and 16 parts of ethyl alcohol. This solution is separated by a porous diaphragm from a strong solution of sodium hydroxide, which contains a nickel cathode. The temperature of the electrolyte is kept at 70°C and a current density of one ampere per square decimetre is employed. After passage of the current for three or four hours, the solution is allowed to cool and iodoform crystallizes out.

Chloroform and Bromoform.—It is claimed that by substituting chlorides or bromides for the iodides in the above process either of these two substances may be prepared.

Camphor.—If turpentine hydrochloride, in a melted condition or in an alcoholic acetic acid solution, be electrolyzed, camphor is obtained. Camphor results from the oxidation of terpine, *i. e.*, oil of turpentine. Artificial camphor is made from turpentine in large quantities by the Ampere Electrochemical Co., but the process is claimed to be in nowise electrical.

Vanillin.—This substance, which is the odoriferous component of vanilla, is obtained by the oxidation of eugenol (oil of cloves). It is much used in the manufacture of perfumes. It is produced electrically on a commercial scale in France.

Artificial Rubber.—A process for the electrical production of artificial rubber is being experimented with, and it is said to promise much for the future. No details concerning the method are being given to the public.

FURNACE PRODUCTS.

The electric furnace owes its great utility to the facility with which its temperature can be regulated and especially to the great elevation of temperature which is obtainable. The amount of heat which is produced in a conductor is dependent upon the resistance of the conductor, the strength of the current, and the duration of the current flow. All of these are easily altered in magnitude. The temperature of the conductor is determined by the rate of development of heat and upon the facility which is offered for its escape. The ultimate stationary temperature is attained, when the rate of escape of heat is equal to the rate of its production. With a given rate of heat production the temperature rises as the facility for the escape of heat is lessened. The many available heat insulators make it possible to produce

any temperature which can be withstood by the conductors.

Calcium Carbide.—This substance, which is prepared by heating a mixture of coke and lime in an electric furnace, constitutes at present the most valuable electrochemical product with the exception of copper. Furthermore, its production requires more power than any other electrochemical industry. Kershaw estimates that in 1900 the power employed was 85,000 horse-power. The rate of production has been in excess of the rate of consumption and the result has been a decrease in the price of the product.

Its value lies in the fact that, when placed in water, acetylene gas is developed to the extent of about five cubic feet per pound of carbide. When burned in air the acetylene gives a flame of great intrinsic brilliancy and of pleasing color quality. Its richness in carbon tends toward a sooty flame. Swan inclines to the belief that the gas may prove of great value in metallurgy as a reducing and carbon carrying agent.

Calcium carbide is put in the class with explosives and dangerous chemicals. It is therefore subject to high freight rates for transportation and is associated with high insurance rates. Owing to the moisture ever present in the atmosphere, it suffers from freight transportation over long distances. These facts militate somewhat against its adoption as a source of illumination for small towns.

Carborundum.—This substance is carbide of silicon. It is an abradent, harder than emery, and is used for the same purposes as the latter. It is made into wheels, into tools of various forms, and into hones. The process of manufacture consists in heating electrically to a very high temperature, a mixture consisting of 60 per cent. pure sand and 40 per cent. powdered coke. To this mixture is added a small amount of common salt and sufficient sawdust to render the mass porous, so that gases, which are liberated in large quantities, may escape. This mixture is packed around a "core" of coarse granulated coke, the grains having diameters of from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch. An alternating current is sent through the core and produces heat, which does not easily escape through the surrounding mixture. The result is a great temperature elevation and the formation of the carbide, some of it being in the form of very beautiful violet-colored crystals.

Artificial Graphite.—Upon the common introduction of arc lighting it was noticed by many observers that the tips of remnant carbons were transformed into something resembling

graphite. The transformation extended only over portions of the tips which had been heated in the lamp to a high temperature. In the manufacture of carborundum it was observed that there was always produced a layer of graphite in the hottest part of the furnace. Upon investigation the conclusion was reached that graphite was not formed by merely heating pure carbon to a high temperature, but that a carbide must be first formed and afterwards be decomposed by the electric furnace heat. Therefore it is necessary to have some metallic salt or oxide mixed with the carbon before heating. In practice a good mixture consists of 97 parts of finely divided amorphous carbon comingled with three parts of iron oxide. This mixture permits of moulding into any desired shape, which is afterwards graphitized. The moulded articles are placed inside of a hollow carbon cylinder of about 20 feet in length and 20 inches in diameter. Current is sent through the cylinder in a longitudinal direction. As the articles become graphitized they acquire a greater conductivity, and the current which flows under a given impressed voltage increases accordingly. In practice the original impressed voltage is about 150 and the amperage about 300. As the graphitization proceeds, the voltage is decreased, although the amperage increases.

Barium Hydrate.—The United Barium Company, is manufacturing about 60 tons per day of this substance at Niagara. It is in the form of large crystals of an inch or more length on the edge. The manufacture by the electrical method has reduced the price of the product to one-quarter what it was previously. It is consumed in large quantities in the manufacture of pigments, in the purification of water, and in the recovery of sugar from beet molasses. In the last case a ton of hydrate is consumed in the recovery of a ton of sugar. The hydrate is made from crude barytes, this being the only natural source of barium. One equivalent of barytes is mixed with three of barium sulphate, and the mixture is heated in an electric furnace. SO_2 is driven off in the form of vapor, leaving barium oxide behind. This oxide, upon being placed in water, becomes hydrated. It is then allowed to crystallize.

Barium Cyanide.—This substance is made by the Cyanide Company at Niagara. It is used in the production of the other cyanides. Barium carbide, a substance which is the analogue of calcium carbide, is mixed with coke, and producer gas is passed through the mixture while it is being heated electrically. The

carbide has an unsaturated molecule, and the three free bonds of each carbon atom easily take an atom of nitrogen.

Phosphorus.—This is manufactured by the Oldbury Electrochemical Co. The electrical process is practically the same as the chemical process, except as to the method of applying heat. Calcium phosphate, either in the form of bones or of natural rock phosphate, is pulverized, mixed with coke, and placed in an electric furnace. Upon passing current through the mixture, the phosphorus becomes vaporized and is collected under water. The electrical process is cheaper than the older chemical one. This is because of two reasons. The temperature necessary to vaporize the phosphorus is quite high. There is therefore a large loss of heat when it is applied to the outside of the closed retorts containing the phosphate. This loss is not present when the heat is produced electrically inside of the retort. Again the practice of the older process was attended with much breakage of retorts, which is absent in the case of the newer.

Corundum.—The Norton Emery Wheel Co. is manufacturing five tons per day of this artificial emery, which differs from the natural emery in being absolutely pure and of uniform specific gravity. The natural variety lacks these two qualities which are essential in the manufacture of a perfectly satisfactory emery wheel. The process of production consists simply in the heating of bauxite in the electrical furnace until water is driven off and the remaining alumina becomes molten. Upon cooling, this latter assumes a crystalline form.

Iron and Steel.—There are a number of experimental plants in various parts of the world manufacturing steel directly from iron ores by means of the electric furnace. None of them has, however, passed the experimental stage. A number of alloys of iron, which are found useful and valuable in the manufacture of steel, are made in considerable quantities by means of the electric furnace. Among these may be mentioned ferro-chromium, ferro-titanium, and ferro-silicon. The first was used in the manufacture of armor plates intended for the cruiser made in this country for the Russian Government.

Silicides.—A very interesting line of substances has been produced by the Ampere Electrochemical Co., by means of the electric furnace, which it has termed *silicides*. They are the analogues of the carbides. Especially interesting is silicide of barium, which decomposes when placed in water with a development of hydrogen gas.

MISCELLANEOUS.

Electrolytic Condensers.—If two carbon electrodes in a solution of zinc sulphate have impressed upon them a small difference of potential, a current will flow until the counter electromotive force of polarization, resulting from the deposition of zinc on the cathode, is equal to and opposes the impressed e. m. f. Upon removing this latter e. m. f. without opening the circuit, an inverse current will flow until the zinc has been redissolved. Such a combination constitutes an electrolytic condenser, its charge being the quantity of electricity associated with the deposited zinc. Its capacity is this quantity divided by the polarization e. m. f. produced by it. This capacity is very large and increases with the area of the submerged portions of the cathode. Such condensers cannot be utilized with potential differences in excess of the maximum polarization e. m. f. They are also very inefficient owing to leakage currents necessary to compensate for local action. For use with higher voltages cells may be used in series. For the same volt-ampere capacity, electrolytic condensers occupy about the same space as ordinary condensers of paraffined paper and tin-foil. They have all the disadvantages associated with liquids.

The Electrolytic Rectifier.—This device in its latest form, as designed by Pollak, consists of an electrolytic cell containing a slightly acid solution of potassium phosphate as an electrolyte. One electrode is of plain lead and the other is of aluminium, which has been formed by macerating it for some time in a solution of caustic soda. If the pressure on a circuit, in which this cell is connected, does not exceed 200 volts, and the temperature of the electrolyte be under 40°C., then the cell will allow current to pass through it from lead to aluminium, but not in a reverse direction. This action is due to the formation of an insulating skin of aluminium hydrate over the surface of the aluminium when it is functioning as an anode. By means of such a cell one lobe of an alternating current cycle can be extinguished. The life of a formed aluminium plate is about 500 hours. The skin then breaks down and separates from the plate.

Electrolytic Interrupters.—The Wehnelt interrupter consists of an electrolytic cell with dilute sulphuric acid as an electrolyte, with a plain sheet lead cathode and with an anode of platinum wire, exposing a small surface (say $\frac{1}{4}$ cm²). The Caldwell interrupter consists of a cell, with almost any electrolyte, with both electrodes of carbon, lead, or other suitable material, the cathode

with its surrounding electrolyte being separated from the anode and its surrounding electrolyte by an insulating diaphragm containing one or more minute perforations. Upon introducing either of these interrupters into a circuit a series of sudden interruptions of the current will occur. These are due to the evolution of non-conducting gases around the platinum wire in the one case and in the diaphragm perforations in the other case. After interruption the circuit closes again as soon as the gases arise, due to their buoyancy. The frequency of interruption can be easily regulated. It increases with increase of impressed voltage, with decrease of inductance and resistance in the circuit, with decrease of exposed anode surface, and with increase of hydrostatic pressure at the place of interrupting gas development. When properly designed and used in the primary circuits of induction coils, these interrupters produce remarkable results. The suddenness with which the magnetic flux which is linked with the secondary, can be made to disappear is responsible for the high e. m. f. developed. The great amount of energy localized at the point of interruption of the circuit is destructive to the surrounding insulation. Lava is employed with considerable success.

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