HIGH ELECTROMOTIVE FORCE.

PROF. JOHN TROWBRIDGE.

I have lately perfected a large plant for the study of the discharges of electricity through gases which I believe is more extended, and on a larger scale, than any at present in existence ; and I have obtained some results with it, especially in the subject of high electromotive force, which throw light upon many mooted points. The source of electricity which produces the electrical discharges is obtained from ten thousand storage cells. From these cells I obtain very approximately twenty thousand volts, and by means of a peculiar apparatus called Planté's rheostatic machine, I am enabled to obtain over one million volts—which enables me to experiment with powerful discharges in air, more than four feet in length.

By the employment of storage cells in the subject of the discharges of electricity through gases, one can form a fair estimate of the amount of energy that is employed to produce the desired effects—for instance, the X rays ; while with the use of electrical machines or induction coils and transformers it is extremely difficult, if not impossible, to form an accurate estimate. Fig. 1 is an illustration of the type of cells of which the battery consists. Each cell is composed of a test tube 5½ inches long and ¾ of an inch internal diameter containing two strips of lead which are separated from each other by rubber bands and are immersed in dilute sulphuric acid. The surfaces of the lead strips are roughened by a mechanical device, and the cells are charged in multiple circuit by means of a dynamo machine. When the cells are properly formed, each one gives two volts and has an internal resistance of one-quarter of an ohm. The problem of insulating these cells was a serious one ; but it was practically solved by mounting the cells in sets of threes, in holes bored in a block of wood which had been carefully boiled in paraffine. The mechanician of the laboratory, Mr. George Thompson, devised a simple switch board which enables me to throw the cells into multiple or into series—to use the entire ten thousand, or suitable portions of this number. The battery gives eight amperes of current with twenty thousand volts, and this amount of energy is amply sufficient to kill a man. By accident an operator received the shock from only one thousand of the cells and was badly shocked and burned. It is prudent therefore in experimenting with this battery to use rubber gloves, even in throwing the switches, and it is recommended to employ only one hand covered with a rubber glove and to keep the other hand in a pocket.

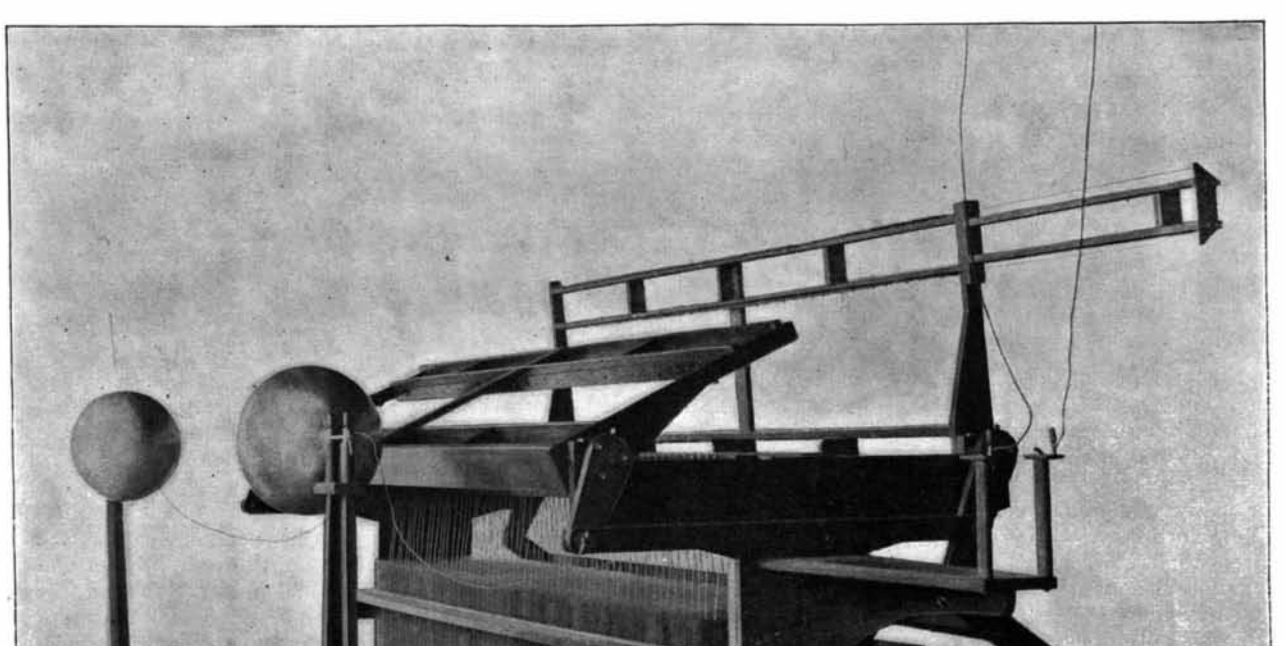

Fig. 2.—PLANTÉ RHEOSTATIC MACHINE.

I had at first intended to use this large battery in the study of electrical discharges through Crookes tubes, but I speedily found that X rays could not be excited by a difference of potential represented by twenty thousand volts. I found that at least one hundred thousand volts were necessary to produce them strongly, and I, therefore, resolved to construct a Planté rheostatic machine. This machine is simply an apparatus by means of which Leyden jars are first charged in parallel and are then discharged in series or by cascade. That is, all the inside coatings of the jars are connected to the negative terminal of the ten thousand cells, and all the outside coatings are connected to the positive terminal of the cells. When the cells are charged, the inside of one Leyden jar is connected to the outside of the next, and so on. In this way a very high electromotive force can be obtained. I use sixty Leyden jars in the form of plates of glass 15 × 18 inches coated on both sides with tinfoil. Starting with twenty thousand volts, I can exalt this to one million two hundred thousand volts. The accompanying illustration (Fig. 2) shows the Planté machine. The mechanician of the laboratory has introduced a notable improvement in the apparatus of Planté. Instead of a revolving commutator such as was used by the latter, Mr. Thompson employed lever arms, by means of which the jars were first charged in parallel and then discharged in series. It was found that the apparatus designed by Planté could not be used for higher voltages than one or two thousand without serious error and loss. By means of this apparatus I can study electrical discharges at least four feet in length—of great body—which are produced by an electromotive force of one million two hundred thousand volts. This apparatus possesses the great advantage that it enables one to obtain a fairly exact measure of such high voltage. When we reflect that the trolley car employs only

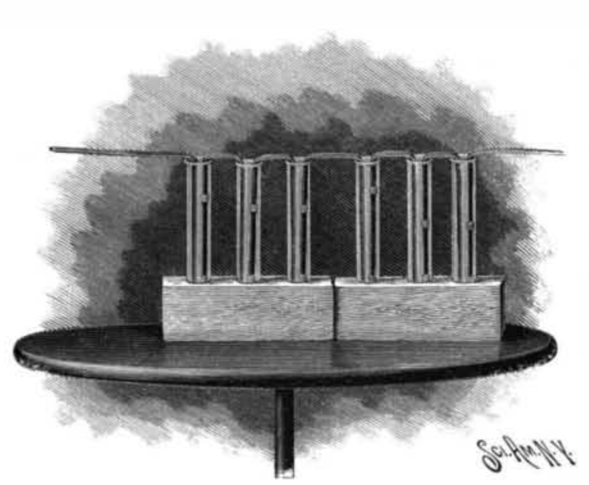

Fig. 1.–THE CELLS.

five hundred volts, and in the system of transmission of power from Niagara Falls it is proposed to use only ten thousand volts, it is evident that the effects produced by voltages of over a million must be of great scientific interest.

The study of such high electromotive forces immediately showed that previous estimates of the electromotive force necessary to produce a spark of a certain length were highly erroneous. For instance, Heydeweiler, a German investigator, believes that Prof. Elihu Thomson's statement, that a spark of five feet in length which he produced required a voltage of five hundred thousand, is very wide of the mark, and Heydeweiler maintains that one hundred thousand would be nearer the truth. I find that even Prof. Thomson's estimate must be more than doubled. Experiments with my apparatus show conclusively that the length of the electric spark between points separated by more than one inch varies directly with the electromotive force. A spark forty-eight to fifty inches in length requires an electromotive force of one million two hundred thousand volts, and a discharge of lightning one mile long would therefore require the enormous number of over one hundred million volts. In reflecting upon the development of such enormous energy in the air we can understand why telephone bells ring during a thunder storm ; why subsidiary sparks occur in networks of wires ; and why telegraphic messages are interrupted. The world beneath the thunderstorm throbs and pulsates with the oscillatory discharges of lightning.

One of the most interesting results of my study of powerful disruptive discharges is the discovery that such discharges will pass through glass tubes which are exhausted to such a high degree that they are said to contain a vacuum ; for the eight-inch spark of a Ruhmkorff coil prefers to jump around the tube to passing through the extremely rarefied space in the interior of the tube. Such tubes, however, are brilliantly lighted by a difference of potential of a million volts and readily show the X rays, and exhibit the skeleton of the hand in a fluoroscope. The so-called brush discharge from the positive terminal of the Planté machine extends visibly to a distance of over a foot. If the hand is exposed to this brush, it produces the well known X ray burn, such as various investigators have received in taking photographs of the skeletons of their hands, or in testing the condition of Crookes tubes by exposing their hands before a fluoroscope. The skin of the hand becomes irritable and turns a bright red color, especially after exposure to cold winds.

This result interested me greatly; for it proved that the so-called X ray burn could be produced by the brush discharge of very high electromotive force. The extent of the influence of this powerful brush discharge is very great. For instance, photographic plates in a plate holder carefully insulated from the ground and covered with a plate of glass half an inch in thickness show the inductive action of the brush discharge from the positive terminal, which is distant at least a foot. These inductive effects are manifested by star-shaped figures on a photographic plate. They are surrounded by dark clouds. When the burn on the back of one's hand produced by such brush discharges is examined by a microscope, similar centers of disturbance (in this case points of inflammation) are seen. Although the Leyden jars of my machine are carefully insulated on supports of vulcanite which are mounted on dry wood, which in turn is supported on rubber, I can obtain a discharge of more than two feet in length when I bring a point connected to the steam pipes to the neighborhood of one terminal of the machine. The other terminal of the machine is carefully insulated. This experiment shows conclusively that it is of no use to insulate lightning rods. My experiments thus far show that no vacuum which I can produce can resist the discharges which are caused by one million volts. It now becomes an interesting question whether there exists mechanical or chemical means by which a so-called vacuum can be produced which will resist such discharges.

ACCORDING to The London Electrician, a curious accident recently happened to a gas engine in the works of Messrs. Nalder Brothers & Thompson, London. Owing to a flaw in the shaft, it suddenly snapped off short outside the bearing. The flywheel, weighing 780 pounds, and the pulley were thus dropped on the floor while running at a rate of 300 revolutions per minute. Fortunately the belt remained on the pulley, and pulled up the flywheel without any serious damage resulting. A motor company was immediately telephoned, and forwarded at once an alternating current motor, by the aid of which the shops were running again the same evening.

THE art of making stockings in a frame was invented by the Rev. Mr. Lee in 1589.

Manufacture of Wax Cloth, Leather Cloth, etc.

The name wax cloth carries us back to those ancient days, several decades removed, when it was really attempted to waterproof materials by means of bees' wax or waxlike substances. At present everybody uses oils or varnishes, also rubber; the latter goods would be distinguished by name. The texture, says The Gummi-Zeitung, may be coarse or fine, but it should be homogeneous. Linseed oil, admixed or not with resins and other oils, is the chief ingredient which is generally applied to the stretched texture. When this is done by hand and brush, an almost obsolete process, of course, the first cloth is stretched near the floor and the others are fixed in succession above it, as the work proceeds. For large pieces the hand brush does not answer. Machines do their work more uniformly. The first coat requires the greatest care; the second coat may be applied as soon as the first varnish is no longer sticky or after thoroughly drying and rubbing the first skin, in order to remove all knots and blisters, etc. No color is admixed to the oil furnishing the first skin. A good wax cloth generally gets three layers and a further facing with a transparent varnish, mostly copal, diluted with oil of turpentine or petroleum. The layers of coloring matters should always be very thin. Wax cloth works are not desirable neighbors; the drying processes are apt to be malodorous. The first coat applied to canvas for packing should also be linseed oil, without any dye, lest the stuff should crack. The black color is produced by means of soot; the texture must be loose. The leather cloth, which came over from America about 1860, has a base of very firm and smooth cotton texture. This is stretched over rolls; the first coat consists of a solution of rubber in petroleum. Before this has completely dried, very finely powdered materials, French chalk, magnesia, ocher, zinc oxide, English red, ultramarine, soot, etc., are spread on the cloth; the sieves are pieces of silk gauze kept in reciprocating motion. The excess of powder is removed by means of soft brushes, and one or more coats of varnish are then applied; the outer skin should always be a transparent varnish. The tar which is to render sail cloth waterproof must be boiled for some time in closed retorts in order to get rid of the more liquid constituents; the distillation products of this operation are, of course, collected. Heavy cloth is tarred on both sides, and is not, as a rule, elastic. The admixtures to tar, certain soaps, rubber, tar oils, etc., do not supply any cheaper articles.

PUEBLO ARTS AND INDUSTRIES.

BY COSMOS MINDELEFF.

In a recent annual report of the Bureau of American Ethnology there appears a full and complete translation of an old Spanish document which is of the greatest importance, not only to the better understanding of the events which led up to and followed the Spanish discovery and conquest of the region we now term New Mexico and Arizona, but also to the student of Pueblo art and culture. The document referred to is Castañeda's narrative of the Coronado expedition, made in 1540, and has a curious history. Its importance is indicated by the fact that, of the hundreds of books and special articles which have been written about the Southwest, probably not one was finished without more or less extended reference to Castañeda. Yet, up to this time no complete translation into English had been printed, and, what is more strange, the fragments we have had were all, with one exception, taken from a French translation, while the Spanish text has been for many years in the custody of the Lenox Library, in New York City.

The narrative was written about 1560, some twenty years after the expedition, but, although search has been made for the original in Simancas, Madrid and Seville, where there are extensive collections of Spanish documents, it has not yet been found. The copy now in the Lenox Library was made at Seville in 1596, and is the one used by Ternaux-Compaus in preparing a translation into French, published in 1838, in his "Collection of Voyages." This French translation has now been shown to be very defective, for the Spanish was sometimes rendered with great freedom, and in several cases the translator failed to understand what the original writer endeavored to relate. Notwithstanding these radical defects, the French translation has been the source of practically all the knowledge of Castañeda's account that we have, and the publication of a complete English translation from the Spanish text will be of great value, especially as the publication is accompanied by the Spanish text itself, and by numerous related documents, in the original Spanish, with English translations, consisting of other descriptions of the same expedition. The translation was made by George Parker Winship, of Harvard University, than whom no one could be more competent, and he is also the author of the article referred to which is printed under the title "The Coronado Expedition, 1540–1542," in the annual report of the bureau referred to.

The value of Castañeda's narrative is largely in the graphic and, on the whole, consistent account he gives of the Pueblo Indians of 1540, their houses, manners and customs, arts and industries. The general truthfulness of the account is apparent, aside from all other proofs, from the fact that, although more than three and one-half centuries have elapsed since the Coronado expedition boldly plunged into the unknown country north of the Gila River, and eventually reached the Pueblo country, Castañeda's descriptions of the manners and customs of the Indians might almost have been written by a careful observer who traveled through the country fifteen or twenty years ago, before the advent of the railroads.

For over thirty years following the Pacific Railroad surveys in 1853–54, which practically first brought the Pueblos under our notice, there were tremendous controversies as to the location of the "seven cities of Cibola," the search for which was the prime cause of the Coronado expedition. It is now universally admitted that the Province of Cibola of 1540 and the Zuñi country of to-day are the same, and this complete identification adds much to the value of Castañeda's narrative. At the time he wrote the Zuñis lived in seven villages located in the valley of the Zuñi River, within a short distance of each other. One of these, called Haloua, has been partly covered by the modern village of Zuñi, built over its remains, while the others are located by well marked ruins in the vicinity.

The houses are described by Castañeda as being ordinarily three or four stories high, but consisting sometimes of seven stories, all with flat roofs. They did not have doors below, but the people used ladders, which could be lifted up like a drawbridge, and so the men could go up to the corridors (or terraces) which were on the inside of the village. The doors opened on these terraces, which served as streets. A reference to the illustration, showing some terraced houses in modern Zuñi, will demonstrate the essential accuracy of this description. The overhanging roofs shown here are mentioned also in the old narrative, and almost the only modern innovations to be seen are the dome shaped structure in the foreground, which is a baking oven patterned after those of the Mexicans, and the chimneys. The latter, although not of aboriginal origin, are one of the most picturesque features of the Pueblo villages.

Externally the chimneys consist of one or more old water jars of pottery, with the bottoms knocked out. The pots are placed one above another, sometimes in a series of seven or eight, and usually rest on a plinth or base of masonry or of adobe. In the interior there is often an elaborate smoke hood, formed of small sticks covered with clay, like that shown on the right of the picture illustrating Hopi grinding and bread making. Sometimes the hood is formed of slabs of stone, cleverly fitted and keyed together. Under the hood there is a fireplace of stone, and the whole structure is commonly placed in a corner of a room, the walls of which furnish two sides of it.

The illustration of terraced houses in Zuñi shows also some of the roof trap doors which are described in the ancient narrative as being "like the hatchway of a ship," for that peculiar construction has come down to the present day unchanged by the lapse of centuries. In the olden days, and to a large extent now, access to the first story rooms could be had only through these trap doors, as no large openings were made in the first story wall. Ladders are used from the ground to the first roof or terrace, and from this other ladders descended into the rooms.

When the Spanish soldiers led by Coronado stormed the first of the "seven cities of Cibola" they were feeble and worn out by long journeying and lack of food, but after an hour of stubborn fighting they conquered and took possession of the houses, where they found an abundance of food; for the Zuñis of old, like their modern descendants, were a provident people and laid by great stores of food. It is no uncommon thing to-day to find supplies sufficient for three or four years carefully put away in the inner rooms of the terraced houses. This trait, which is entirely at variance with the improvidence which characterizes nearly all the other Indian tribes, is one of the peculiarities of the Pueblos; and until law and order were established by the American conquest of the country in 1846, it made these people the target of numerous attacks by the surrounding wild tribes—the Utes, Navahos, Comanches and Apaches—who found in the Pueblo homes convenient and never failing storehouses, from which they could draw supplies of food.

The Pueblo Indians have always been successful farmers, and even under the unfavorable conditions which prevail in the sub-arid region where their homes are located, they seldom fail to secure good crops. In the dry, clear atmosphere for which New Mexico and Arizona are noted, food is easily preserved, and almost everything is dried for future use. Meat of all kinds is merely cut into long strips and hung in the open air for a few days, after which it will keep indefinitely. In the late summer and autumn months the somewhat somber yellowish gray tone of the houses is enlivened by strings of red peppers hung on the walls or festooned from the tops of the ladders; split squashes line the tops of the raised copings, while hundreds of square feet of the roofs are covered with peaches, split and whole, or with bushels and bushels of corn, dark blue, white, and parti-colored.

In fact, corn has always been the staple, the main reliance of these people. Among the Moki towns in northern Arizona, where the conditions are very unfavorable, large crops are raised without irrigation, although the average white farmer would be hard pushed to harvest the amount of seed he put into the ground. The methods followed are peculiar and distinctively Indian. The seed is always planted in what appears to be pure sand, generally in the bed of some intermittent stream or drainage channel, where deep down in the ground there is always a little moisture. The seed is planted at a great depth, often two feet or more; holes are made with a planting stick and a small handful of grain is dropped into each. The plants come up in thick clumps, instead of in rows, and are not thinned out; for when the summer rains come the water flows in its natural channels, and only heavy clumps could withstand its force.

The native corn or maize has practically disappeared within the past ten years. This is much to be regretted, for in sweetness and delicacy of flavor it was much superior to many of our so-called sugar corns. Perhaps in some remote districts away from the traveled routes it may still be found, but elsewhere the partial settlement of the country by whites and the constant passage of wagons has destroyed it. Where wagons go, there American corn is carried to feed the horses, and the Indians, tempted by the larger grain of our corn, have picked up the waste and planted it in their fields. The well known facility with which corn cross-fertilizes has done the rest, and the native species are now almost extinct.

However, corn is to-day, as it has always been, the distinctive Indian grain, and they have many ways of preparing it for food, but the bulk of the crop is dried, and, as occasion demands, is made up into bread. The illustration, which is from a photograph of a model in the National Museum in Washington, shows a group of Moki (or as they call themselves, Hopi) women and girls preparing piki or paper bread. In one room in each house there is a binlike trough along one side, placed directly on the floor and framed in with low slabs of stone set on edge. This bin is divided by transverse pieces of stone into three or four compartments, and in each of these there is mounted on a slight incline a flat piece of rough stone, usually black lava, which is abundant in that country. This is the metatl of the Aztecs, the mitata of the Mokis, and in connection with a small piece of flat stone which is rubbed back and forth over the lava slab, is the grinding mill of these people.

The corn, having been previously soaked in water to loosen the hard outer skin, is thrown into the first compartment, where it is rubbed between the stones into a coarse meal. This is passed over into the next compartment, where it is ground finer, and then into the next, where it emerges in a fine meal, as fine as our wheaten flour. Castañeda, in his account of Cibola, says that a special room is set apart for the grinding of the corn, and that this room contains a furnace and three stones made fast in masonry. Three women sit down before these stones; the first crushes the grain, the second brays it, and the third reduces it entirely to powder. The accuracy of this description is apparent.

The fine powder which comes from the third grinding is mixed with water to a thin batter, which another woman spreads with her hand on a heated stone, and immediately after peels off a thin layer about the thickness of heavy manila paper. A number of sheets of this peculiar bread are shown piled up in the center of the picture in front of the mealing bin. Ordinarily it is of a dark blue color, as it is made from blue corn, but for ceremonial feasting it is made of pink, or yellow, or white, or variegated corn, and in each case partakes of the color of the grain. When fresh, this bread is quite palatable, but when a day old it becomes very brittle; and, as it is usually made without salt, it tastes much like sawdust.

The flat stones on which the paper bread is baked, one of which is shown on the extreme right of the picture, are considered very valuable and often descend from mother to daughter through many generations. Their manufacture is a secret process, carried on only by certain old women of the tribe at a distance from the villages and accompanied by numerous rites and ceremonies. A certain kind of stone must be selected in the first place, and it must be of even grain and free from cracks or flaws. Then, after being rubbed smooth, it is treated with pitch and perhaps other ingredients, with frequent exposures to fire and smoke, and at intervals certain incantations and formulas must be repeated. At one stage in the preparation the strictest silence must be observed, as, it is said, a single word spoken then will crack the tablet. If all goes well, the final product is a stone of jet black color, instead of the light yellowish gray of the original sandstone slab, with a highly polished surface, from which the flakes of paper bread peel off readily. If, however, there was any flaw in the stone, or if some of the formulas or incantations were omitted or wrongly pronounced or spoken in the wrong order, the stone