water supply excepting that gathered during the brief rainy season of the winter months. Isolated from the interior by the precipitous coast range of mountains, there were no streams of sufficient permanence or volume to supply the 2,100 acres included in the ranch. With water for irrigation, Hope Ranch possessed every requirement for a semi-tropical paradise; without water it was little more than a barren waste.

The problem has recently been solved, and a supply permanent and sufficient for all purposes has been gained by boring into the sides of a mountain and tapping a plentiful reservoir there concealed.

Santa Ynez Mountain, which rises to a height of 4,000 feet, about five and one-half miles distant from the ranch, is distinguished as being the dominant peak of the neighboring range. It was noted that all of the little streams with permanent flow had their sources in this mountain. Geological investigation disclosed that Santa Ynez was composed of a stratum of shale 3,000 feet in width inclosed at either end by walls of hard, impervious sandstone several hundred feet in thickness. The flowing creeks had cut channels or cañons through the sandstone at elevations of from 1,900 to 2,200 feet above the sea. The project was entertained of boring a tunnel through the sandstone and into the vertical stratum of shale at an elevation of a thousand feet below the sources of the streams, with a reasonable certainty of striking an inexhaustible flow when the sandstone was pierced and the stratum of shale rock, saturated with moisture, attacked.

The project met with favor, and for a year past the work has been unremitted. Three months ago the shale was entered and water found. A total length of 500 feet into the shale has been driven and a daily flow of 2,721,600 gallons secured; more than enough for all purposes of the ranch and allowing a large surplus for irrigating outside lands, as well as affording a welcome addition to the supply of the municipality of Santa Barbara.

The tunnel itself is 1,377 feet above the sea. The water will be conducted through 7 and 8-inch pipes to reservoirs at Laguna Blanca, with a capacity for 200,000,000 gallons, situated 138 feet above tide, and also to another lake of less dimensions 398 feet in elevation.

BEHR'S MONO-RAILWAY.

This idea is gradually being brought into practical shape. In the early days of the proposed Manchester and Liverpool Behr Railway, a good deal was said about high speeds and safety when running round curves, as though all that was necessary to be done was to provide means to take up the centrifugal stresses due to the train only, says The Electrical Review. Passengers did not count, and we had to point out that if speeds of 100 miles per hour were run round curves of what we will term short radius, the passengers would hang like wet towels over the seat backs. Mr. Behr, in fact, like many other enthusiasts, has been too ready to assume all the virtues for the railway system he is pushing, and has been hiding his head in the sand in the hope that by so doing the sight of others would be similarly obscured. But doing this cannot annul the laws of mechanics, and in his recent paper on the subject which we have reprinted, we are glad to see that definite statements have taken the place of general platitudes. Thus we are told that a speed of 83 miles per hour was recorded round a curve of 540 yards radius, and we are now told that on the proposed line the minimum curve will have a radius of 750 yards. As regards speeds of 120 or 130 miles per hour we do not think much. They should be easy to attain on a sufficiently straight line. It is simply a question of power, and Mr. Behr can no doubt find out from electrical constructors how much power he must put into a car of 60 or 70 feet length to secure such speeds, how large or how many must be the motors to move such a car in 20 minutes between the two cities. On this subject Mr. Behr tells us nothing beyond that he will have a station of 7,500 horse power capacity. This is for a ten minutes' service, and there will be four trains running at one time, so that the motive power of each train is apparently calculated at nearly 2,000 horse power for one carriage only. We should like to hear more about the power and less about the brakes. The stopping of a train can be effected just as quickly as the sitting power of the passenger will allow, for it can be done by grip brakes. The only consideration is that the structure must be such that the grip brake employed shall not rip it up. In bridge work it is usual to calculate the braking effect of the train as regards its buckling effort on the chord on which the stress is resisted, and very careful calculations will need to be made in regard to the destruction of the stored energy of a car at 130 miles per hour when quickly brought to rest by a grip brake. Especially at points of curvature will this effect be apt to cause danger, for it is only on a straight line that the rails can resist as a strut. Thus, as regards both the safety of the proposed speed and the possibility of rapid retardation, we see no reason to doubt the system, but we should like to see figures of the power required and of the size and speed of the motors, the space they are going to occupy, and so on.

As regards retarding effort, it is stated that speed can be retarded at the rate of three miles per hour per second. Thus a train at 60 miles per hour should be stopped in 20 seconds, and one at 110 miles an hour in 37 seconds, during which time it will run 995 yards. This is with the Westinghouse brake, while with a magnetic brake acting on four grip rails, a train at 110 miles per hour should be stopped in emergency in 500 yards. Prof. Carus-Wilson, in the discussion on the paper, however, doubts the friction brakes being possible, because so much energy has to be dissipated. Would it not be possible to carry water to use on the friction brake at times of emergency? Lieut.-Col. Alan Cunningham pointed out the necessity for tilt round curves. We want to see the Behr railway at work, and are glad to see that the effect of centrifugal force is more fully recognized than it was even a year ago. High-speed running is fully as easy and smooth as low-speed work, and the whole question resolves itself into one of power and straightness. Those who know anything of the size of a 30 horse power tram-

car motor will naturally ask for information about the motors to absorb 2,000 horse power. Where are they to be placed? What is their speed and diameter, and do they really need to be of such a power as the central station estimate appears to indicate?

INDUCTION COILS AND INTERRUPTERS.

THE rôle of the induction coil, which is a very interesting apparatus and readily lends itself to the performance of a number of amusing experiments, has become very important since the inception of researches upon the Roentgen rays and wireless telegraphy. As for interrupters, they have been the object of particular study, and many models have been devised that are giving satisfaction.

In the present article it is our purpose to describe

FIG. 1.—THE GUERRE INDUCTION COIL.

some new and simple forms of these apparatus that have given very good results.

Fig. 1 shows an induction coil of the Guerre type. Here the secondary coil is wound in sections on a series of flat disks 0.04 of an inch in thickness. The silk-covered wire, while being wound around these, is passed into a bath of insulating material. The disks are afterward mounted, one alongside of another, upon the primary of the coil and are connected in pairs and in tension. In his coils for X-rays, M. Guerre connects the extremity of the negative primary wire with the end of the secondary coil opposite the positive primary wire, grounding the two and also the negative pole of the battery. He thus obtains what he calls a "unipolar coil." This coil permits of producing a 3 or 4 inch spark that gives a good illumination of the bulb. In experiments in radiography and fluoroscopy sufficiently rapid interruptions are obtained by means of an ordinary vibrating interrupter controlled by a spring hook.

M. Guerre has, in addition, devised two new mercury interrupters for powerful induction coils and that are worthy of mention. The first of these (Fig. 2) is entirely separate from any coil. It consists of a bent strip of steel, A, that carries

accelerates or diminishes the vibrations. A plunger fixed to the ebonite cover of the cup permits of regulating the level of the mercury during the operation, and, consequently, the duration of the passage of the current.

These new arrangements are very ingenious, and permit of obtaining very interesting results in the study of Roentgen rays and Hertzian waves.—For the above particulars and the accompanying engravings we are indebted to La Nature.

HIGH-POTENTIAL PHENOMENA.*

By A. P. CARMEN.

IN the earlier history of electricity there was nothing that excited the interest of the world more than the electric spark. It is hardly more than two centuries since the first electric spark was observed. We of this day have become so accustomed to startling discoveries that it is only with difficulty that we can understand the childlike amazement with which men in the eighteenth century heard of electric sparks an inch or so in length, and how the shock of crude little Leyden jars with their faint illumination was a matter for a year's wonderment and letter writing. The rapid development of galvanic or current electricity, the invention of the dynamo and of

FIG. 2.—MERCURY INTERRUPTER.

the electric motor, and of alternating-current apparatus, and their extended use for lighting and power seemed to engross for years men's thoughts and activity, and high-potential or static electricity, with its less understood forces and more elusive phenomena, attracted less and less attention until a dozen years ago. There were so-called practical men who advocated writing our text-books on physics and electricity with static electricity relegated to an appendix. Only in the laboratory of the scientist was it regarded with much interest. All this is now changed. The disruptive discharge with its electrical spark has been found to be the center of a group of phenomena all-important in our understanding, not only of electricity and magnetism, but of light, radiant heat, and even of some fundamental properties of matter. And not only in pure science but in its industrial applications, the phenomena which center about and accompany the disruptive electric discharge are holding the interest of the electrical world. From the spark go out waves, traveling with the velocity of light, and these waves are the bearers of messages, giving us wireless telegraphy and wireless telephony. In connection with the oscillating static electric field, we get also some of the most beautiful illuminations

FIG. 3.—MERCURY INTERRUPTER.

at its extremity a small rod which enters an iron cup, B, containing a layer of mercury covered by a layer of petroleum. This strip is kept in constant vibration by means of an electro-magnet supplied by a local circuit of batteries. Another circuit is formed by the outgoing wire of the battery, the primary wire of the coil, the vibrating strip of steel and the mercury cup, which is itself connected with the other pole of the electric source.

The interrupter shown in Fig. 3 is still simpler than the one just described. It consists of a strip of steel bent and curved according to the contour of the soft iron of the coil and exceeding the latter by a few fractions of an inch. The rod placed at the extremity of this strip enters a receptacle, A, containing mercury and petroleum. A spring held by a set screw

of vacuum tubes. There are those who think that the electric light of the future is to be that from these electric discharges of high potential and of high frequencies in vacuum tubes.

Another circumstance that has forced these phenomena upon the attention of practical electricians is the introduction into commercial work of alternating currents of high potentials. It is only a few years ago since we were wrestling with the problem of handling a thousand volts. To-day, the use of 10,000 volts is not uncommon, while 20,000 and 30,000 volts are perfectly feasible, and even 100,000 volts have been considered possible. With such pressures

* Lecture delivered before the Illinois State Electric Association at the recent meeting in Champaign, Ill. Mr. Carmen is professor of physics in the University of Illinois.—Western Electrician.

the problems of electric discharge become the serious ones. At such potentials it becomes so very apparent that we are dealing with forces far beyond the little wires which we have formerly fancied carried the power. We propose this afternoon to review rapidly some of the fundamental phenomena of static-electric discharges and to show you one group of these phenomena, namely, that generally known as the Tesla experiments.

In this subject there is an advantage in starting with the very elements, so as to connect our ideas with familiar phenomena. I hope you will therefore pardon me if my account is very elementary for a few minutes.

Let us start with the well-known experiment of our school days—that of the fur and the vulcanite rod. We rub them together, and, upon separation, we find they are electrified or have charges of electricity. By this we usually mean that they have the property of attracting light objects, as pieces of paper, pith balls, or thin gold leaves. If we perform this experiment in a dark room we shall see still other phenomena, namely, a glow and even small sparks on the fur and along the rod where the two have been in contact. We get this glow and the sparks more pronounced when we electrify an insulated metal ball. This we can do by rubbing the electrified vulcanite along the metal body. The vulcanite rod thus communicates its electrification to the ball. When a body is thus electrified it has a tendency to give up its electricity to surrounding bodies. We describe this tendency by the term electric pressure or potential. We say the body tends to discharge itself because the electricity is at a pressure or potential higher than that of a neighboring body. Some substances offer very little resistance to this pressure. Thus, a piece of copper wire will allow an easy passage to the electricity from an electrified body. Such substances are called conductors. Other substances offer great resistance to the passage of the electricity. Rubber, glass and air are substances of this kind. They are called non-conductors or insulators. But the electric pressure or potential of a body may be made so great that it overcomes the resistance of the insulator and breaks through it. We then have the disruptive discharge. This may take the form of a spark, or it may be a phosphorescent glow or a brush discharge. In each case this is produced by the pressure or potential of the electrified body. We have the electricity constantly tending to flow from points of higher potential to points of lower potential.

How can we produce this high difference of electric pressure or potential, that is, a pressure capable of breaking through layers of air and giving disruptive discharges? We shall not try to mention all possible methods, but shall notice four, which are used frequently in the study of high-potential phenomena, and with which you are familiar from your papers and books. They are, first, static electrical machines, such as the Holtz and the Wimshurst machines; second, primary and secondary batteries; third, the ordinary induction coil or transformer; fourth, the Tesla high-frequency induction coil.

The static electrical machine is a piece of apparatus that cannot be said to have graduated yet from the physical laboratory, but since the discovery of the Roentgen or X-rays and the revived interest in electric-discharge phenomena, it has attracted more attention. We have several forms of the machine, as the Holtz, the Toepler and the Wimshurst machines, all of which are represented in the physical cabinet of the University of Illinois.

A description of these machines is not necessary here. It is sufficient to know that by revolving glass plates near similar fixed or moving plates we can get those plates highly electrified, and that, by certain devices, we can collect the electrification, so that a high difference of potential is produced between the discharge terminals of the machine. Static electrical machines are high-potential generators, but they give very small quantities of electricity; that is, the current is exceedingly small, but under very high pressure. To increase the quantity we use multiplate machines. Such machines do not have a higher potential, and hence do not give longer sparks, but they give us thicker and more continuous sparks; that is, they produce more quantity. We have been constructing here in the physical laboratory of the university a Wimshurst machine with twenty plates. Each plate is two feet in diameter, and it gives a heavy spark seven inches long [demonstrating].

The second method of producing an electrical pressure is by means of batteries. The terminals of an ordinary gravity cell are electrified. We have delicate instruments in the physical laboratory to show that they have the same kind of attraction as the terminals of the Holtz or the Wimshurst machine, but the pressures or potentials in this case are almost infinitesimal compared to that of the Holtz machine. Experiments made many years ago by Lord Kelvin show that it would take about 5,500 gravity cells joined in series; that is, so as to add their potentials to produce a spark one-twentieth of an inch long in air. The potential of a gravity cell is just a little more than a volt. This is our unit of electric pressure; that is, to produce a spark one-twentieth of an inch long in air requires 5,500 volts. To produce a spark of four inches requires probably over 125,000 volts, or as much as would be given by 125,000 gravity cells in series. But the current given by one gravity cell through a mile of telegraph wire is possibly greater than that given by this static machine. You can see that the galvanic cells are not well adapted to laboratories of limited means to the study of high potentials. Prof. Trowbridge, of Harvard, has a battery of 20,000 small storage cells, each giving him two volts, so that he can get a direct pressure of 40,000 volts; but that is the only case I know of where such very high potentials have been secured directly from a battery. We can, however, get high pressures from galvanic currents by the use of the induction coil. The induction coil consists of two separate coils of wire carefully insulated and fixed over a common iron core. A current, which is made and broken rapidly or is reversed rapidly, is sent through one coil and a difference of potential or electric pressure is by this means produced at the terminals of the other

coil. The first coil is called the primary coil and the other the secondary coil. The modern alternating-current transformer is, as you know, this induction coil adapted to commercial work. The induction coils which we have here are step-up transformers; that is, they enable us to take the low-pressure current of the primary coil and raise it to the high-pressure current of the secondary. This is accomplished by giving a proper ratio to the number of turns on the two coils. In this induction coil [indicating] we have about 14 volts' pressure in the primary circuit, and in the secondary we get 150,000 volts, possibly more, for it is hard to measure potentials that break across so many inches of air. I may say that the construction of a coil to give such pressure requires the greatest care. It means winding and insulating on the secondary coil of from 15 to 20 miles of wire of about the size of a hair.

There is another form of the induction coil which has attracted a great deal of attention. It is the famous Tesla coil, the form which Mr. Nikola Tesla used a few years ago in some brilliant public lectures which he gave before the electrical engineers of New York and of London. The Tesla coil is an induction coil with very high insulation and without any iron core. The Tesla coil which we have here [indicating] has the primary coil wound on a hard-rubber spool and this separated by several inches of air from a secondary coil which is wound on a glass tube. Often an oil insulation is used. Through the primary coil we send the high-potential discharge of our induction coil, or we can send the discharge of the Wimshurst machine. We thus have a high pressure in the primary and a still higher pressure in the secondary. But possibly the most important part in Tesla's coil is that we have a very fast interrupter in the primary, and so we get a very high frequency in our secondary. In the primary of the ordinary induction coil we have a vibrating interrupter which makes and breaks the current possibly 500 or 600 times a minute. Mr. Tesla introduces an interrupter which interrupts several million times a second. We introduce in the secondary of the first induction coil a Leyden jar across the ends, and then pass this discharge through the primary of our Tesla induction coil. Now the spark of a Leyden jar is oscillatory. That which looks like a single flash is, in fact, a series of oscillations back and forth of hundreds of thousands a second. The discharge of a Leyden jar is like the release of a spring. It vibrates backward and forward on each side of its final position of rest. The first man to show this fact was our own famous countryman, Joseph Henry. We take advantage of this oscillatory character of the Leyden jar discharge in the Tesla coil. The current induced in the secondary of a Tesla coil then differs from the current in an ordinary alternating-current circuit in two ways. First, it is at an enormously higher pressure, and, second, it oscillates so much more rapidly; that is, it has a higher frequency. In an alternating circuit we commonly have about 125 alternations a second. A Tesla coil will often have a million alternations a second, and Prof. Trowbridge, of Harvard, records one with 10,000,000 alternations a second. This high frequency plays a very important part in the phenomena that accompany the discharges from a Tesla coil.

We will now notice some of the phenomena of these currents. The first thing, and possibly the most striking to many of us, is that the wire terminals are all aglow. The electrification seems to leap from the wire at every point. In fact, it does escape in every direction. The excitation that we have here is not confined to the wire; in fact, in some cases it would rather go through the high resisting air than along the metal conductor. We have a loop of wire connecting the terminals of the coil and coming close together at one point, but still leaving a very considerable air gap. Now, to ordinary currents, the resistance of that air gap is thousands of times greater than that of the metal wire, but to these high-frequency currents the wire offers such a high resistance that the currents will jump across the air gap rather than go along the wire. This resistance of ordinary conductors of high-frequency currents is called impedance. Many of you are familiar with it in connection with lightning discharges. A lightning discharge is an oscillating current of high frequency; it will leap across air gaps rather than go around coils of wire. In our electric-lighting plants we make use of this fact by fixing convenient air gaps so as to protect our dynamos and other electrical apparatus. In the case of the current that we get from the Tesla coil the frequency is so high that the human body offers an enormous resistance, and these currents can be handled without injury, and that in spite of their high potential. The current glides over the skin without injury to the body. With ordinary frequency this amount of electricity would probably be fatal.

Striking as are these discharge effects in air at ordinary atmospheric pressures, they are still more striking and brilliant when they take place through tubes from which the air has been more or less perfectly exhausted. Take, for instance, a large glass tube connected to the air pump so that we can exhaust the air from it. It has two metal terminals, one entering at the upper end and one at the lower end, and we connect these to an ordinary induction coil. The discharge will not take place at ordinary atmospheric pressures, but as we exhaust the tube and the air becomes rarer the discharge begins to take place and streams of purple light are seen to come from the positive terminals. At a still higher rarefaction this purple light brightens into a beautiful reddish-purple spindle, and at higher exhaustions still the whole tube becomes aglow with a beautifully striated light. This is about as far as we can go with a mechanical air pump in our exhaustion. For higher vacua we use mercury air pumps and thus get those beautiful luminous effects that about thirty years ago Sir William Crookes discovered. Now these light effects are somehow connected with the rapid movement of the remanent electrified gas molecules—at least that is the way Crookes looked at it. In the tubes which Crookes used the discharge is between metal terminals or electrodes which are inserted through the glass walls of the tube.

A striking phenomenon in connection with these

high-frequency electric discharges which we get from a Tesla coil is that a vacuum tube need not have a terminal or electrode in order to be lighted up. Here [indicating] we have some highly exhausted tubes, a bulb and this long snake-shaped tube. They are simply glass tubes with no metal electrodes. We bring them into the region about this high-frequency discharge coil, and you see how they immediately light up. Somehow the remaining gas molecules have been set in motion, and we have this electric glow. You can see the same phenomena when we bring these tubes near the large Wimshurst machine. Perhaps this illumination is not very bright to you, but by taking tubes containing phosphorescent substances we can get a light which, if it is not as brilliant as our modern incandescent lamps, yet it may possibly compare with the tallow dips which our fathers had to use. Mr. Tesla sees in these tubes the possibility of the electric light of the future. We could have the ceilings of our rooms electrified, and then our lamps, these vacuum tubes, would light up anywhere in the room, electric lamps without wires. Indeed, we might go still further and make the walls of our rooms vacuum chambers, which would give a soft, diffused light similar to the light of day when an electric discharge was started in the room. But, even if this dream be never realized, and we still have to use our present fragile and low-economy electric lamps, this fact of the lighting up of these tubes in this whole region tells us something about electricity and electrical forces which is rightly regarded as one of the most brilliant and far-reaching discoveries in physics of the century.

It was the clear mind of Michael Faraday that first saw that electricity was something that extended away beyond conductors; but it was James Clerk Maxwell, one of the few geniuses of all time, who first grasped completely the grand conception that electricity is a movement and displacement in an ether which extends through all space and permeates all bodies. When a stone is dropped in a still pond you have seen how the waves go out in ever-widening circles, carrying the energy to the farthest shore. You know how the air vibrates from the pulsations of a tuning fork transmitting the sound energy. Thus the ether may transmit energy. The disturbance set up by the electric spark is transmitted out in waves through the ether, traveling with the velocity of light, for light itself is but an electric disturbance, a wave motion in this same ether. It is only a dozen years ago that this grand conception of Faraday and Maxwell was verified completely by Hertz. To-day we use the little electric sparks to send out electric waves, and Marconi has invented an instrument so sensitive that it is said he can detect these waves fifty miles and more from the spark that started them. It may be that you and I will see the power of Niagara transmitted to distant points by waves in the electric ether, as even now the energy of the sun is transmitted to us across space in this ether. This is the suggestion of one of our most practical electrical engineers, and who can say that this is a mere dream? Thus is the little electric spark which excited the wonder of the eighteenth century revealing to us things still more wonderful, and suggesting to us possibilities of nature far beyond our boldest dreams of a very few years ago.

NUT CRACKING BY ELECTRICITY.

An industry but little known, which has grown from small proportions in the last three years until now hundreds of thousands of dollars are invested in it, and it gives employment to several thousand persons, is that of cracking nuts for confectioners and fancy cake bakers. Three plants have been established in St. Louis. The output of the largest is some 1,500 tons annually, representing 125 carloads of nuts.

The work is done by machinery principally, electricity being the motive power. The process is slow, each nut having to be fed to the crusher by hand lengthwise. After the shell is cracked, the nut falls into a receptacle, from which it is taken and winnowed by an air blast. The meat is picked from the crushed shells by hand, women and girls being employed in this work.

The meats are assorted, wholes and pieces being sold separately. The latter go largely to confectioners, who use them in the manufacture of nut candy. The wholes go to fancy cake bakers for use in nut cakes.

Domestic nuts are the only kind broken here. They include the pecan, hickory, butternut, walnut and hazel nut. The foreign nuts are cracked before importation, a saving of 50 per cent in freightage being thus made.

The machinery employed in cracking nuts is expensive and covered by patents. It is closely watched to prevent any invasion of the rights of the inventor, and access to the workroom is jealously guarded.

When the kernel of the nut is extracted, it is placed in cold storage to prevent it from becoming rancid. The meat is so rich that when packed the oil is slowly but surely squeezed out of the kernel, rendering it unfit for market.

In addition to the machinery employed, large quantities of nuts are cracked by hand in a press-like arrangement worked with a lever. Here, too, only one nut is cracked at a time. The daily output of an electric machine is about seventy-five pounds. Five-eighths of the people employed in nut cracking are girls, their delicacy of touch being found well suited to the business.

St. Louis is the center of the distribution of the products of the Southwest, Texas, Tennessee, and Louisiana. Many million pounds of pecans are distributed through this market annually. The kernels are sold largely in the East, New York, Philadelphia, and Boston being heavy consumers.

The pecan is the principal nut used for the trade by the plants here, and most of the pecans are purchased in Texas. The Louisiana product is preferred by them because the shell is not so hard as that of the Texas nut, and consequently the work of extracting the kernel is comparatively easy.

There is no waste in the nut-cracking industry. Such of the meat as would be unfit for the trade for any reason is utilized, the oil being extracted and sold to manufacturing chemists. Even the hull is utilized, being used as fuel. The shells of the pecan, walnut, and hickory make a specially bright fire.