THE NEW INSTRUMENT OF EXECUTION.

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FOR several years the writer has carefully studied the details of the many accidental deaths from electric-lighting circuits, in order to determine their causes and, if possible, to discover means for their prevention. Three classes of current are in commercial use: the continuous, which flows steadily in one direction; the pulsating, whose impulses are intermittent, though constant in direction; and the alternating, which is a series of rapid reversals. Investigation showed that the first and second could by proper safeguards be made harmless to the general public, while the third was by its very nature hopelessly deadly.

Early in June, 1888, these conclusions were published by me in a prominent New York daily, with a description of the necessary protective apparatus. At once I was fiercely and bitterly attacked by the adherents of certain alternating-current interests, who loudly proclaimed their current to be "perfectly safe." Feeling sure that many more deaths would be occasioned by dealing carelessly with this deadly agency if it were regarded as harmless, it seemed an imperative duty to prove my statements to be true, and I asked Mr. Thomas A. Edison for the loan of some necessary apparatus which could not be elsewhere obtained.

His enemies have not yet forgiven him for his great kindness in permitting me to make the proposed experiments in his magnificent electrical laboratory, which is, beyond doubt, the finest in the world. These experiments proved that my suggested apparatus would save life and rob the continuous current of danger, so far as the public was concerned, and that the alternating current would produce instant and painless death at very low pressures. This work, which was for the purpose of protecting life,

gave me expert knowledge of death-currents, and brought to me a request from the New York State authorities to select and purchase for them the apparatus for electrical executions.

I was reluctant to undertake this, knowing that it would subject me to violent abuse, but I felt that this use of the "safe and harmless" current would educate the public to handle it with caution and thus save many lives. I declined to assume the responsibility of designing for this purpose a machine whose use would be an experiment with human life, but preferred to select a type of dynamo which had killed many innocent men who made accidental contact with its deadly wires. My experiments showed that the greater the number of alternations per second, or the longer the time of contact with the subject, the less was the pressure required to destroy life. It is therefore evident that the death-dealing qualities of various currents are approximately proportional to the product of the amount of electrical horse-power exerted in the body of the subject, the length of the contact in seconds, and the number of alternations per second.

The first factor is found by multiplying the current strength in ampères by the pressure in volts and reducing the product to horse-power by dividing by 746. By what is known as Ohm's law, the current strength will be always equal to the electrical pressure divided by the resistance in ohms. Therefore the amount of electrical horse-power received by a subject depends directly upon the resistance encountered in passing through his body. There has been a great amount of nonsense brought forward recently on this subject by numerous electricians and physicians who testified that the resistance of the human body could not be accurately determined because of its mysterious and enormous variations!

The greater portion of the electrical resistance of a living animal is in the skin, due to thickness of the epidermis, the presence of insulating fats and oils, and the lack of sufficient moisture. This resistance may be reduced by increasing the area of contact or the amount of pressure between the skin and the electrodes conveying the current, or by increasing the amount of saline conducting fluid in the tissues of the epidermis. If any one of these factors is permitted to vary, wide variations in the result are produced; or, in other words, a measurement of the resistance of a human body includes the resistance of the body

itself plus the resistances of the points of contact, which may be enormous. A New York physician recently cited a case whose electrical resistance was said to be 500,000 ohms, which is quite a high degree of insulation; in such a case the measurement must have been made between the pointed tips of long Chinese finger-nails bearing lightly upon the electrodes. One thousand ohms would represent the resistance of the body itself, the remainder being the resistance of the contacts and finger-nails. To settle this matter, Mr. Edison had resistance-measurements made of between four hundred and five hundred men, and with his characteristic originality devised means for obtaining practically constant factors. Two jars were filled with a weak solution of caustic potash and connected to the measuring apparatus. Each man dipped his extended hands into the liquid until the ends of the middle fingers touched bottom. The hands were immersed for thirty seconds before readings were taken. This delay permitted the potash to act upon the oil in the skin, converting it into a soap soluble in water, thus practically eliminating the resistance of contacts and epidermis.

The average resistance was found to be 1,000 ohms and the highest but 1,970; the variation being evidently due to the amount of skin surface in contact with the liquid, since the number of ohms per square inch of surface was practically the same in all cases in which the area was measured. The report of Mr. Edison's chief electrician, Mr. A. E. Kennelly, upon these tests is most conclusive. In ordinary applications of electricity to the human body, when the skin is not, by Mr. Edison's method, specially prepared to receive it, the passage of the current itself rapidly reduces the resistance of the epidermis by bringing into it more of the saline fluids of the body. The greater the pressure of the current used the more rapid is the fall of resistance.

Bearing in mind that the amount of electrical energy received by a person who accidentally touches two charged conductors depends upon the area, pressure, moisture, and duration of contact, as well as upon the difference of electro-motive force between the points touched, it is easy to explain the miraculous tales of the men who, often in good faith, claim to have received the "full force of the dynamo" without serious results. The man with the mandarin nails might receive 3,000 volts on his claw-tips without wincing, but he ought not to boast that he had "taken the

entire charge." A parallel case would be that of a man who survived a rifle-shot because the ball spent its force on a pocket-book and merely bruised his chest.

The physical effects of an electrical current upon the human body are three-fold. By what is called electrolysis, the saline fluids which form the conducting medium are decomposed, the hydrogen and acids appearing at the negative pole and the oxygen and bases at the positive. This decomposition and the passage of the current itself produce heat. As the volume of the hydrogen thrown off is double that of the oxygen, a movement of the liquid toward the negative pole is set up. Aside from this, a decided motion of the liquid in the same direction is caused by the passage of the current itself. If a vessel containing a conducting fluid be divided into two sections by a vertical partition of parchment, and an electrical current passed from one side to the other, the liquid surface will be raised on one side of the membrane and lowered on the other. In case the alternating current is used, the surfaces will remain level, but the constant change of direction of the electrical current will produce corresponding alternations in the movement of the fluid, thus delivering to the membrane a series of blows whose force depends upon the amount of electrical energy expended. Thus a man receiving a pressure of 1,000 volts, and having an electrical resistance of 1,000 ohms between the two points of contact, would sustain the force of 1.33 horse-power. Portions of this power would be absorbed in the production of heat and chemical decomposition, while the main effect appears in violent vibrations of the fluids and tissues, delivering tremendous blows within the vital organs.

This is undoubtedly the secret of the life-destroying power possessed by the alternating current. That the nerves share this vibration is proved by a recent experiment of Professors Ayrton and Perry. If in a magnetic field the alternating current be passed through a stretched wire, the latter will give out a musical tone if it be tuned to respond to the same number of vibrations as the number of alternations of current per second. It is evident that the molecules of the wire were vibrating before the string was put into the proper condition to produce sound. This is corroborated by the fact that wires become crystallized from carrying overloads of the alternating current for long periods, and by microscopical examination of the nerves of animals killed

by this current under high electrical pressure, since the nerve-sheaths are distinctly granular in parts of the body which have received the brunt of the current.

The chemical decomposition and heating effect of the current which a human body would ordinarily receive from electrical systems in present use would be too small to produce in themselves fatal injury, unless long continued, and there is not a case on record of death from these causes alone. It is true that the characteristic indication of death by electricity is the peculiar fluid condition of the blood and its dark color, which seem due, in part at least, to its loss of oxygen, since passing oxygen through it restores its normal appearance. But it has never been determined whether this produces or follows death, or whether it is caused by chemical or by mechanical action. As the combination between the blood-corpuscles and their oxygen is a feeble one, it seems possible that the current might disturb the relationship and set the oxygen free to form other combinations. On the other hand, the mechanical shock might produce the same result. In one of my early experiments upon animals, death was caused by a continuous current, and the characteristic condition of the blood was observed in a post-mortem examination by an able physiologist. It seemed probable that this death resulted from what is known as the extra-current from the magnets of the dynamo, which, on opening the circuit through the subject, would give a sudden rise and fall of pressure, analogous to the effect produced by a single alternation of current. Therefore in a subsequent experiment apparatus was used which prevented the extra-current from reaching the animal, and the highest then available pressure of the continuous current (1,420 volts) produced no ill effects.

In the latter case the amount of chemical decomposition must have been greater than in the first experiment, since much higher pressure was used. This led to the conclusion that pulsations, interruptions, or alternations of the current produced death, though it failed to determine whether the blood of the uninjured animal had been altered by the current, as in the other case, but restored to its normal condition by subsequent respiration. Dr. George E. Fell, president of the American Society of Microscopists, states that in a living amœba the protoplasm contracts when a feeble current of electricity is passed through the fluid containing it, and that a slight increase of current is fatal.

It is probable that a similar effect is produced upon the blood-corpuscles, and this experiment under the microscope would be interesting.

The physiological effects of electrical currents upon the human body have been accurately observed and described, though many physicians, through lack of mechanical knowledge, have false ideas on one important point. Since some men show signs of pain from a feeble current of medical electricity, which can be received by others without discomfort, it is assumed that the latter persons cannot be killed by any amount of electrical force. They might as well say that, since a trained player can catch a base-ball when thrown at a rate which would knock down and cripple a novice, a ball fired from one of Krupp's monster cannon cannot be relied upon instantly to kill a man whom it strikes. In each case it is merely a ball in motion that is dealt with, but the difference in the amount of power exerted is enormous. A continuous current causes a tingling sensation, stimulates nervous action at the negative pole, depresses it at the positive, and, if long continued, produces under the electrodes chemical burns or blisters due to electrolytic decomposition. The closing and opening of the circuit produce muscular contractions, which are intensified by alternating the current or by placing an electro-magnet in the circuit. An infinitesimal current passed through the sciatic nerve of a galvanoscopic frog causes a contraction which will lift a quarter of an ounce one-half to three-quarters of an inch. As this amount of work is beyond the power of the current itself to accomplish, it must be assumed that the electricity merely excites the nerve and allows the residual vital force to exert itself. If this be true, it may be possible that a heavy shock of electricity may cause a man's own muscles to kill him by their powerful contraction.

If a series of shocks are received at the rate of fifteen or more per second, the muscles controlled by the nerves affected do not have sufficient time to relax, and therefore assume a rigidity proportional to the number of impulses per second and the electrical energy exerted. During this state of muscular tension the sensory nerves in the parts affected seem to be deadened to external impressions, and dentists have long used this fact to diminish the pain of tooth-drawing. An increase in the number of impulses or alternations per second, or in the electrical pressure, produces

a greater degree of insensibility to pain until absolute unconsciousness is reached. In my experiments, 0.101 electrical horse-power with 26.6 alternations per second produced unconsciousness and death; at 68.3 alternations per second, 0.075 horse-power, and at 288 alternations, 0.0049 horse-power, produced the same result.

Personal experience and the record of accidental shocks from electric-light circuits prove that insensibility to pain is produced by the continuous current at pressures of 1,800 or more volts, while the alternating gives the same result at about 160 volts. It may, accordingly, be confidently assumed that any reported case of intense suffering from an electrical shock is due to imperfect contact and therefore to low pressure exerted on the body itself. This is verified by the fact that such cases are usually accompanied by severe burns, and a burn is the evidence and result of poor contact. Applying the foregoing facts to electrical execution, it is evident that the alternating current is especially well adapted for the purpose. To determine what electrical pressure shall be used, it is merely necessary to search the death-records; the Jablochkoff system has slain its victims at 100 volts, while dozens have been killed at 1,000 volts. A contact such as was made by Mr. D. A. Henry, who was killed September 2 by 1,000 volts of this current, must have measured at least 5,000 ohms. He was instantly and painlessly killed by an expenditure of less than 0.275 horse-power. One-tenth of this amount has killed strong, vigorous men, but in order that no chances should be taken, the criminal's resistance can be reduced to 500 ohms by immersing both hands and feet in the potash solution. At 1,000 volts' pressure he would receive 2.75 horse-power, or one hundred times as much as is necessary to cause instant death.

A higher pressure would be dangerous to the attendants, since the alternating current even at 1,000 volts has killed three or more innocent men through contact with insulated wires. The preparations necessary for electrical execution are very simple. The condemned criminal's cell is visited by the prison authorities and his hands and feet are saturated with the weak potash solution which so rapidly overcomes the skin's resistance; during this space of thirty seconds or less his electrical resistance may be measured, though Mr. Edison's researches in this line have rendered even this unnecessary. Shod in wet felt slippers, the convict walks to the chair and is instantly strapped into position;

his feet and hands are again immersed in the potash solution contained in a foot-tub connected to one pole and in hand-basins connected to the other. With this perfect contact there is no possibility of burning the flesh and thus reducing the effect of the current upon the body.

Dials of electrical instruments indicate that all the apparatus is in perfect order and record the pressure at every moment. The deputy-sheriff closes the switch. Respiration and heart-action instantly cease, and electricity, with a velocity equalling that of light, destroys life before nerve-sensation, at a speed of only one hundred and eighty feet per second, can reach the brain. There is a stiffening of the muscles, which gradually relax after five seconds have passed; but there is no struggle and no sound. The majesty of the law has been vindicated, but no physical pain has been caused.

Such is electrical execution. And yet strenuous attempts have been made to befog the public mind in order to prevent the use of the alternating current for the death-penalty, lest the public should learn its deadly nature and demand that the Legislature banish it from streets and buildings, thus ending the terrible, needless slaughter of unoffending men.

HAROLD P. BROWN.

AN ENGLISH VIEW OF THE CIVIL WAR.

VI.

BY GENERAL VISCOUNT WOLSELEY, K.P., ADJUTANT-GENERAL OF THE BRITISH ARMY.

THE LAST volume of this most interesting series of papers begins with an account of the attack upon and defence of Charleston. Were I bound to select out of all four volumes the set of papers which appears of most importance at the present moment, not only from an American, but also from a European, point of view, I should certainly name those which describe the operations at Charleston.

All European powers, England especially, are deeply interested in this question of naval attack *versus* land defence. Since the time of the Civil War many changes have, no doubt, taken place; many inventions have been made which greatly affect the relations between ships and forts. The size of guns has enormously increased. Torpedo work in all its forms has been immensely developed, and the use of the electric light has materially helped all night operations. Ramming has been taken more and more into account in the construction of all men-of-war. Various forms of armored ships have come into existence and have been subjected to all such experiments as peace admits. It is never very safe, however, to assume that anything will take place in war precisely as the result of peace trials would lead one to believe. It would be no good reason, however, for refusing to adopt new plans or novel inventions in our next war, because they have not been tried and found to answer well in some former one. To act upon such a principle would be to handicap very heavily the nation that adopts it. It would be to hand over many great advantages to a more courageous, a more intelligent, and a more enterprising enemy. But it is only possible safely and usefully to apply the results of peace experiments to war preparations by