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Recent Investigations in Faradic Electricity;

Variation and Control of the Current by Rapidity of Interruption and Variation of Coils, and the Single-wire High-tension Current.

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RECENT INVESTIGATIONS IN FARADIC ELECTRICITY: VARIATION AND CONTROL OF THE CURRENT BY RAPIDITY OF INTERRUPTION AND VARIATION OF COILS, AND THE SINGLE-WIRE HIGH-TENSION CURRENT.

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I have been for years more or less interested in the therapeutic development of faradic electricity, but have as yet made no public mention of the interesting results achieved; hence it is with pleasure that I can now not only present a *rêsumê* of my investigations and experiments, but can demonstrate the practical results accruing therefrom—the new faradic apparatus—together with some of the novel physical and physiological results obtained thereby. With safety I may say that the therapeutic usefulness and adaptability of faradic electricity has been largely increased by the widely extended range and the controllability of interruption, and the defining and precising of the various secondary coils, as evolved by experiment directed toward the precising and controlling of the faradic current; the essential features from which all has branched being the rapidity of interruption and the character of the secondary coil. But whatever may have been achieved, and all that I can now show, although new in form, is merely a developing and perfecting of principles laid down in my first paper on "Electricity in Gynecology," read before the American Gynecological Society at its Baltimore meeting in 1886, and of axioms then outlined and clinically demonstrated. In that paper I called attention, first, to the importance of the variability of interruption and the determining of these interruptions; secondly, to the importance of differently constructed secondary coils as necessities for the variation and perfect control of the therapeutic effects of faradism; and thirdly, to the necessity of precision in all the essential details for purposes of record, dosage, and comparison. I sought, in respect to faradic electricity, the same precision and possibility of record and dosage that had so rapidly advanced galvanism in professional favor as a therapeutic agent; and I believe that the points at that time aimed at have now been achieved, and that satisfactory results may be confidently looked for.

With the introduction of the galvanometer the constant current made rapid progress, but it is only within recent times that attention has again been given to faradic electricity, and such progress as has been

made has been precisely in the lines mapped out in the paper above referred to. This will be better explained by giving an outline of the status of galvanic electricity then and now. It was not many years ago (at Baltimore in 1886), that I vainly attempted to procure a galvanometer in the city named for the purpose of demonstrating its use in therapeutic applications. Such an instrument could not be obtained until my esteemed friend, Dr. Wilson, by aid of the telegraph, succeeded in securing one from Mr. Fleming, in Philadelphia. It is probable that hardly a milliampèremeter was in use at the time; the galvanic current was vaguely and crudely applied. Now it has become an exact and well-defined agent of known therapeutic value. It was the galvanometer—the guide to precision, to dosage and record—which gave to galvanism its impetus and the confidence of the profession; and it is this precision, this possibility of record and dosage, which is needed to place faradism upon its proper basis.

But what was the status of the more variable sister to the continuous current, the more intangible induced, or faradic, at that time? Then, and for years thereafter—until Messrs. Waite & Bartlett produced a battery in accord with the suggestions made in that very paper toward the greater variation of interruption and coils—the ordinary sharp-current instrument with a single coil and a practically non-variable interruptor held sway and was used throughout. We must, of course, except the Tripier instrument made by Gaiffé, which, however, was used only by a few specialists, and was almost wholly confined to scientific laboratory experiments; and the Rockwell instrument, made by Kidder, with a secondary coil of different sized and lengthened wire, wound on one and the same spool and tapped so as to be used either singly or in series. This was the pioneer instrument in this country, and certainly the best. Such was what was known as "faradic electricity" in electro-therapeutics when I outlined what I deemed the essentials for progress, the very principles upon which the instrument now perfected is based. These principles I will quote from the paper already referred to:

"The effect of the current varies with the number of interruptions and with the nature of the helix, . . . with the length and thickness of the wire forming the secondary coil. . . . Sedative effects are best attained by the utmost frequency of interruption, and muscular effects by slow interruption. . . . A current of feeble tension and greater quality as developed by the short coil of thick wire has the best contractile effect on the muscle, and a current from a long coil of fine wire, a current of higher tension and less quantity, affects the muscle less and the nerve more."

To all this I still adhere, and I am gratified to see that these principles are gaining ground and are bringing faradic electricity to the front, as is evident from the demand for improved instruments and the more

general manufacture and use of instruments with well-regulated coils and interruptors; yet, while this is a great improvement, more still must be achieved. The best of these instruments, those made for Goelet and Hutchinson by the Galvano-faradic and the Chloride of Silver Battery Co., the Fleming instrument, and the Mackintosh imitation of the Gaiffé, as well as the earlier models of my own instrument made by Waite & Bartlett, approximate to some extent the desired conditions; but they lack the necessary range, precision, and controllability of interruption and coils.

Faradism in its present status is incomplete and unsatisfactory as a therapeutic agent; and as the character, the quality, and the effect of the faradic current, quite contrary to the galvanic, depend entirely upon the producing apparatus, it is this which must be improved. Clinical experience had told me that the rapidity of interruption and the character of the secondary coils were the essential elements, so that I sought to obtain in these factors the utmost range and precision. With such objects in view the new apparatus was constructed; it is the direct result of physical and physiological experiment based upon a knowledge of clinical needs and therapeutic demands, and substantially proves the correctness of the course pursued and the remarkable variation of current-effect which can be produced.

I here refer to the instrument itself, because, as I have already stated, it is upon the apparatus that the quality and effect of the faradic current depend—unlike the galvanic, which is practically independent of the generator, currents from all sources being about the same.

To give the induction current the necessary range and precision, it proved essential that the instrument be provided with:

1. An adjustable, variable, and recordable interruptor of great range up to 50,000 or 100,000 interruptions per minute, with a motive power separate and distinct from that of the primary inducing flow.

2. A series of secondary coils of definite quantity and electro-motor force, with great range, each adapted to a certain therapeutic purpose.

3. An adjustable core, with scale to determine its position.

4. The possibility of precise record of all details; this means a primary coil of known resistance and electro-motor force proportionate to current strength and secondary coils to be used, and a primary current of known intensity.

I would strongly urge a uniformity or construction for core and primary coil, and uniformity of primary galvanic flow; this would greatly facilitate record and comparison, and could easily be accomplished, as most primary coils are very much alike, and there is no great variation in the galvanic force employed—from 2 to 6 volts and from 600 to 1300 milliampères being generally used; this is readily controlled by rheostat and galvanometer, and brought to the desired average intensity.

The new apparatus is constructed with reference to precision in all details, but it is the interruptor, with motive power separate and distinct, securing interruptions far more rapid than any hitherto obtained, and interruptions determinable in number, together with precisely defined secondary coils, which give the instrument its individuality, and I take pleasure in saying that the satisfactory result which has been achieved is due to the kindly manner in which Messrs. Waite & Bartlett have placed their efficient force and their material at my disposal; while the solving of practical problems, the practical carrying out of my ideas, I owe to Mr. Harry Waite, who has been my constant aid in all experiments made in this city; therapeutic tests being constantly made in my clinic by my assistants, Drs. Ameiss and Temm.

The interruptor. While the rate of vibration or interruption is one of the essential features of faradic electricity, it has hitherto been regarded merely as a necessary mechanical factor for the production of the current, of no therapeutic value whatsoever. Although variability is the very life and essence of faradic electricity, attention has never been directed to the importance of interruption in medical currents. Some vague references have here and there been made. Gordon, in his *Electricity*, briefly mentions a high-speed interruptor used for experimental purposes, but does not say what those experiments were, and, in fact, lays no further stress upon this fact. Dr. William Scheppegrell, of New Orleans, in a most progressive publication which has just come to my notice, speaks of a similarly constructed interruptor as adaptable to galvanic and faradic currents, but gives no details as to any peculiarities of current, and makes no especial therapeutic claims for such current. Dr. William Hutchinson is the first to speak of therapeutic effect, and in a paper read before the American Electro-Therapeutical Association in October, 1892, advocates the singing rheotome, claiming interruptions of great rapidity, with astonishing anæsthetic effects; he unfortunately bases his measurements of speed upon aural comparisons with the tuning-fork—giving results which have not been fully borne out by my own investigations—and I may here say that I deem more positive tests of the rate of the interruptions necessary than these, as few possess the delicate ear and the musical training necessary to make these comparisons; but no matter what the speed possible, the rapidity of any vibrator so constructed cannot be controlled within a satisfactory range, nor can the necessary rate of vibration be secured whenever desired; any good features which it may possess are of no avail until it is used with a motive power separate and distinct from that employed for the coils. I deem it of less value for medical purposes, as its rate of interruption depends upon the strength of the therapeutic current to be used; hence rapid interruptions are out of the question where mild currents are to be employed, rapid interruption necessitating strong currents.

I must here express myself more fully upon this point, as I deem the separation of vibrator, or interruptor, from the induction coil itself essential to the development of this form of electricity as a therapeutic agent. Hitherto the interruptor has been regarded as a mere mechanical factor, a mechanical necessity for the production of the induced current, and it has been in no way connected with therapeutic effect; hence it has been a part of the apparatus, and will always be directly connected with it in the average coil for the sake of simplicity of construction and cheapness.

In order to obtain the most satisfactory physiological and therapeutic results from the faradic current, the interruptor must be separate and distinct from the coils and propelled by a distinct motive power, for the following reasons:

Changes in the primary galvanic current are necessary to control the rapidity of interruption, and this must be accomplished without affecting the physiological current from the coils, as changes in the primary flow supplying the coils must be accomplished without affecting the rapidity of interruption—all of which can be done only by employing a separate motive power for each.

For the purpose of properly actuating the vibrator, primary galvanic currents of too great an intensity have been used.

Rapidity of interruption or alternation is a factor of large general importance, too long overlooked, which will yet claim greater attention, both for mechanical and for therapeutic purposes in connection with faradic electricity and with alternators and vibrators of other kinds. Mr. Tessla has demonstrated the marvellous mechanical results of rapid vibration, and D'Arsonval revealed the surprising insensibility of the system to currents of extremely rapid alternation, and also proved their sedative effects. For physical, physiological, and therapeutic purposes, rapidity and variability of interruption and alternation are most important, and if it is true that the effect of the faradic current is mainly due to its mechanical influences upon the molecular constitution of the organism, the great importance of regulating that vibration is evident. That mechanical vibration is potent as a curative agent has been repeatedly proven, first in England, and interest in this subject is at present excited by the experiments of Charcot with the *médecine vibratoire*. Isolated cases have been published. Boudet, of Paris, cured facial neuralgia by the vibrations of a tuning-fork, 200 per second, communicated to a sounding-board upon which was fixed a small rod with ball end, which was placed upon the face at the point of exit of the infra-orbital, thus communicating this vibration to the nerve. After an application of from five to six minutes the pain ceased for a time, and by continuance of the treatment a cure was achieved. In the Salpêtrière a large tuning-fork was used, placed upon an extensive sounding-box, the atmospheric vibrations produced thereby acting as did the rod in the other case, and with

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similar satisfactory results, even to the restoration of muscular activity in the paralyzed lower arm of a hemi-anæsthetic. Varying rates of vibration have been successfully used by Dr. J. Mount Bleyer, of New York, in the treatment of diseases of the ear, and if there is any truth in the theory of the variation of molecular vibration as determining nerve disease and its cure by corresponding vibrations, the necessity of precisely determining the vibrations used is self-evident.

But it is only to the interruption of the faradic current that I will here refer. The increased rapidity of these interruptions and the ability to control them render the application of effective currents possible to the most sensitive tissues, and give the greatest scope to the efficiency of those currents, especially increasing their sedative powers. The new instrument gives us every variation of interruption; we retain the vibrators as before used upon the Waite & Bartlett battery, but with a separate motive power of, at most, two Gonda cells; there is a single impulse key; the slow vibrator giving us up to 1000 or 1500 interruptions, and the rapid vibrator giving from 1000 to 3000 or 4000. These, of course, cannot be controlled with absolute precision, and precision within such limits is hardly necessary, but if desired it can be attained by the new instrument, which gives us slow interruptions with absolute precision up to 400 per minute, and all the more rapid interruptions from 3000 to 50,000 and 100,000 per minute can be obtained with a like precision.

The interruptions are obtained from the commutator upon the axle of a small motor, and have been determined in number by the use of the speed indicator, which is compared with the current intensity propelling it, the speed being governed with precision by the current used; hence, after the preliminary experiments the rate of interruption, or the speed of the motor, is indicated either by the galvanometer or, when a red-acid cell or storage battery of known force is used, by the rheostat. This instrument, however, serves not only as a controllable high-speed interruptor for these condary faradic current, but may be used as interruptor or alternator for the primary and for the galvanic current. I will here only speak of it as an interruptor in faradic electricity, and its importance in this capacity will be appreciated after a brief review of some of the physiological experiments made which demonstrate the great variation of effect produced by variation of the rate of interruption.

The effect of faradic electricity, best demonstrated by mild currents, slowly increases with the rapidity of interruption, as observed both upon motor and sensory nerves, up to 2500 or 3000 per minute; then slowly decreases with an increase in the rapidity of interruption. The greater the current strength the greater the number of interruptions necessary to reduce or annul its effect completely, the muscle ceasing to respond before all impression upon the sensory nerve is lost. A moderate current, such as that from coil No. 3 of my battery (Waite & Bartlett) at 45 of the

scale, or one-third of the coil in circuit, will produce muscular contractions with from 45 to 100 interruptions per minute; this current grows stronger with an increase in the rapidity of interruptions up to 4000 per minute, then soon decreases. Muscular contraction ceases at 5000, at 6500 its sensory effect is barely noticeable, and before a rapidity of 10,000 is reached it ceases to be felt altogether. A very strong current, such as one from No. 3 coil completely overlapping the primary, with an inducing force of four Leclanché cells, and applied through large moist electrodes—in other words, a current too strong for therapeutic applications with the ordinary vibrator at 3000 per minute, is barely perceptible with 25,000 interruptions per minute, and ceases to be felt altogether at 28,000. The rapidity of interruption controls the physiological effect of the current as perfectly as the sledge movement of the secondary coil, so that, all other conditions remaining unchanged, it is an index of current strength which may well be utilized. The therapeutic value of rapid interruption rests upon our ability to employ strong, efficient currents without discomfort, and is found in the nerve-quieting, sedative effects of these interruptions with fine coil currents.

The coils. Therapeutic use having proved the variable effects produced by coils of different length and thickness of wire, my experiments were made on this basis: that quantity and electro-motor force of current, as determined by resistance or diameter of wire and number of winds were the determining factors, as far as physiological and therapeutic effects of the secondary coil are concerned; and this has been proved correct, but the practical question remained as to the precise conditions under which currents of the greatest therapeutic value were produced, and under what conditions each special effect would best be obtained. Coil upon coil was wound as previous results seemed to indicate, and although still reserving final decision, I should now say that we have at least approximated the physiological and therapeutic extremes. Motor, to the exclusion of sensory effect—that is, painless influencing of the muscle—is most satisfactorily attained by secondary coils of the lowest possible resistance with the largest possible electro-motor force or number of winds: by the heavy-wire coil, with a resistance of 0.7 or 0.8 of an ohm and 500 to 600 winds, of No. 15 wire, and better still by an increase in the electro-motor force by the use of fine wire in multiple—this being a coil of 6500 winds of No. 32 wire, with 4.1 ohms resistance. The opposite condition, that is, the highest possible resistance with the lowest possible electro-motor force, produces the most painful currents as used for purposes of counter-irritation—this is a coil of No. 40 wire, 528 winds, and 180 ohms resistance. The utmost penetration, together with satisfactory general therapeutic effects upon the nerve, is obtained by coils of higher resistance and greater electro-motor force. Thus, a generally serviceable coil is one of from 4000 to 6000 winds and from

250 to 740 ohms resistance; for sedative purposes, for the benumbing or anæsthetic effects, a still higher electro-motor force is necessary, as in a coil of 9000 or even 12,900 winds and 2500 ohms resistance.

To better illustrate what these figures mean, I will say that the longest coils heretofore made for medical instruments have, in the best, been of 3500 to 4000 winds, or 2000 feet, and good vibrators gave 3000 interruptions per minute, or 50 per second.

Such have been the results obtained after careful experimentation with coils of the most various kinds. We have seen that low resistance with high electro-motor force is the coil most effective upon muscle, causing least sensation; and the highest resistance with the lowest electro-motor force is the very opposite—is the most intensely nerve-irritating coil without muscle effect; while the penetrating motor and sensory effects, varied by the character of application, are produced by an increase of both resistance and electro-motor force, sedative effects being best produced by the highest possible electro-motor force. But I believe that a limit is to be placed to this, at least when used in connection with the ordinary battery force and primary coil, and that this need certainly not exceed 9000 or 10,000 winds.

From all clinical and physiological experiments it is evident that the quantity and electro-motor force of the current, as indicated by resistance and by the number of winds, are the determining factors; hence an instrument can be of value only when these data are given, and given with precision; coils must be accordingly marked, just as the dosage is indicated for any other remedy, and for purposes of record and comparison these points must be referred to. For the sake of comparison, it would be preferable that certain standards should be adopted, yet as this is almost impossible, each manufacturer advocating his own special instruments, these instruments should at least be precise, with definite and clearly indicated qualities.

It would seem needless to insist upon the use of properly constructed coils, such as best serve the purpose intended to be accomplished, and yet attention must be directed to this point, as some still claim all effects from one and the same coil, or from one and the same coil tapped at different points. It is, indeed, true that varying effects can be obtained from one coil by varying the method of application, but by no means so distinctly and so satisfactorily as by a variation of coils; in short, such results are primitive, partial, and incomplete. Each of the coils I have selected answers a definite purpose, best attaining the desired effect without complication by other unnecessary and often deleterious action.

The coil of 4.1 ohms resistance and 6500 winds contracts the muscle thoroughly without influence of any kind upon the nerve, and the coil of 180 ohms resistance and 528 winds produces a painful counter-irrita-

tion without any effect upon the deeper tissues; and nothing demonstrates more strikingly the great importance of resistance or diameter of wire upon the physiological effect of the current: this coil gives a painful current and does not in the least affect the muscle, whilst a coil of 0.85 of an ohm resistance and 528 winds gives a current which is hardly appreciated by the sensory nerves, but acts well on muscular fibre; and this striking contrast may be observed with the same number of winds in circuit, or precisely the same electro-motor force. It needs but the testing to prove the necessity of coils so varied for the satisfactory use of faradic electricity in medicine; hitherto it has not been a very useful agent, for the reason that our apparatus has been imperfect and we have lacked the means of developing the most valuable feature of this form of electricity.

Actual galvanometric measurement of the secondary faradic current in micro-coulombs is possible, but is no indication whatsoever of physiological effect, hence useless for the physician and useless for record and dosage. Until greater progress is made we must refer to the following data in lieu of direct measurement: *a*. Strength of the primary galvanic inducing force. *b*. Character of primary coil. *c*. Position of core. *d*. Number of winds and resistance of secondary coil and its position upon the scale in reference to the primary. *e*. Number of interruptions. *f*. Character and location of electrodes. *g*. Duration of séance. This record is possible only with precise, well-authenticated instruments, and instruments in which the motive power controlling the interruptor is independent of that used for the coils.

In conclusion I may say that by means of this increased rate of interruption and a greater variation in secondary coils, the therapeutic possibilities of faradic electricity have been greatly extended; and by the exact determination of the rate of interruption, with the character and position of the secondary coil—the character of secondary coils being determined by their resistance and the number of winds—comparison, record, and dosage are possible. Not only can we attain a great variety of therapeutic effects by the proper combination of the various essential factors, but as these can all be defined and determined, dosage and record are approximated to such an extent that with instruments properly constructed and precised, satisfactory work will be possible and faradic electricity will assume its proper place as a therapeutic agent.

The single-wire high-tension current is one of the products of the induction coil which is, perhaps, of greater interest experimentally than of value therapeutically, yet I will take the opportunity of demonstrating curious phenomena which have developed from Mr. Harry Waite's suggestion of grounding one pole. The negative pole of the break current being the most intense, this is used, and the positive

grounded; a high-tension current is thus obtained, even at quite a distance from the generator; it is similar to the static, and produces some curious effects. This current is more like a pure static than like the so-called static induced.

While there may be little therapeutic use for the high-tension single-wire current, it is nevertheless worthy of trial, and I desire to call attention to it as useful in neuralgic conditions; and applied by the hand of the operator in the various forms of headache and in the giving of massage, marked physiological effects have been observed, but I am not as yet in a position to demonstrate their therapeutic powers.

The mechanical effects are shown by the glow of the incandescent lamp and by the spark, which is like the static; a small electric lamp, such as is used for laryngeal purposes, or a 118-volt incandescent lamp, may be set aglow twenty, thirty, and more yards away from the apparatus, by contact with the negative pole, if the glass bulb of the lamp be held in the hand of the operator, it being indifferent whether or not he be upon an insulated platform; it will likewise glow if he pass the current through his body, seizing the negative wire in his hand and grasping the metallic base of the lamp in the other, then approximating the glass bulb to some other individual. While this is the carrying of the current by means of a single wire, it is a pure induction effect, and not like those startling results obtained by Mr. Tessla—dependent upon rapidity of vibration, unless it be molecular. The glow will be produced as a momentary flash by single contact; as contact is more rapidly made, as vibration or interruption succeed each other more rapidly, even at from 500 to 1000 per minute, these successive flashes merge into a constant glow, a glow which varies with each individual lamp: in some it follows the carbon filament, or centres upon that part of it nearest the fingers or hand grasping the glass bulb; in others it is independent of the filament, as a diffuse glow, but most frequently more intense toward the grasping fingers. Different lamps of the same voltage act very differently, probably owing to the different conditions of the vacuum—its more or less perfect state; so also is the effect a different one, whether the vibrator of the coil itself is used or whether the separated interruptor is employed, which gives no flash on single contact, either make or break, and does not produce the glow until a rapidity of from 8000 to 10,000 per minute is obtained. This reaches its height at from 10,000 to 15,000 interruptions per minute, decreasing as these grow more rapid. These effects were produced by a red-acid or Grenet cell. Only carefully wound, well-insulated coils can be used, by reason of the extremely high tension of the current—which, on a damp day, will throw a spark of one-third of an inch. The most satisfactory results were obtained from a coil of high electro-motor force, 9000 winds of No. 36 wire; both physical and physiological effects diminished with an increase or decrease of

electro-motor force, and are barely noticeable from coils with as few as 4000 winds, or with as many as 13,000.[1]

The spark produced in damp weather has quite an effect through high resistance. From the point of a metallic electrode it is painful, and acts intensely upon motor points, but the skin must be very dry. When applied by means of the entire hand, to the forehead, for instance, no sensation is produced, and yet a physiological effect is undoubted, so that this must prove a satisfactory method of therapeutic application, as any degree of sensation can be produced by a lessening of pressure until the surfaces are barely in contact.

Mild, general applications of this high-tension single-wire current have a marked constitutional effect, as became evident from the similar conditions experienced by all engaged in these experiments, and repeatedly experienced. A weariness, a relaxation, with nervousness in some, was followed by a healthy tire and refreshing sleep. The ordinary metallic electrode touched lightly to the motor points, with slow vibration, 80 to 100 per minute, contracts the muscle forcibly, and without pain; 500 to 1000 vibrations per minute are more painful. The rapid vibrator, 3000 per minute, gives a softer current, the sensation in all cases disappearing with a firm pressing down of the electrode.

I have cited these high-tension single-current effects from high voltage coils of the faradic apparatus on account of the physical facts which they demonstrate, and for the purpose of indicating therapeutic possibilities.

The peculiarities of opening and closing current, of positive and negative pole, of varying rates of interruption, and of difference in coils, are all marked in the high-tension current; the flash on single contact is observed only in the opening, not in the closing current, as the predominance of opening over closing current, which increases with increase of resistance, is very great with this high resistance; the predominance of the negative over the positive pole is likewise strikingly evident; the light, like the physiological effect, increases with the rate of interruption to a certain point, and then decreases; so likewise does the effect increase with an increase of the electro-motor force, or the number of winds in the coil, attaining a maximum with a certain relation of electro-motor force to resistance, then again to decrease as electro-motor and resistance increase still more.

In the glow of the lamp we see the fact well demonstrated that a certain phase of current, a certain coil, within given limits of the electro-motor force and resistance, is necessary to determine a certain effect.

[1] As one coil of 13,000 winds has produced intense single-wire currents, I cannot be positive upon this point; and these coils demand such careful winding and insulation that they are not always fitted for high-tension experiments; this was with a resistance up to 2500 ohms; with lower resistance a higher electro-motor force could be utilized, *i. e.*, if heavier wire be used, and the result would be much more intense, as we find it from the Ruhmkorff coil.

Precisely so is it with the coils needed for motor and nerve effects. We also see that a certain rate of vibration best produces the light effect, as definite rapidities of vibration are most effective for different physiological effects.

Therapeutic possibilities only can be indicated, as there is hardly sufficient intensity in the single-wire currents as obtained from the ordinary medical battery, even with 9000-wind coils, to produce very marked effects, and these are dependent to a considerable extent on the weather. To produce always reliable and efficient currents of this kind, we must have a stronger primary galvanic flow, and coils of higher electromotor force, with less resistance, than is possible from the small spools of the medical instrument.

I was highly elated at the result of our first experiments, which happened to have been made under extremely favorable conditions, but soon found that these could not be relied upon, so that I would now be less sanguine in the hopes of therapeutic success; and yet this current merits consideration and trial. It is certainly of interest in its physical features.

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