Acupuncture & Electro-Therapeut. Res. Int. J. Vol. 2, pp.33-42, 1976. Pergamon Press.
Printed in Great Britain.

KIRLIAN PHOTOGRAPHY AS AN ELECTRO-THERAPEUTICS RESEARCH TOOL

WILLIAM A. TILLER Ph.D.
Professor, Dept. of Material Sciences
Stanford University, Stanford, California, U.S.A.

(Received 6 *June* 1975; *Accepted* 30 *September* 1975)

Abstract—The key elements of physics involved in the Kirlian process and the corresponding set of simultaneous equations that must be satisfied during the discharge are presented. Explanations of almost all the experimental observations made to date are forthcoming from this equation set. The theoretical foundation for building a future array of research tools based on this process has been given.

Key Word Index—Electrical discharge; skin monitoring; governing equations; quantitative analysis; physics; biomaterials.

Photographie Kirlian en tant qu'outil de Recherche Electro-Therapeutique

Résumé—Les éléments elés de physique, contenus dans le processus de Kirlian et L'ensemble correspondant d'équations simultanées qui doivent être satisfaits pendant la décharge sont présentes. Les explications de presque toutes les observations expérimentées faites à ce jour proviennent de cet ensemble d'équations. La fondation théorique nécéssaire a l'élaboration future d'un large éventail d'outils ed recherches bases sur ce processus est presentée.

Mots clés: décharge électrique; observation de la peau; equation fondamentals; analyse quantitative; physique; biomatériaux.

Die Kirlian-Fotographie als ein Electro-Therapeutisches Forschungsinstrument

Zusammenfassung—Die Hauptbestandteile der Physik des Kirlian-Prozesses und des entsprechenden Systems der Gleichungen, die während der Entladung erfüllt sein müssen, werden beschrieben. Von diesem Gleichungsystem ergeben sich Erklärungen von beinahe allen experimentellen Beobachtungen, die bis heute gemacht worden sind. Die theoretische Grundlage für ein Zukünftiges System von Forschungsinstrumenten, die auf diesem Prozess basieren, wird gegeben.

Schlüsselworte: elektrische Entladung; Hauptmessungen; Leitgleichungen: Quantitative Analyze; Physik; Biomaterialien.

1. INTRODUCTION

Although most work to date in the Kirlian photography area has been of a qualitative nature and there has been much controversy concerning the operant energies involved, our present and future needs for reliable research tools necessitate that we develop a quantitative understanding of this important process. It is the purpose of this paper to sketch what seem to be the key elements of physics involved in the process (at the physical level of measurement) and to lay out the corresponding set of simultaneous equations that must be satisfied. On such a theoretical foundation, one would hope to build an array of effective research tools in the future. A strong interrelationship has been found to exist between research on acupuncture, particularly acupuncture-induced phenomena in the cardiovascular and nervous systems, other electrotherapeutics research and Kirlian photography [1-4].

Previous research, associated with spark discharges, appears to be very relevant to the Kirlian process which is schematically illustrated in Fig. 1. It suggested to Boyers and the author [5] that the *in situ* light generation mechanism was associated with the "streamer" process of corona discharge. This is associated with a special electron avalanche condition in the gas space between two electrodes. When the applied voltage and gap spacing are appropriate, the positive

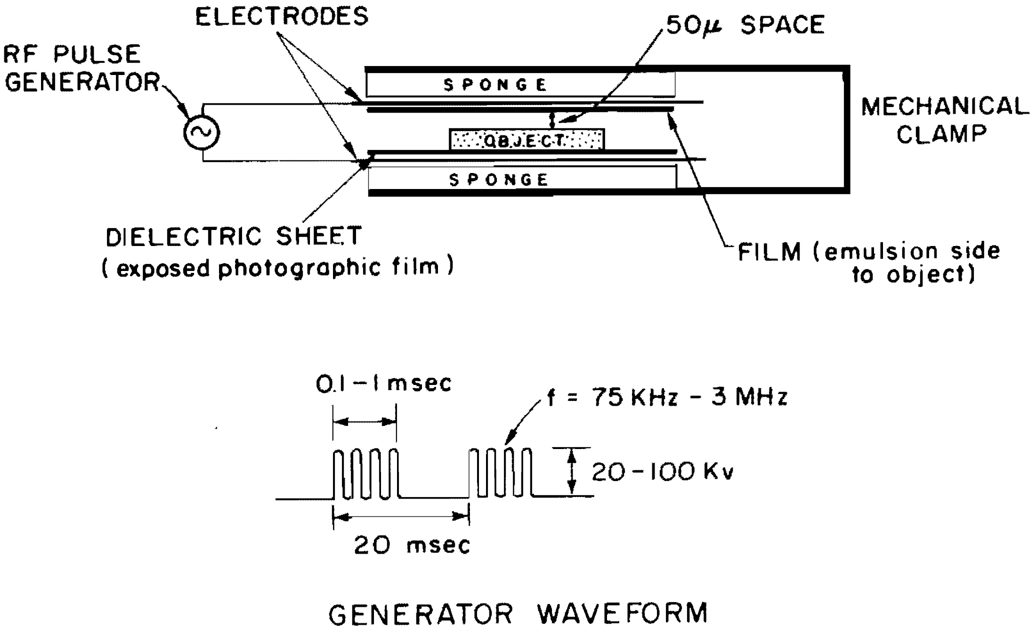


Fig. 1. Simple electrode device and power supply characteristics used in Soviet Kirlian photographs of leaves and other simple objects.

ion cluster created by an electron avalanche reaches a critical density where its self-electrostatic field is sufficient to draw significant numbers of newly created electrons back to itself. These recombining ions and electrons produce the emission of electromagnetic radiation. For air as the discharge gas, the only visible light comes from nitrogen ions recombining with electrons to yield nitrogen atoms and photons in the ultraviolet range. Thus, the visible light is blue. If helium or a hydrocarbon gas replaced the air in the gap, the light generated would have been green or red, respectively.

From U.S. and European high-voltage engineering studies of the 1930's and 1940's, several important observations were made about the "streamer" characteristics [3, 5-14]: (1) Many discrete avalanche tracks occur between the electrodes often being initiated at sharp protuberances on the electrode because of electric field enhancement due to point effect. (2) The length of discharge track that emits light increases linearly with applied voltage beyond a critical threshold voltage. (3) The morphology of the discharge pattern in the point-plane electrode configuration changes dramatically between positive point-negative plane and negative point-positive plane. (4) The morphology of the discharge pattern exhibits great variability and character shifts due to the presence of electronegative ions at different concentration levels in the air.

Not only was the source of light predicted in our earlier study, but an explanation of all the different colors observed on film was given [5]. Subsequent experiments showed this theoretical picture to be confirmed [7-9] and demonstrated convincingly that the three modes of discharge illustrated in Fig. 2 are operative and yield different color results. When u.v. light enters the front side of the film because of a discharge in the air on that side of the film, the color is a shade of blue progressing towards white at high intensity. When the u.v. light enters the back side of the film because of a discharge forming in a small air gap between the metal

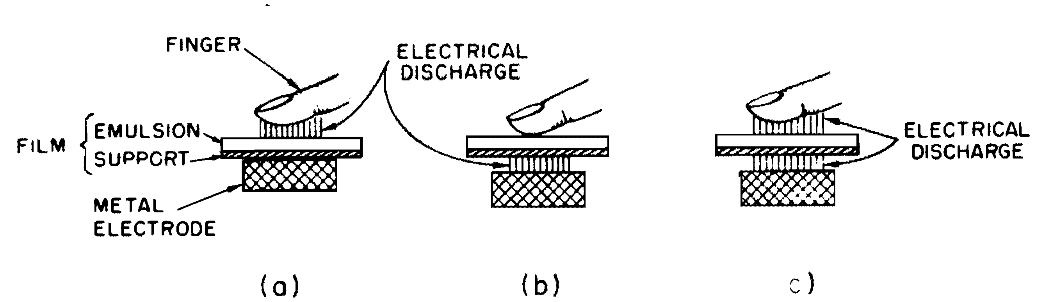


Fig. 2. Three modes of film exposure via light produced by the electrical discharge in air gaps between either/both film and finger and film and metal electrode (the actual discharge becomes normal to the finger surface).

electrode and the back side of the film, the color is red, orange, yellow or a shade of green depending on the light intensity. When discharge occurs at both sides of the film, we obtain a summation effect; i.e., red + blue = magenta.

Factors that have not been adequately explained to date are: (1) Why do low-frequency "ring down"† devices yield evidence of some physiological state changes whereas carefully controlled high-frequency devices, such as illustrated in Figs. 3(a) and 3(b), show no significant evidence for physiological state changes [9, 10]? (2) Why does a person sometimes show no discharge halo around his finger compared to a few hours earlier when a bright halo is present? (3) Why does one sometimes see splotches of red color in the interior of a ground of blue color on the fingerpad if it is not purely artifact; i.e., is there unique information available here? (4) What must one do to optimize the information-gathering capabilities of the Kirlian process? The answers to these questions and others are the object of this paper. In the following sections, a quantitative description of the Kirlian process is given from which a variety of relevant conclusions may be deduced.

2. GOVERNING EQUATIONS

The total electrical circuit in the Kirlian process is illustrated in Fig. 4 and, assuming insignificant skin potential, the Kirchhoff current law yields

† "Ring down" refers to the rapidly decaying voltage oscillation of a system in response to an excitation impulse.

$$V = I(Z_o + Z_f + Z_s) + V_G \tag{1}$$

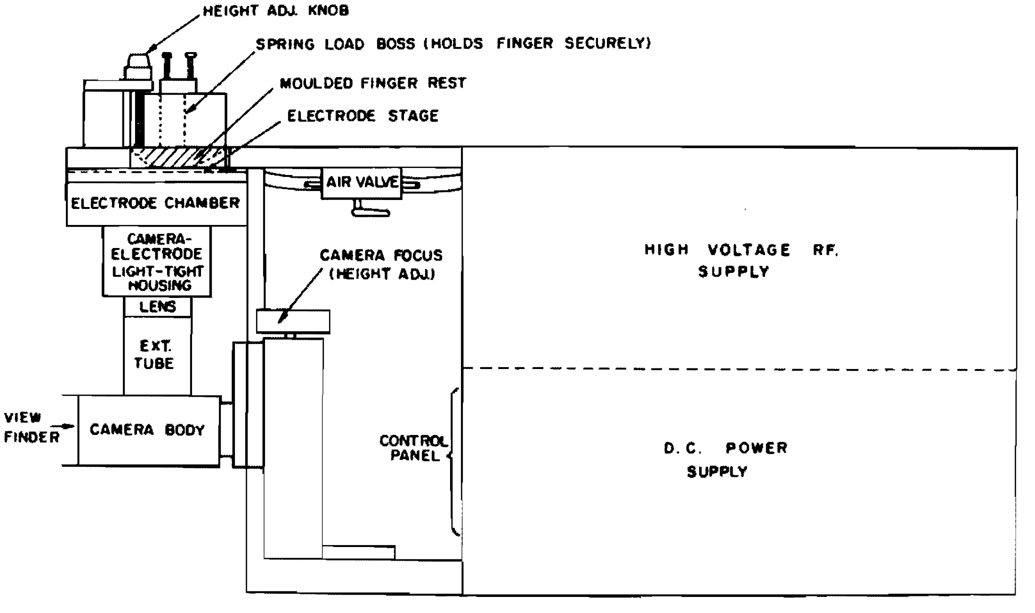
where V is the power supply voltage and Z_o is its internal impedance, Z_f and Z_S are the film and skin impedance, respectively, while V_G and I are the gap voltage and discharge current, respectively. No light effect will appear on film unless streamer formation occurs which requires that V_G exceed the critical streamer onset voltage, V_G^*, which is very close to the Paschen's law voltage for spark discharge. Thus, V_G^* will vary with p.d (gas pressure, p, in mm of mercury x gap distance, d, in cm) as illustrated in Fig. 5 and given by

$$V_G^* = f_1\,(p \cdot d, n_{el}) \tag{2}$$

where f_1 is a function describing the shape in Fig. 5 and n_{el} is the concentration of electro-negative ions† as electron scavengers and the larger is n_{el}, the larger V_G^* must be to produce the critical avalanche condition for light generation.

Onset of light generation produces considerable photo-ionization so that many new electrons are generated, the discharge current increases greatly so that V_G must decrease via equation (1) to that level where the gap overvoltage

$$\Delta V_G = V_G - V_G^* \tag{3}$$



3. (a) Functional diagrams of the transparent electrode device.

† A molecule or ion which readily adds an electron is called an electro-negative ion.

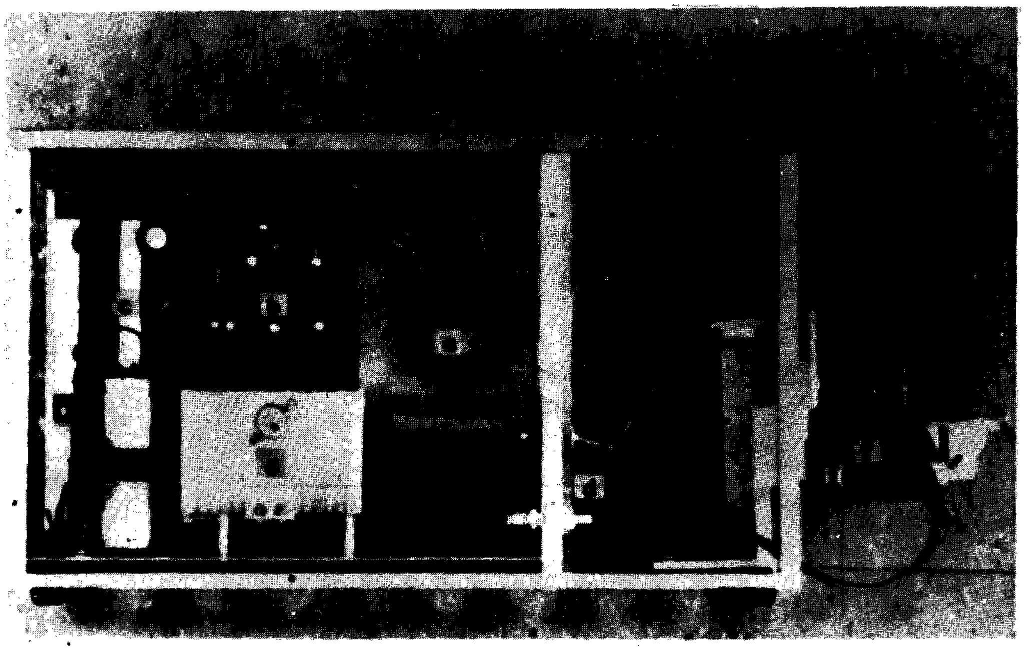


Fig. 3. (b) Functional diagrams of the transparent electrode device.
(a) 28 V d.c., 3 A power supply; (b) 20 kV a.c., 2 mA, 100 kHZ power supply; (c) internal control panel; (d) external (operator's) control panel; (e) high-voltage transformer; (f) camera; (g) transparent electrode assembly and object positioning control.

is sufficient to maintain I. Experimental data on the growth of I with time for several constant overvoltage conditions and bare metal electrodes is given in Fig. 6. For the Kirlian voltage conditions represented by Fig. 1, we must expect that the r.f. voltage cycles under the pulse will provide current versus time cycles like that given in Fig. 7 and represented by

$$I = f_2(\Delta V_G, \omega) \tag{4}$$

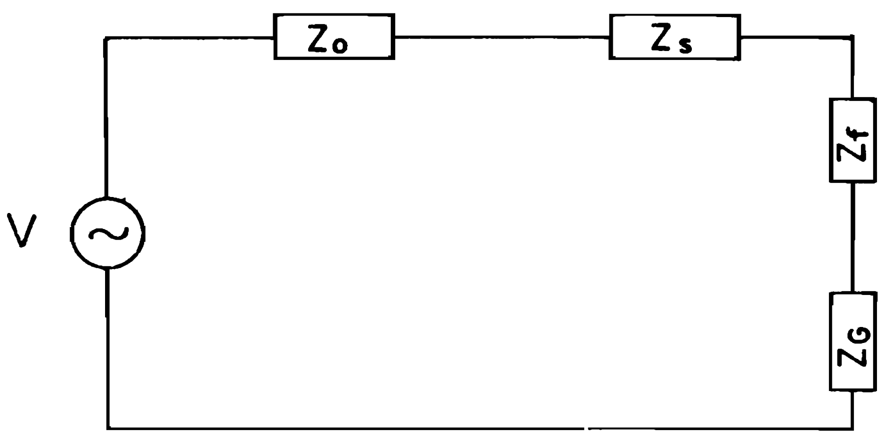


Fig. 4. Circuit elements in typical Kirlian photography system.

where f_2 is the functional shape given in Fig. 7 and ω is the r.f. frequency of the power supply.†

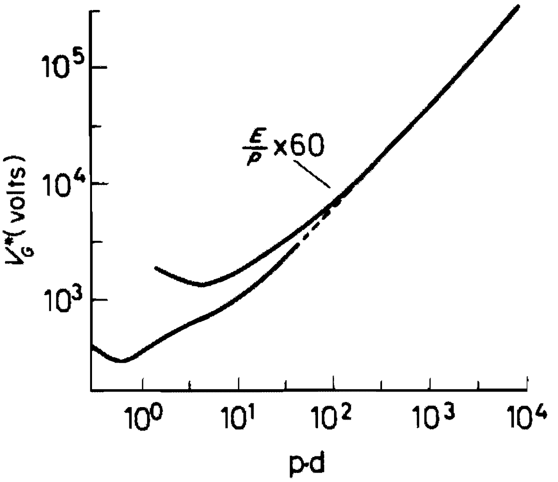


Fig. 5. Experimental (lower) and calculated (upper) curves showing the relationship between breakdown voltage, V_G^*, and $p.d$ for air at 1 atm [9].

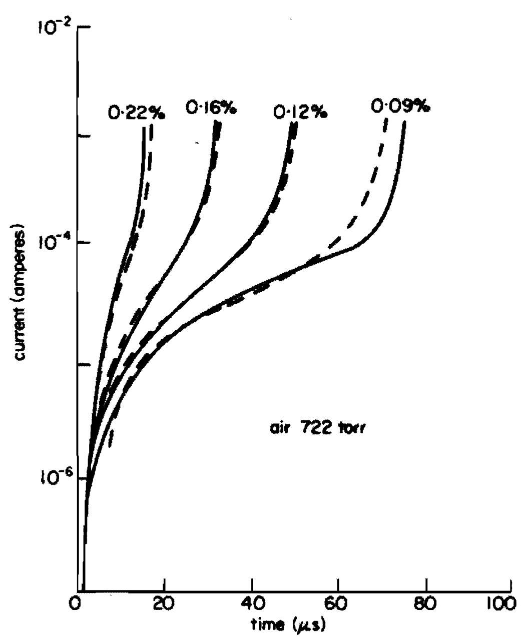


Fig. 6. Comparison of current growth with time in air for various overvoltages obtained experimentally [10] (dashed) and calculated [11] (solid).

†Strictly speaking even with negative values of ΔV_G, a minute current flows in the circuit due to the normal Townsend discharge but it leads to no light generation.

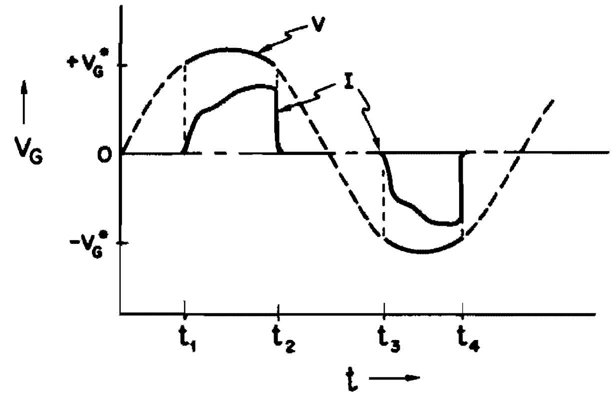


Fig. 7. The gap voltage, V_G, and discharge current, I, as a function of time indicating that significant current flows only when V_G exceeds the critical voltage V_G^*.

Another constraint on the system containing inherent information about the Kirlian process is that of continuity of electric flux at both the finger and at the film; i.e.,

$$\epsilon_i E_i - \epsilon_G E_G = \rho_i, \text{(where } i = S, f_f, f_B) \tag{5}$$

where ϵ is the dielectric constant, E is the electric field, ρ is the surface charge density and i refers to skin, front side of film and back side of film. The electric field is related to the voltage via

$$E_j = \frac{V_j}{l_j} \quad \text{(where } j = G, S, f) \tag{6}$$

where l_j is the air gap for G, the thickness of the stratum corneum for S and the thickness of the film for f.

3. DISCUSSION

From the foregoing 6 equations, it is possible to discriminate five unique ways via which one may monitor a physiological change in the organism. This is illustrated in Fig. 8.

From equations 1-4, we note that the only way an electrical impedance change of the skin can be observed is if the following condition holds:

$$\Delta(IZ_S) \sim \Delta V_G \tag{7}$$

Thus, the change of the skin impedance during an experiment must create a sufficient voltage drop across the stratum corneum that ΔV_G is significantly altered and thus the light output in the discharge is significantly altered. If we evaluate the skin impedance at frequencies greater than ~ 100 kHz, which the Soviets stated were the best frequencies to work with [8], we find that both Z_S and I are so small that $IZ_S/\Delta V_G \ll 1$ and no effect should be seen [9]. This is consistent with the Stanford results [9, 10]. If we go to the frequency region ~ 1-10 kHz, then both Z_S and I increase significantly so that $IZ_S/\Delta V_G \gtrsim 1$ and changes in Z_S due to physiological alterations may be observed. Interestingly enough, this is the region where most of the inexpensive "ring down" devices operate and where people claim to see physiological effects [8].

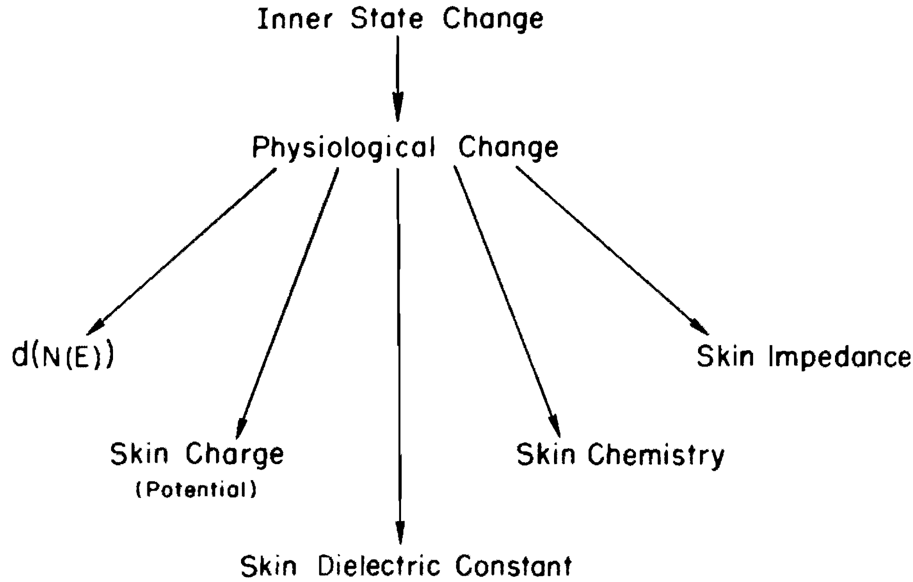


Fig. 8. Representation of unique information channels for monitoring physiological state changes associated with internal state changes via Kirlian photography.

From equation (2), we see that V_G is dependent on the concentration of electro-negative ions in the gas phase such that V_G will increase as n_{el} increases. In the Kirlian discharge, the individual current channels carry sufficient energy density to evaporate spots of the stratum corneum. Organic matter often makes good electronegative ions so that these vapor products will tend to scavenge electrons, increasing V_G and causing ΔV_G to be decreased. Very small changes in skin chemistry, especially for small air gaps may cause dramatic changes in the discharge halos. The description of Soviet studies in this area [11] suggests that much of their Kirlian photography changes are consistent with this mechanism. Since their dietary and bathing habits are appreciably different from those of the U.S. subjects, certain key aspects of skin chemistry may also be sufficiently different to be noticeable via Kirlian.

If this is the information channel that the Soviets use for monitoring living systems, then they would wish to work in a frequency range where skin impedance effects did not produce artifacts in their studies; i.e., they would seek to work in the region $\gtrsim$ 100 kHz which they stated was best via their experience. In addition, for their studies, they may not wish to work at high light levels but at low light levels and may be monitoring electron impact information which might be most affected by the scavenging properties of the electronegative ions. For such studies, different kinds of film or sensors would be in order.

From equations (5) and (6), we can see that variations of ϵ_S with physiological state influence the Kirlian discharge. If we set $\rho = 0$ for the convenience of description, we can see that, as the moisture content of the stratum corneum changes, ϵ will change (in addition, the skin impedance will change). Changes in ϵ by factors of 2-3 are easily possible. If E_S were unchanged, then E_G must change to satisfy equation 5. Via equations (6) and (2), this requires a change in both d and V_G. However, E_S will be changed somewhat because Z_S will change with water content of the stratum corneum and I will be changed via equation (1). We can thus see that the size of the discharge halo and its brightness will be influenced by changes in ϵ_S (d, V_G and I changes follow).

Certain physiological changes give rise to changes in surface charge density, ρ, on the skin and yield correlated changes in skin potential, ϕ. Under certain special circumstances, these local changes in ρ and ϕ can be large. Obviously, via equations (5) and (6), they may produce significant changes in E_G. Let us suppose that the magnitude and sign of ρ are such that E_G must become very large to satisfy equation (5). Then, from (6), either V_G must become very large or d must become very small. But via Fig. 5, we see that, since we normally operate on the right branch of the curve, if V_G becomes large, distance d must also become large and E_G doesn't change much. Thus, to satisfy these equations, the discharge must flip from the normal values of d at the emulsion side of the film to the very small values of d associated with air gaps at the back side of the film; i.e., the discharge moves from right branch operation in Fig. 5 to left branch operation. This would produce spots of red color in the background of the fingerpad such as has been observed.

Combining changes in ϵ_S, ρ_S and Z_S, it is possible to create conditions wherein, for a given V, V_G falls below V_G^* and no sensible light generation occurs. This is one explanation of the absent discharge halo around a person's finger where, a few hours earlier a bright halo was observed. Other explanations are also possible [9].

In Fig. 8, we see another pathway for gaining information concerning a physiological state change; i.e. by monitoring the change in the density of electron states in the skin $\Delta N(E)$. If there is a change in the electron population of the density of states curve, $N(E)$, then there will be a change in the number of photoelectrons emitted by the skin associated with impinging u.v. photons. The emitted photoelectrons, if sufficient in density, can greatly alter the electron avalanche conditions in the gap and lead to a decrease in V_G^*. Following this path, one can hope to gain basic solid state physics type of information from living systems.

Since all five of the above described information channels are feeding information, at different relative amplitudes, into the light pattern that is eventually registered as a Kirlian photograph, auxiliary quantitative data such as Z_S, ϵ, etc., will be of great value in the translation of Kirlian information to physiological state information. In fact, as we dig deeper, we will even see that two values of skin impedance are important, one for the forward direction of current flow and one for the reverse and that these lead to certain unique polarity effects in the discharge halos of fingerpads. We can also expect to find some relationship between the initial location of discharge channels and acupuncture points because of their low electrical resistance compared to the surrounding expanse of stratum corneum. However, to effectively reveal this data, one must cope with the time-dependent charge transfer between the streamer channel and the skin.

It should be clear at this point that we have passed another significant hurdle in the study of Kirlian photography. The quantitative foundations have been outlined and, although much work remains to be done with respect to broadening the scope and deepening the detail of the calculations, we are now in a position to begin designing effective instrumentation for research studies. In the future, this technique should find great use in the fields of medicine, biology, agriculture, psychology, psychiatry and materials science.

Acknowledgement–This work was partially supported by the Ernest Holmes Memorial Research Foundation.

REFERENCES

1 Y. Omura, Patho-physiology of acupuncture treatment: effects of acupuncture on cardiovascular and nervous systems–1, *Acupuncture & Electro-Therapeut. Res., The International Journal,* 1, 51-141, 1975.

2 Y. Omura, Electro-acupuncture: its electro-physiological basis and criteria for effectiveness and safety—1, *Acupuncture & Electro-Therapeut. Res., The International Journal,* 1, 157-142, 1975.
3 Y. Omura, Editorial: Some historical aspects of acupuncture and important problems to be considered in acupuncture and electro-therapeutics research, *Acupuncture & Electro-Therapeut. Res., The International Journal,* 1, 3–44, 1975.
4 Y. Omura, Electro-acupuncture for drug addiction withdrawal syndrome, particularly methadone and individualized acupuncture treatments for the withdrawal syndromes of drug addictions and compulsive habits of excessive eating, drinking alcohol and smoking, *Acupuncture & Electro-Therapeut. Res., The International Journal,* 1, 231-233, 1975.
5 D.G. Boyers and W.A. Tiller, On corona discharge photography, *J. appl. phys.,* 44, 3102, 1973.
6 W.A. Tiller, The Light Source in High-Voltage Photography, in *The Energies of Consciousness* (Eds. S. Krippner and D. Rubin) Gordon & Breach, N.Y., 1975.
7 D.G. Boyers and W.A. Tiller, The color in Kirlian photography—fact or artifact?, *Functional Photography,* 11, *3, pp.20, May 1976.
8 C. Dobervich, Kirlian photography revealed, *Psychic,* VI, 34, 1974.
9 W.A. Tiller, Kirlian photography, its scientific foundations and future potential, *Physiological Physics and Therapies,* (edited by D. N. Ghista) Marcel Dekker, N.Y., 1976.
10 W.A. Tiller, D.G. Boyers and H.S. Dakin, Towards a Kirlian device for monitoring physiological state, Part I: device considerations, submitted to J. Psychophysiol.
11 S. Krippner and D. Rubin, *Galaxies of Life,* Gordon & Breach, N.Y., 1973.
12 J.M. Meek and J.D. Craggs, *Electrical Breakdown of Gases,* Clarendon Press, Oxford, p.375, 1953.
13 H.W. Bandel, Measurement of the current during the formative time lag of sparks in uniform fields in air, *Phys. Rev.,* 95, 1117, 1954.
14 A.L. Ward, Townsend or streamer breakdown, *Proc. VI Int. Conf. Ionization Phenomena in Gases,* 2, 313, 1963.