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Progress in understanding

With four to five years of Kirlian photography experience[1-5] under our collective belts, it is time that we in the West tallied up what we actually know about the process. What are the scientific foundations about the process? Do we really see manifestations of unconventional energies flowing in living systems, or are we misinterpreting the results of poor technique? What is the real potential of this process once the "wow!" syndrome has been penetrated? These are the questions to be dealt with in the present paper with the primary emphasis being directed towards the first question.

Studies carried out in the author's laboratory and in other laboratories have shown that the primary mechanism of light generation in Kirlian photography is associated with the electrical discharge through the gas (usually air).[6] The basic color seen is a consequence of light emission from excited gas atoms and ions as they change their basic energy states via recombination and relaxation processes. Air gives a blue emission (from the nitrogen), hydrocarbon gas gives red, helium gives green, neon gives orange, etc.

Other colors observed in the ultimate photographic data may be due to either (a) Intense electrical discharges in narrow air gaps occurring at the backside of the film between the film backing and the electrode plate so that light enters the film from this direction also. Because of normal color film construction, this can lead to an extensive range of colors appearing on the developed film.[5-7] (b) Vaporization of cellular tissue due to the microarc impacts of the electrical discharge may produce a high local hydrocarbon content to the gas thus leading to a red-emitting component in the discharge gas. (c) A new and unspecified energy is emitted by the living system at sufficient intensity to alter the energy states of the gas constituents and thus the primary emission colors of the discharge gas.

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Abundant experimental support has been found for case (a) and, in fact, by varying the spacing between the fingerpad and film and between the film and the electrode plate, the entire range of colors observed by investigators around the world has been reproduced on one healthy subject over a time period of about 30 minutes of testing.[5,7] Some support for case (b) has been found in the author's laboratory and in those of others by the use of transparent electrodes. In air, one usually obtains only a blue to white color but sometimes aspects of red begin to appear. If one then takes a tissue and cleans the transparent electrode, there is an immediate return to a blue to white color.[8] To date, there is no direct and clear evidence for case (c).

From studies of high voltage electrical engineering, we have learned how the voltage, gas chemistry, electrode shape, and electrode polarity influence the discharge.[7,9] We also know, to a fair degree, how the frequency of the voltage source influences the results which means that pulse shape and pulse duration effects are also known.[7] In addition, we are coming to know some of the characteristics of the living electrode that strongly influence the discharge and, in the next section, we shall see that there are five separate and distinct physiological information channels via which Kirlian photography can tap information about the living system.[7]

In the next section, we will see how an inner state change can lead to a set of physiological changes which may be monitored via any or all of the five channels. It will be seen that we have uncovered the set of equations governing the gas discharge and its modulation via the physiological parameters of the living system under study. Thus, we are now able to qualitatively explain all the phenomena observed to date by experimenters around the world (excluding some aspects of the phantom-leaf effect). It seems as if we are now in a position to write a computer simulation program to print out the size and intensity of fingerpad halos as one varies the physiological, gas and power supply parameters of the system. It seems that we are now in a position to design meaningful equipment for Kirlian studies in medicine, agriculture, biology, phychology and materials science. In each area, the optimum operating conditions are slightly different so that the best equipment and experimental technique will also be different.

The set of governing equations and their consequences—The electrical power distribution in the total system is illustrated using the Kirchoff current law for the circuit which is

Equation A

$$V = I(Z_o + Z_f + Z_s) + (V^*_G + \Delta V_G).$$

Here, the presence of surface changes has been neglected, 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 $V_G = V^*_G + \Delta V_G$ and I are the gap voltage drop and the discharge current, respectively. No light effect will appear on the film unless streamer formation occurs which requires that V_G exceed the critical streamer onset voltage, V^*_G by some overvoltage ΔV_G. Paschen's law voltage for a spark discharge is very close to V^*_G; thus V^*_G will vary with pd (gas pressure, p, in mm's of mercury and gap distance, d, in cm's) as illustrated in figure 1 and represented functionally by

Equation B

$$V^*_G = f_1 \text{ (pd, } n_{e1}).$$

In "equation B," f_1 is the function describing the shape of Figure 1 for a particular value of n_{e1} which is the concentration of electronegative ions in the gas. The more effective are the electronegative ions as electron scavengers and the larger is n_{e1}, the larger V^*_G must be to produce the critical avalanche condition for light generation. At constant gas pressure and constant V^*_G, we note from Figure 1 that the discharge can occur at both a very small spacing

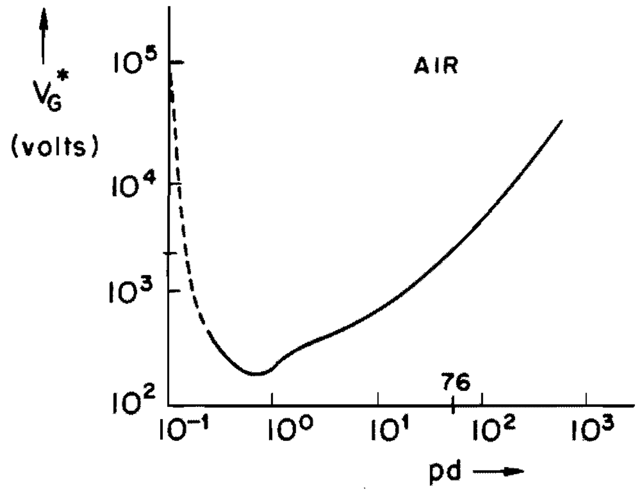

Fig. 1. Schematic illustration of air breakdown voltage, V^*_G, as a function of the product, gas pressure, p (in mms) X electrode spacing, d (in cms).

and at a much larger spacing for values of V^*_G above the minimum in Figure 1. For normal gap spacings (1 mm), the operating conditions are on the right-hand branch of the curve.

Onset of light generation produced considerable photo-ionization so that many new electrons are generated and the discharge current, I, increases greatly. Thus, V_G must decrease via "equation A" to such a level that the gap overvoltage

Equation C

$$\Delta V_G = V_G - V^*_G$$

is sufficient to maintain the current level I satisfying "equation A". For two planar metal electrodes, the growth of current with time, t, for a constant value of overvoltage has been found to be given by Figure 2 (next page)[10,11] and represented by

Equation D

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

where f_2 is the functional shape given in Figure 3 (next page), and ω is the radio frequency of the power supply. For our application here, wherein one of the electrodes may be biological tissue, the proper picture is somewhat more complex and beyond the scope of this paper; thus we shall merely recognize, in passing, that Figure 3 and "equation D" are only approximations to the truth. Finally, because of the light generation mechanism involved in the discharge process, the light intensity, L, for a particular gas will be proportional to the electrical current, I, through the gas; i.e.,

Equation E

$$L = \eta I$$

when η is the photon generation efficiency.

The other important constraint on the system containing inherent information about the Kirlian process is that of continuity of electric flux at all interfaces in the discharge system; i.e., at the finger and film surfaces. We thus require the following equation to be satisfied:

Equation F

$$\epsilon_i E_i - \epsilon_G E_G = \rho_i \; ; \; i = s, f_f, f_B$$

where ϵ is the dielectric constant, E is the electric field, ρ represents the surface electrical charge and i refers to skin (s), front side of film, f_f, or back side of film, f_B. The electric field is related to the voltage drop across the particular item via

Equation G

$$E_j = \frac{V_j}{\iota_j}; \; j = G, s, f$$

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

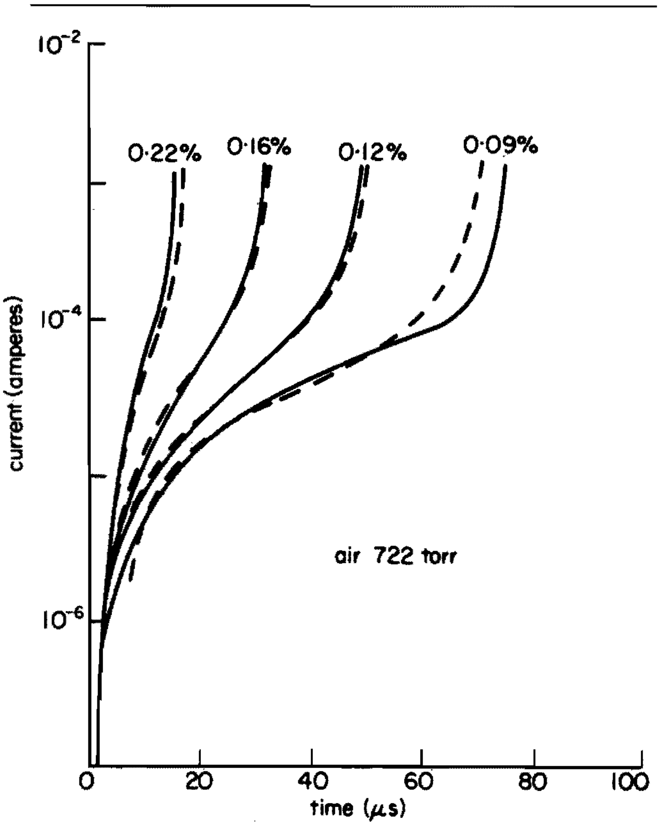

Fig. 2. Comparison of current, I, growth in air for various constant overvoltages obtained experimentally by (-----) by Bandel and calculated by Ward.

From the foregoing equations, it is possible to discriminate the five unique information channels, illustrated in Figure 4, for monitoring physiological changes in an organism associated with a specific internal state change. Starting from the right, we note that the only way that an electrical impedance change of the skin can be observed is if the voltage drop across the stratum corneum (I Z_s) is much greater than the overvoltage on the gap (ΔV_G). This allows changes in the skin impedance to be of such magnitude that the changes in the voltage drop across the skin will be of the same order as the overvoltage on the gap which, via Figure 2, will greatly change the discharge current, I, and thus, the generated light intensity, L; i.e., we need

Equation H

$$\delta(I\, Z_s) \sim \Delta V_G.$$

If this occurs, the altered light intensity can be readily recorded on film. Evaluating the skin impedance, Z_s, at frequencies greater than or equal to ~ 100 kHz, where the Soviets stated was the best frequency range in which to work,[12] we find that both Z_s and I are so small that I $Z_s/\Delta V_G \ll 1$ and no effective change in overvoltage should occur.[7] This is consistent with the Stanford results[7] and with some European results[13] where power supplies of 100 kHz were used. However, if one performs the same calculations in the frequency range of approximately 1 to 10 kHz, then both Z_s and I

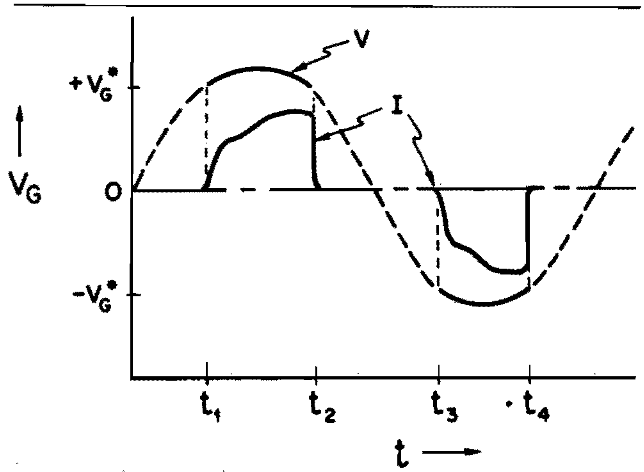

Fig. 3. The gap voltage, V_G, and discharge current, I, as a function of time for metallic electrodes (zero wall-charge case) indicating that significant current flows only when V_G exceeds the critical voltage V^*_G.

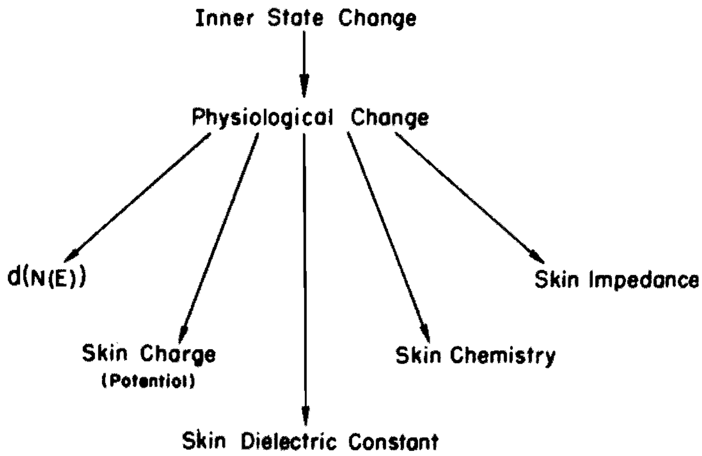

Fig. 4. Representation of unique information channels for monitoring physiological state changes associated with internal state changes via Kirlian photography.

increase significantly leading to $I\ Z_s/\ \Delta V_G \gtrsim 1$. In this case, changes in Z_s due to physiological changes should be observable with the Kirlian technique. It is of interest to note that most of the inexpensive "ring down" devices generate frequencies in the range of 0 to 150 kHz, with power peaks in the range 3 to 12 kHz. Thus, where people claim to see physiological effects with Kirlian is consistent with these predictions. Unfortunately, none of these inexpensive power supplies yields sufficiently reproducible electrical pulse trains to obtain high reproducibility in the Kirlian photographs. Another quirk of some of these supplies is that Z_o is sufficiently small that loading of the supply with Z_f and Z_s causes a shift of the power frequency spectrum.

Turning, now, to the next information channel, we note from "equation B" that V^*_G is dependent on the concentration of electronegative ions in the gas phase such that V^*_G will increase as n_{el} increases.[9] In the Kirlian discharge, the individual current channels carry sufficient energy density to evaporate spots of the stratum corneum. Organic matter generally produces 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 suggest that many of their Kirlian photography changes are consistent with this mechanism. Since their dietary and bathing habits are appreciably different from those of American 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 influence their data; i.e., they would seek to work in the region > 100 kHz, which they stated as being best via their experience. They do not appear to have yet discriminated the differences between these two information channels and, although we appear to be utilizing the skin impedance channel, they appear to be utilizing the skin chemistry channel. 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.

For the next two channels, we note from "equations F and G" that variations of skin dielectric constant, ϵ_s, and skin charge, ρ_s, must influence the discharge. If we set $\rho_s = 0$ in "equation F" for convenience of description, we can see that, as ϵ_s changes, as a result of moisture content changes in the stratum corneum, the electric field, E_G, in the air gap must change. Changes in ϵ_s by factors of 2 to 5 are easily possible. Of course, this will also change the skin impedance in a significant way. If we assume that E_s is only slightly changed, then E_G must change as much as ϵ_s has changed, and this requires, via "equation G," changes in both d and V_G. We thus see that the size of the discharge halo and its brightness will be influenced by changes in ϵ_s (V_G, I and d changes will follow). If, for constant pressure, p, we take the slope of Figure 1, we have E_G as a function of d. In Figure 5 (next page), we have plotted $|E_G|$ versus d for p = 1 atmosphere and note that, in the region where people normally work (d ~ 0.1 to 0.5, millimeters and V^*_G ~ 2 to 5 kv), the slope of Figure 1 is almost constant. Thus, small changes in $\epsilon_s\ E_s$ may require large changes in d to satisfy "equation F" simultaneously with "equations A and D." Since the power supply delivers power over a range of frequencies and, since Z_o, Z_f, Z_s and V_G are frequency-dependent parameters, the equations will be satisfied over a range of d-values producing a certain halo-width. →

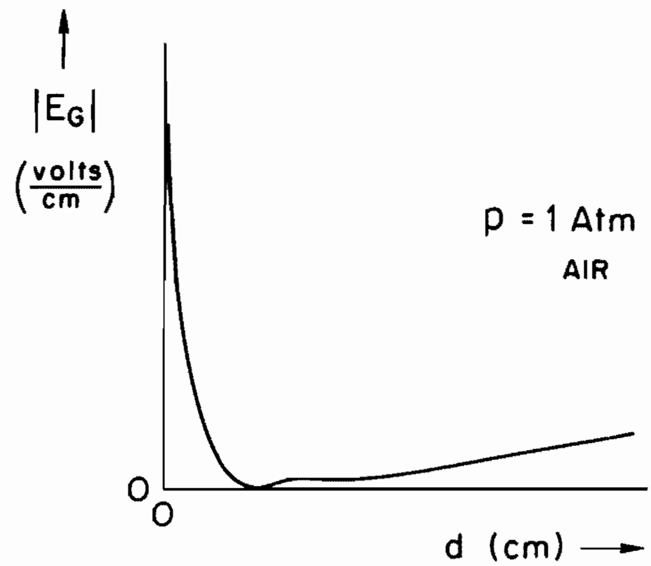

Fig. 5. Plot of absolute value of electric field strength $|E_G|$, for air in the gap as a function of electrode separation distance, d, for p = 1 atmosphere.

Certain physiological changes give rise to changes in surface charge, ρ_s, on the skin and yield correlated changes in skin potential, ϕ. Under certain special circumstances, these local changes in ρ_s and ϕ can be large. Obviously, via "equations F and G", they may produce significant changes in E_G. Let us suppose that the magnitude and sign of ρ_s are such that E_G must become very large to satisfy "equation F." Then, from Figures 1 and 5, the discharge can no longer function on the right-hand branch of the curve but 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-hand branch operation in Figure 5 to left-hand branch operation. This would produce spots of red color in the background of the fingerpad such as has been observed to occur in some cases.[7]. These gaps behind the film are illustrated in Figure 6.

Combining changes in ϵ_s, ρ_s, and Z_s, it seems possible to create a requirement for an extremely large value of E_G which could occur only at an extremely small value of d. However, at this small value of d, V^*_G has become so large as to actually exceed the power supply voltage, V, so that no sensible light generation occurs. This is one possible explanation for the absence of a discharge halo around a person's finger where, an hour earlier, a bright halo might have been observed.

The last of the five channels for gaining information concerning a physiological state change is that associated with monitoring the change in the density of electron states in the skin d 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 as a result of the impinging ultraviolet photons from the gas discharge in air (nitrogen-ion recombination events). The emitted photoelectrons, if of sufficient 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 about the molecular electrons in living systems.

Portents for the future 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 simultaneous data such as values of Z_s, ϵ_s, I, etc., will be of great value in the translation of Kirlian information into physiological state information. If we settle for only partial information concerning what is available on these channels, then we cannot expect the system to have much diagnostic utility since these few fragments of physiological information could probably have been produced by a large number of different inner state changes. However, if we clearly discriminate all five information channels and delineate all the available physiological information, then the technique does have diagnostic value since very likely only one or two inner state changes could have produced such a specific array of intercorrelating data.

We shall find, as we dig deeper, that Z_s has two

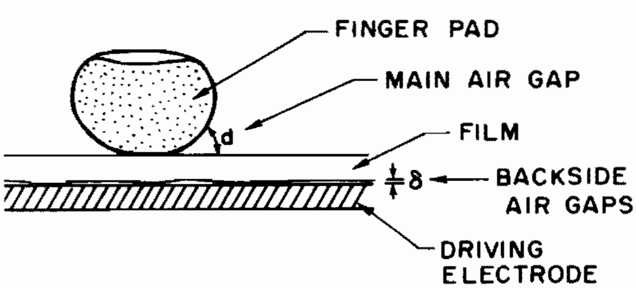

Fig. 6. Schematic illustration of discharge gap distance d for a fingerpad-film combination plus the small air gaps of distance δ between the film and the back side of the electrode.

values depending upon the electrical polarity of the skin relative to ground. One value is related to the forward direction of current flow while the other is related to the reverse direction and they produce certain unique polarity effects to the discharge halos of fingerpads. They arise because of the selective permeability of the stratum corneum for ions of opposite sign. Identification of the type and degree of permselectivity provides information about the ionization state of the fixed ions in the membrane (thought to be associated with the mucopolysaccharides in skin). This ionization state is, in turn, related to the pH of the tissue fluids—a very important parameter concerning our state of health. It is felt that future Kirlian studies will be able to provide such information.

Lower electrical impedance

We can also expect to find some relationship between the initial location of discharge channels and acupuncture points because of their lower electrical impedance compared to the surrounding expanse of stratum corneum. However, before we can effectively reveal these data, we must cope with the time-dependent charge transfer between the discharge channels and the skin. 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.

It should be clear from the foregoing that Kirlian photography, as presently practiced, does not reveal the aura that a clairvoyant sees around a person. However, we may eventually find that a correlation exists between these two patterns. The Kirlian discharge process has a perfectly reasonable and useful physical explanation based upon the flow of conventional energies. Up to the present, we have not found manifestations of unconventional energy revealed by this process; however, only after greater familiarity with the quantitative aspects of the process will we know what unexplained factors remain as potential evidence for such new energies. To date, the phantom-leaf effect comes closest to being a likely candidate for the "non-conventional energy award." However, a good portion of the effect is explicable in conventional terms[14] and, as we carefully study it further, we may find that it, too, has a perfectly reasonable physical process path determining its quantitative explanation.

It should also be clear at this point that we have passed another significant hurdle in the study of Kirlian photography—we have outgrown the childhood stage, our "Wow" stage, and we now know how to interpret carefully gathered data.

At the present moment in time, this author is extremely optimistic about the potential utility of this technique. In the future, the technique should find great use in the fields of medicine, biology, agriculture, psychology, psychiatry and materials science. When financial support becomes available for studies in such areas, we can anticipate an explosive growth of our understanding. **OP**

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