A Comment

WILLIAM A. TILLER

Department of Materials Science, Stanford University, Stanford, California 94305, U.S.A.

In the past, I have been quite critical of the protocol used in earlier experiments with the phantom leaf effect. *All* pictures published in the U.S. until recently were taken with inadequate protocol in that the leaf was never cut prior to first placing it in the system. The earlier procedures utilized to reveal this effect were clearly open to the criticism of chemical pattern sensitization or electrical charge pattern sensitization of the film (Tiller, 1975). Now, the present study by John Hubacher and Thelma Moss, the videotape results of Dr. Moss (1975) and her coworkers and the beautiful sheet-film result of Robert Wagner (1975) have been carried out under acceptable protocol and it is found that the phantom leaf appears once every 20 (Moss) to 100 (Wagner) attempts. It is clearly a real phenomenon in need of explanation.

To begin to understand this phenomenon, it is useful to recall why one obtains a total leaf discharge even though the electrode contacts the leaf at only one small point. This occurs because the internal resistance of the leaf is low, due to the high electrolyte content of the tissue fluid, so that the entire internal portion of the leaf is almost an isopotential domain. As a result, it is as if the second electrode made a direct internal contact with the inside surface of every point on the outer membrane of the leaf so that the full voltage difference, $\Delta\Lambda$, is applied between every point of the leaf and the lower planar electrode. This isn't quite true as there is some voltage drop as one moves from the electrode contact out to the furthest tip of the leaf, but this drop, δV, is generally small with respect to the applied voltage difference, ΔV. Of course, the discharge occurs most strongly at the edges because of the "point effect" whereby the high curvature of the surface increases the local electric field strength far above the average field strength and thus leads to strongly enhanced discharge current density at the points, which means strongly enhanced light intensity as well. In addition, marked vaporization of surface moisture, vaporization of surface hydrocarbons and electroosmotically produced surface products will occur preferentially from such regions of high local field strength.

Turning to a cut leaf, such as that produced by Wagner, we must now ask ourselves how an electrical discharge can occur across the air gap in the cutaway region. Clearly, the following must occur,

1) a voltage drop must develop across the cut portion sufficient to drive a discharge and

2) the conductivity of the air must increase, either by radiation-induced ionization or by chemical ion seeding, to such a degree that electrical discharges can occur at the available voltage differences.

Observations of Dr. Moss's videotape results provide a clue in that the initial leaf discharge did not show any light effect in the cutaway portion. Gradually, one saw a billowing type of discharge cloud moving out from the cut surface to eventually fill the cutaway region. This cloudy type of discharge did not seem to project appreciably beyond the original outer envelope of the leaf. These observations strongly suggest the vaporization of ionized tissue fluids at the freshly cut surface by the microarcs developed there during the general discharge. Clusters of charge of sufficient density will act like momentary point electrodes at some potential difference with respect to the driving electrode and discharges through this chemically altered gas may occur between them and the driving electrode. In addition, vapor deposition will occur from this cloud onto both the film and the glass plate. The deposition on the glass plate will act as a partial conductor to extend the leaf potential into the cutaway regions. One would expect such an effect to be prevalent with young leaves in springtime because that is when leaves have both a high ion and fluid content (and perhaps also some special chemicals in the tissue fluids at that time).

It is well known that the addition of certain gaseous atoms to a main gas can greatly enhance the ease of electrical discharge through the gas. For example, the addition of only 20 parts per million of argon to 1 atmosphere of neon will decrease the gas breakdown voltage from ~ 1000 volts to ~ 250 volts at an electrode separation of 1 mm (Penning, 1931). It is also well known that supersaturated water vapor will tend to condense around free charges to reduce the local electric field strength (basis for cloud chamber physics). Thus, we can begin to see why a discharge in the cutaway region may be a small probability event if the ion seeding process is operating. Such a process would depend on

1) fluid content of leaf,

2) ionic type and content of leaf,

3) additional chemical constitution of tissue fluids,

4) location of the cut relative to easy flow channels for tissue fluid,

5) local humidity of the air,

6) local temperature of gas as affected by discharges,

7) evaporation rate as affected by discharge current and pulse duty cycle,

8) temperature of glass slide for deposition,

9) volume of air space, relative to cut surface length, into which gaseous products can flow,

10) power supply type and operating supply output voltage, etc.

The likelihood of being able to reproduce the same amplitude-set for this array of variables in sequential experiments is very small. Thus, the proper critical balance of factors leading to this type of gas-seeded discharge is clearly a "sometime" thing.

The loose end in the present argument is: How does one explain the observation that the gas-seeded discharge continues to propagate to approximately the outer envelope of the original leaf and then stops? Here, the author has great difficulty in finding a reasonable explanation. The leaf undoubtedly functions as an electrical and a mechanical antenna. However, at the electrical level, the scale of expected effects at $\sim$ 10 kHz does not fit the observations, but at the mechanical level, it does (wavelengths $\sim$ 1–2 cms). Thus, perhaps a type of mechanical resonance develops in the cut leaf which sets up constraining waves in the adjacent air which has the natural form of the whole leaf (should be a resonant mode). This would tend to confine the vapor cloud within the whole leaf envelope. Looking at the Wagner picture, the author does not feel completely satisfied with this explanation; however, it is offered for the purpose of focusing specific attention on the problem.

A final remark should be made about pulsatory phenomena in these kinds of studies. Because of the arrangement of the glass dielectrics and the metal pieces, one should anticipate certain capacitor effects to develop and be out-of-phase with the driving electrode. Net charging-up and discharging sequences should occur in a fairly repetitive way so that this effect would need to be integrated with the earlier gas-seeding explanation.

REFERENCES

Moss, T. Private communication, June, 1975.

Penning, F. M. Comment. *Proceedings of the Royal Academy of Sciences, Amsterdam*, 1931, **37**, 1305.

Tiller, W. A. Tiller comments. *Psychic*, August, 1975.

Wagner, R. Private communication, June, 1975.

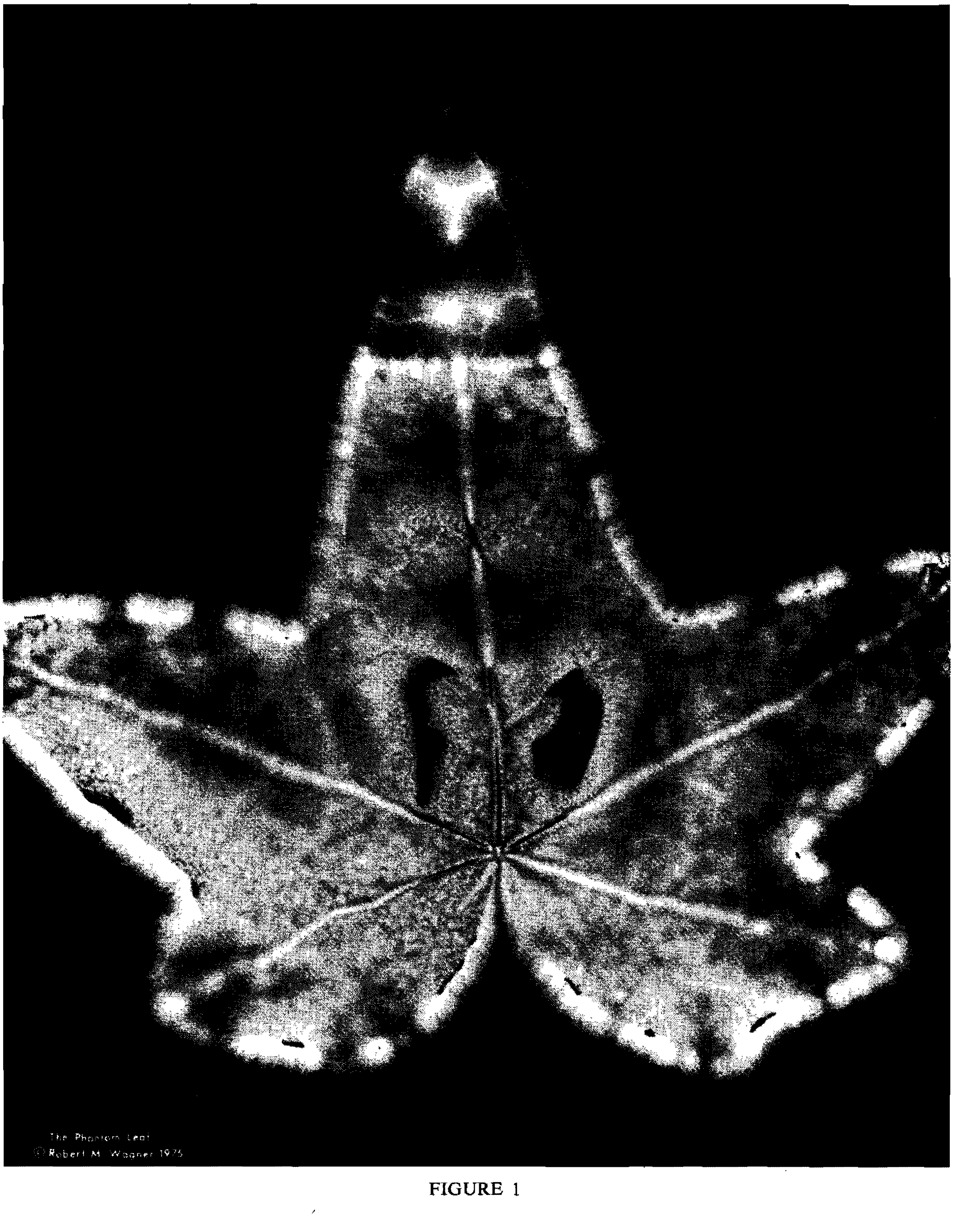

FIGURE 1