satisfactory. On the other hand, inorganic carbonates are improbable, primarily because of the low cosmic abundance of certain necessary elements such as lead.

In his first paper Sinton (*1*) discussed in considerable detail the possible contributions of Martian thermal emission to the observed intensities. For the 1956 observations, for which there was no spatial resolution, he estimated an effective temperature of 279°K. After matching the experimental data with an appropriately weighted combination of a curve of a blackbody at 279°K and a laboratory reflection spectrum of lichen, he deduced that the thermal emission was a minor contribution, rising to perhaps 33 percent of the total intensity at 3.8 μ. This result was adopted in the interpretation of his 1958 observations.

To obtain a feeling for the intensities we have plotted three curves in Fig. 9—the blackbody curves for 255° and 300°K and the reflected intensity for a Martian surface element perpendicular to the sun, assuming a sun temperature of 5500°K. To calculate the latter we assumed an arbitrary reflectivity of 0.01, a value which may be somewhat low. For the emission curves an emissivity of 1 was adopted so that the values are probably a few percent high for the Martian surface. The spectra presented by Sinton (Fig. 1) are essentially effective reflectivities. However since the solar intensity varies only slightly over the wave-number range covered, they also are good representations of the energy leaving the surface.

Several points of interest now arise. It is seen that, even for a temperature of 255°K, the thermal emission can make a very significant contribution. We have not attempted to calculate effective temperatures for Sinton's two Martian spectra (Fig. 1) but we would estimate from Gifford's isotherms (*9*) and Sinton's 1956 calculated effective temperature of 279°K that 255°K is not excessively high. It appears then that the contribution of the thermal emission, at least near the Mars I band, is comparable to the reflected radiation.

This raises the question of the band intensities. It is expected that the emission spectrum will be relatively featureless. Whatever features are present will be opposite to the reflection features and will tend to smooth the Martian curve. It follows that the pure reflection spectrum would have spectral features more pronounced than any observed spectrum which is the resultant of both reflection and emission. In particular, the relative intensity of the Mars I band in a pure reflection spectrum would be greater. When, in addition, one considers the large bright areas included in the nominal Syrtis Major spectrum, it is clear that the spectral features would be more intense if only the dark area were observed. At least this is true if the features are attributed to effects solely of the dark areas as Sinton's measurements indicate. This makes the assignment of the Mars I band, the one most affected by these considerations, still more difficult since we have observed in the laboratory no intense features in this region. It also stipulates that if organic matter is responsible for the other two, the material must have a very high surface concentration.

There is an alternative to the contribution of emission as an explanation for the increase of intensity in the Martian reflection in spectrum at lower wavenumbers. All of the samples examined, which contained water, show such an increase, attributable to the wing of the very intense water band at 3400 cm^{-1}. Samples containing no water, such as paraffin wax, do not exhibit this effect. If the increase in the Mars spectra is not due to the characteristics of the emitted radiation it may arise from water in the surface material. The water could be in the liquid state in plants, in minerals as water of crystallization, or adsorbed on the surface.

We unfortunately have no answers for the major questions raised here. At present we know of no satisfactory explanation of the Martian bands. Observations of the planet with improved spectral and spatial resolution, in conjunction with radiometric temperature measurements, could possibly define the problem sufficiently to enable a solution to be found (*10*).

D. G. Rea
T. Belsky
M. Calvin

Space Sciences Laboratory and
Department of Chemistry,
University of California, Berkeley 4

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Skin Impedance and Phase Angle as a Function of Frequency and Current

Abstract. *The impedance of the human skin decreased from approximately 130 to 30 Kohm as the frequency of a-c input increased from 1 to 1000 cycles per second. Over this same range of frequencies, the phase angles changed from −2 to −58 degrees. Changing the peak-to-peak current through the subject from 14 to 62 microamperes had no effect on either the impedance of the skin or the phase angles.*

An adequate system for measuring the electrical properties of the skin, such as that required in research on galvanic skin response, should have three minimum requirements. It should (i) be relatively free from artifacts due to the apparatus, such as electrode polarization and uncontrolled variations in current; (ii) use parameters whose effects are understood; and (iii) give results which are unambiguous and meaningful within the standard body of electrical theory. The d-c systems which are commonly used for studying galvanic skin responses do not generally meet these requirements, in that polarization effects are difficult to control, the levels of current applied are often unspecified or subject to uncontrolled variation, and the assumption is sometimes made implicitly that the body acts as a simple linear resistor.

A number of studies, such as those of Burns (*1*) and Grings (*2*), have shown that the human integument has capacitative characteristics which vary as a function of the frequency of the a-c input. However, these researchers have not measured phase angles and impedance at very low frequencies. The

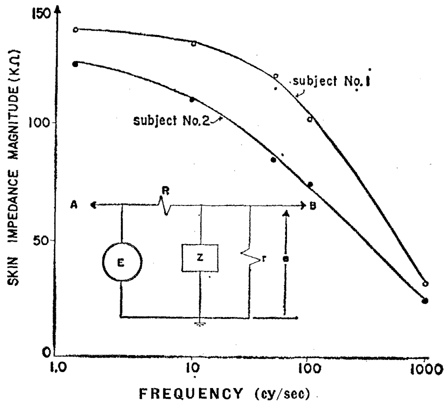

Fig. 1. The magnitude of impedance of the skin as a function of frequency, and a schematic diagram of the apparatus for measuring skin impedance (inset). Points A and B are connected to the horizontal and vertical inputs, respectively, of an oscilloscope. The remaining symbols are explained in the text.

range of 1 to 1000 cy/sec is most important for research on galvanic skin response, since higher frequencies have been reported (*3*) as measuring general dielectric characteristics of body tissue and not the properties of skin alone. The purpose of the present research was to determine phase angles and impedances of human skin as a function of frequency over the range of 1 to 1000 cy/sec. The current densities were also varied.

The output of a model M2-Southwestern Industrial Electronics audio oscillator was connected through a high resistance to the skin of the subject and from there to the vertical plates of a model 502 Tektronix oscilloscope (Fig. 1, inset). The sine wave output from the oscillator was connected directly to the horizontal plates of the oscilloscope. A Lissajous figure was obtained in which the degree

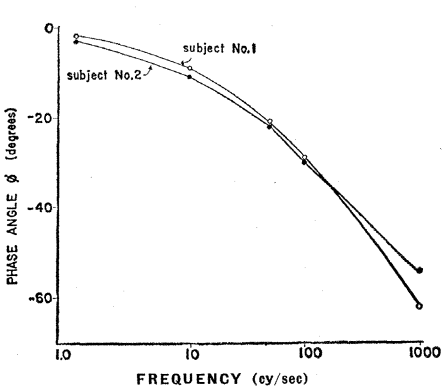

Fig. 2. Phase angle as a function of frequency.

of ellipticity was related to the electrical capacity of the skin. The complex skin impedance, Z, was computed from the following formula: $Z = eR_p/(E' - e)$, where $R_p = Rr/(R + r)$ and $E' = Er/(R + r)$. The oscillator voltage E, the voltage developed across the skin e, and their relative phase angle were read from the Lissajous figure. The input resistance, r, of the oscilloscope was 1 megohm. The series resistance, R, was 0.5, 1, or 2 megohms. The current passing through the subject's skin was given by $i = (E' - e)/R_p$, as is evident from the relation $e = iZ$. The symbols Z, e, E', and i are complex numbers whose magnitudes and phase angles are functions of frequency. The formulas for Z and i result from straightforward passive-network analysis of the circuit in the inset of Fig. 1.

Two subjects were tested over five frequencies, 1, 10, 50, 100, and 1000 cy/sec, in ascending and descending order. Three levels of current, ranging from approximately 14 to 62 μa, were studied in ascending and descending order.

Medcraft circular silver electroencephalograph electrodes, 1.0 cm in diameter, were taped tightly to the pads of the second and fourth fingers of the left hand. No artifacts resulted from movement of the fingers or hand. The electrodes were used "dry," without external pastes, to avoid some of the problems described by Montague (*4*) and by Edelberg and Burch (*5*). These authors found that basal skin resistance depends greatly upon the type and concentration of electrode paste used. However, it is known from the work of Stoughton (*6*) and Griesemer (*7*) that no electrode is truly dry because a surface layer of emulsified material is always present on the skin and provides some sort of natural fluid medium.

Figure 1 presents the mean impedance for each of the two subjects and clearly shows the marked influence of frequency on this measure. At 1000 cy/sec the impedance drops to approximately 20 percent of its value at 1 cy/sec. Over the same range the phase shift, ϕ, changes from about -2 degrees to -58 degrees (Fig. 2). It is interesting to note that the two subjects have similar phase angles but relatively more discrepant impedances. This suggests that phase angle may be a more useful measure than impedance, because individual differences in base level are reduced to a minimum.

The magnitude of the impedance and the phase angle were invariant with changes in the level of current, in the range used. This implies that current variation need not be considered as a source of error and that the skin acts as a linear system to impressed a-c voltage. In contrast, Davis (*8*) and Grings (*2*) have shown that current does affect base resistance, or galvanic skin response, when a d-c system is used, although these authors studied a wider range of currents.

In summary, it appears probable that the use of low-frequency a-c sine wave inputs avoids some of the artifacts often associated with research on galvanic skin response, and provides, at the same time, unequivocal measures of certain electrical characteristics of the skin.

ROBERT PLUTCHIK
HENRY R. HIRSCH
National Institute of Mental Health, Bethesda 14, Maryland

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21 May 1963

Startle Reaction: Modification by Background Acoustic Stimulation

Abstract. *Six rats were exposed to a sequence of gunshot-like acoustical bursts during silence, during steady noise, and during pulsed noise. Assessment of their startle reactions to the bursts revealed that a background of steady noise enhanced the response, whereas a background of pulsed noise produced suppression of response. It is hypothesized that pulsed noise causes a relative refractory state in the mechanisms responsible for startle and that steady noise may enhance startle by masking uncontrolled punctiform acoustic stimuli.*

When a sudden intense sound is presented to a member of the class Mammalia, the immediate response often consists of an abrupt reflexive move-