ELECTRICAL PROPERTIES OF THE HUMAN BODY

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A study was made of the electrical conductivity and sensitivity to electrical shock of the human body. The possible influence of several factors was investigated. The results are separately reported with respect to each factor studied.

1. **Resistance related to contact pressure of the electrodes.** A circular metal disk of 8 sq. cm. area was placed in contact with the palm of each hand. A constant voltage was applied and the current noted as the contact pressure increased. The data are graphed in fig. 1. It may be seen that the resistance decreased rapidly as the pressure increased up to a pressure of about 15 grams per sq. cm. and at 50 grams per sq. cm. the resistance change with pressure was very small. For subsequent testing contact pressures were maintained greater than this value.

2. **Resistance related to contact area.** Upon placing the same electrodes at the same pressure upon different skin surfaces, different resistances were found. However, in a restricted region (such as the palm of the hand) the resistance remained nearly constant as the electrode was moved about. For a contact area of 8 sq. cm. the average resistance per sq. cm. for 21 cases was 277 thousand ohms. For a contact area of 4 sq. cm. the average resistance per sq. cm. for the same 21 cases was 242 thousand ohms. Twelve volts of potential was applied in all these cases. The interpretation would seem to be that the resistance is essentially a surface or "thin layer" characteristic. In further investigation of this question contact was obtained by immersing the hands in salt water to a measured depth. The area of the hand immersed was computed and the resistance per sq. cm. calculated as before, giving an average resistance of 450 thousand ohms per sq. cm. The probable error of the hand area measurements is, of course, large. Also the character of the surface is not homogeneous. However, this value suggests that the salt solution merely serves to make good electrical contact at the skin surface.

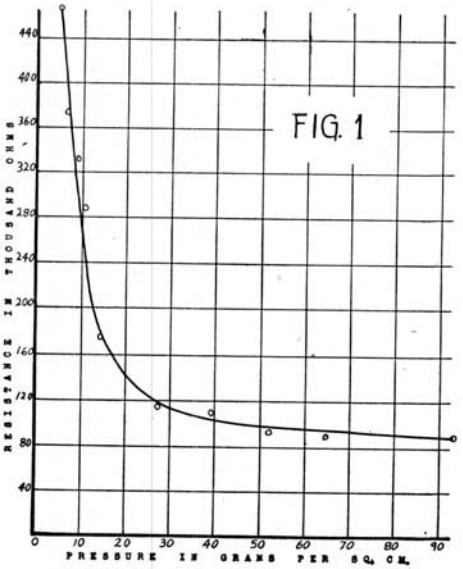

FIG. 1

	SUDDEN		GRADUAL	
Name	Volts	MA	Volts	MA
C	48	1.5	75	3.6
A	23	.62	60	3.4
K	28	.36	70	3.7

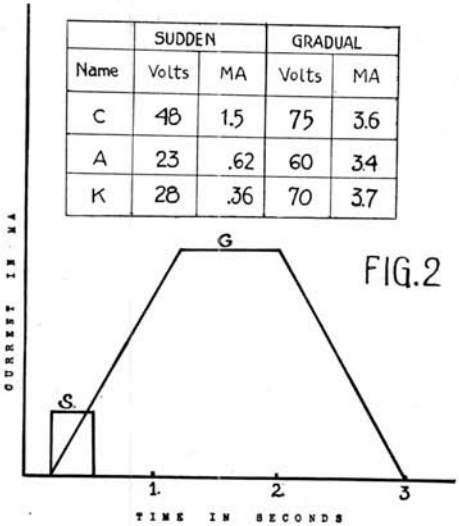

FIG. 2

TABLE I—POLARIZATION EFFECTS
(Resistance in thousand ohms per sq. cm.)

Name	Salt solution on hand		8 sq. cm. electrode on hand		4 sq. cm. electrode on hand		8 sq. cm. electrode on arm	
	R^+	L^+	R^+	L^+	R^+	L^+	R^+	L^+
b	435	680	215	260	165	170	740	580
c	340	425	150	170	100	110	170	350
d	785	830	265	270	280	270		
g	610	442	175	160	170	140		
h	340	372	210	220	160	150		
i	325	360	235	195	150	140		
j	325	360	235	250	130	150	430	1900
k	320	340	225	165	180	180	2100	360
A	595	710	140	140	100	86	860	170
B	720	740	110	112	69	58	540	270
C	455	365	150	140	130	120	430	680
D	430	500	150	175	110	130	240	330
E	410	520	250	260	150	170		
I	440	480	400	460	200	350		
F	430	560	190	195	150	160		
J	370	460	240	315	130	135		
G	430	500	225	350	200	190		
H	380	445	390	325	125	150		

TABLE III—VARIATION OF RESISTANCE WITH CURRENT
(Resistance in thousand ohms per sq. cm.; Current in MA.)

Name	Breakdown Voltage	Breakdown Current	Res. before Breakdown	Res. after Breakdown	Breakdown Polarity	Breakdown Current opposite Polarity	Ratio of Res. before and after Breakdown
K	16	.36	600	133	L^+	.06	4.5
M	9	.30	150	28.5	R^+	.22	5.3
A	13	.60	1000	57.1	L^+	.12	17.5
c	11	.44	120	.40	R^+	.42	3
E	15	.60	400	30	R^+	.16	13.3
L	14	.26	1000	50	R^+	.06	20
b	22	.30			L^+	.24	
K	12	.22	5000	83.3	R^+	.14	60
I	15	.44	160	34.8	L^+	.22	4.6

TABLE IV.—SENSITIVITY TO SHOCK WITH CURRENT THRESHOLD CURRENT FOR SHOCK IN MA

Name	Salt Solution	8 sq. cm. electrode on hand	4 sq. cm. electrode on hand	8 sq. cm. electrode on arm
a		.78	.66	
A	.635	1.12	1.2	.04
b	.55	.64	.59	.24
c	1.65	1.4	1.5	.08
d		.65	.44	
e		.505	.46	
f		.49	.46	
B	.70	.975	1.1	
C	1.3	1.075	.665	
D	.725	1.0	1.05	
g	1.75	1.15	.92	
h	1.55	.82	.765	
E	1.45	.80	.98	.60
i	1.75	.89	1.0	
j	2.1	.745	.925	
K	1.45	.96	.67	.16
I	1.35	.46	.69	
F	1.3	.92	.88	
J	1.85	.665	1.4	
G	.94	.57	.51	
H	1.65	.88	1.45	
I		1.02	.55	.19
M				.22
L				.26
K				.035
AVERAGE	1.334	.844	.858	.203

3. **Polarization effects.** Interesting polarization effects were observed under suitable conditions by reversing the polarity of the applied voltage. In each case tested after passing a certain threshold current, at a given applied voltage, the current was larger in one direction than in the other. In some cases the current was larger when the right hand was connected to the positive pole, in others the left hand. Values of resistance with indicated polarity are compiled in table I. Counter E.M.F's may contribute to this effect; however the explanation is probably not simple.

4. **Variation of apparent resistance with current.** Assuming the total impedance to flow to be resistance, currents were observed for varying values of voltage and the corresponding resistances calculated. In all cases the resistances diminished as the current increased. Finally, at a certain threshold value the resistance seemed to "break down" in an unstable manner and the current increased several fold at a given voltage applied for a couple of seconds. Moreover, on applying a given lower voltage the current was found to be several times larger than when tested at the same voltage before the break down occurred. In those cases tested, a recovery occurred in about ten minutes. The data taken in a typical case are shown in table II. The summary for nine cases showing this effect appears in table III.

5. **Relative effects of steady and surge currents.** In all cases it was found that if a slowly rising voltage was applied the subject experienced a localized burning sensation so intense it practically

masked the usual muscular contraction sensation. For this reason the sensitivity to shock was tested by closing a key to a potentiometer circuit for about two seconds and then releasing the key. If, instead of permitting the current to surge through on contact, a rheostat was manipulated so the current built up over a period of a second or two and then diminished to zero, the peak current reached a much larger value before it was felt than when a "surge" current was used. Typical data are shown in fig. 2.

6. **Sensitivity as effected by polarity.** In some cases the current necessary to produce shock was greater when in one direction than the other. However, this difference was not as great as the change of effective resistance with polarity. Also the sensation was sometimes felt much more readily in one hand than in the other. This difference varied widely with individuals.

7. **Sensitivity as affected by the location of the electrodes.** The tests included comparisons of the currents necessary to produce sensations when the electrodes were placed in the hands and when placed on the upper arm. In general the current required for sensation was considerably larger for the hands than for the upper arms. Also the sensation in the hands was usually described as a "tingle" whereas the usual word for the upper arm was a "prick". The data pertaining to shock are summarized in table IV.

TABLE II.—EFFECT OF BREAKDOWN CURRENT
(Resistance measured in thousand ohms)

Name "1"					
left hand +			right hand +		
volts	MA	Res.	volts	MA	Res.
8	.05	160	8	.05	160
9	.06	150	9	.06	160
10	.09	111.1	10	.08	125
11	.10	110	11	.10	110
12	.12	100	12	.12	100
13	.16	81.3	13	.14	92.8
14	.19	73.7	14	.18	77.8
15	.44	34.0	15	.22	68.2
8	.23	34.8	8	.12	66.7