## 9301

# Is the Q-Factor of Body Segments Independent of Size and Shape?*

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One of the striking features of the methods proposed for the clinical measure of Q-factor[1, 2] is the apparent lack of relation between the values obtained and the physical conformation of the subject under test. No corrections for size, shape, height or weight are made. The tissues under investigation (arm-to-arm segment) are considered as a single piece of dielectric having a characteristic Q-factor and it is assumed that differences in size and shape have a negligible effect on the magnitude of the results obtained. It is proposed, in the present paper, to show that this assumption is unwarranted and that results based thereon are seriously open to question.

It may be noted at the outset that the Q-factor of a given material is, in general, independent of its size and shape only if it be electrically homogeneous. In considering the special case of the arm-to-arm segment, it is evident from the anatomy alone that we are dealing with a heterogeneous impedance composed of muscle, tendon, aponeurosis, fat, nerve, vascular tissue, etc., of which each component may be supposed to have special electrical properties. The work of Eyster and his co-workers[3] and of Katz and Korey[4] indicates that this is indeed the case. When low frequency alternating current transverses the thorax or the trunk, it distributes itself unevenly throughout these segments in proportion to the conductivities (admittances) of the component tissues, the least amount of current flowing in the membranous portions thereof—viscera and peritoneal cavity—and the greatest in the muscular masses. However, the data obtained by these authors were derived from measurements on animals and are limited to the abdominal and thoracic portions of the trunk. The frequencies involved are also of a different order

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1 Brazier, M. A., West, B., *J. Surg., Obst. and Gyn.*, 1935, **43**, 429.

2 Horton, J. W., and Van Ravenswaay, A. C., *J. Frank. Inst.*, 1935, **220**, 557.

3 Eyster, J. A. E., Maresh, F., and Krasno, M. R., *Am. J. Physiol.*, 1933, **106**, 547.

4 Katz, L. N., and Korey, H., *Am. J. Physiol.*, 1935, **111**, 83.

than those employed in Q-factor determinations. It is proposed to show that their findings apply equally well to the arm-to-arm segment and to man at frequencies in the vicinity of 10,000 cycles.

In approaching this problem, it may be noted, that it is not sufficient to show that the arm-to-arm segment is heterogeneous as to impedance alone. Obviously tissues of differing impedance may vary little as to Q-factor, *i. e.*, the ratio between their reactive and resistive components may still remain substantially the same. The heterogeneity of the arm-to-arm segment will, therefore, be considered not only as to impedance but also as to Q-factor.

If this segment were composed of a single homogeneous material, a low frequency alternating current flowing therethrough would distribute itself evenly. Should it be shown that the current distributes itself unevenly, it would follow that the segment in question is heterogeneous as to impedance. The tissues of low impedance, in this case, would show the largest current densities and those of high impedance, the smallest. Two methods for measuring current density in a body segment are given below.

*Flux Density Method.* The experimental principle employed in this method is the following: The arms, carrying pure sinusoidal alternating current, are treated as the primary of a transformer and variations in current density are determined by moving a small exploring coil, acting as a secondary, over the arm surface. The current induced in the exploring coil is then amplified and shown in a proper indicating instrument.

The circumference of the arms was explored in this way at 3 levels: (1) in a transverse plane passing through the elbow, (2) in a similar plane passing through the arm midway between elbow and axilla and (3) in a plane passing through the axilla and the outer border of the acromion. In addition, the thorax was explored at the various points on its anterior and posterior surfaces to determine the upper and lower limits of the current path.

*Experimental Procedure:* The source of current used was a cathode-ray type phasemeter (Radio Instruments Co., model G) having a built-in V-T voltmeter and supplying substantially harmonic-free oscillations at a frequency of 11,000 cycles and 0.3 volt. The exploring coil was wound in the form of an annulus of square section one inch in diameter composed of 500 turns of No. 40 wire and had a total impedance of 290 ohms at the frequency employed. It was completely shielded electrostatically and also shielded electromagnetically on all sides except for a small opening exposing the coil to the magnetic field of the body. The current induced in the exploring coil was fed into a variable gain 120 db. A-F amplifier connected on its output side to the V-T voltmeter of the phasemeter. All leads were shielded and made long enough to permit measurements to be made 8 feet from the phasemeter and well outside any field generated therein. The indications of the V-T voltmeter appeared on the cathode-ray tube screen as a horizontal band whose width varied with the intensity of the field cutting the exploring coil. A scale graduated in one-half inch divisions mounted in front of the screen permitted measurement of the band width and could be read with magnification to 0.1 division. Current density measurements were made with the subject standing and the arms in a horizontal position. Absorbent cotton soaked in 1% saline was wound around the forearm to a point about 5 inches below the elbow level and held in place by a spiral winding of one inch lead tape. Current was fed to the arms by means of 8-foot leads attached to the lead tape windings.

In making measurements, the small opening in the electromagnetic shielding surrounding the exploring coil was brought into apposition with the surface of the arm (grounded side) or the chest so as to expose the coil windings to the field of the body and the coil was then slowly rotated until the band on the cathode-ray screen gave a maximum width. This was found to occur when the coil lay in a plane passing through the longitudinal axis of the arm and in a horizontal plane passing through the thorax. Under these conditions, the coil was being cut by the maximum flux in the underlying tissues.

Preliminary tests having shown that the results obtained were qualitatively the same for different individuals, final measurements were made on a lean normal female, 26 years of age, having an arm circumference at the mid-biceps level of 8 inches.

The form of the fields† around the right arm is shown in Fig. 1.

The outline of the field shows the current density to be a minimum over the olecranon and the acromion and to increase moderately over the larger muscles to reach a maximum at the bend of the elbow, on the medial side of the upper arm and just behind the anterior wall of the axilla, *i. e.,* following the neuro-vascular bundle containing the median nerve. The small difference in current density for points over the olecranon and over the ulnar nerve is noteworthy.

Exploration of the thorax showed the upper and lower limits of the current path to lie between 2 horizontal planes passing through

† The fields shown represent the average of 2 independent measurements made with the current leads and phasemeter placed first in front of, and then behind, the subject. This was done to correct for small effects on the magnetic field of the body due to the position of the leads themselves.

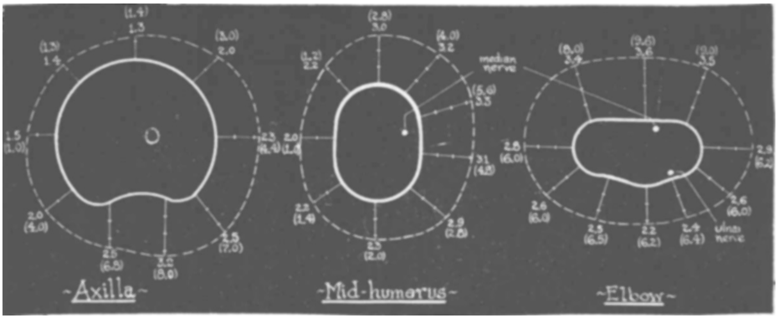


FIG. 1.

Current densities measured at the surface of the arm. The 3 sections are taken in transverse planes passing through the axilla, mid-humerus and elbow of the right arm. The form of the magnetic field around the arm is shown in dotted lines. The flux densities indicated are in arbitrary units.

Changes in phase angle obtained by the capacity increment method are shown in parenthesis (observed values multiplied by 1000).

the 2 axillae and through the base of the neck. The field was found to diminish in a regular way from values shown in the section through the axilla (Fig. 1) to a value of 1.0 division as the exploring coil was moved inwardly along the anterior and posterior chest wells from the shoulders toward the sternum and spine. Repeated explorations over the anterior surface of the neck failed to show any increase in field strength in the region over the thyroid gland.

*Constant Capacity Increment Method.* This method for measuring current density was designed to be independent of any magnetic field due to the current leads and to serve as a check on the results obtained by the flux density method. The experimental principle involved is the following: If the Q-factor of the arm-to-arm segment be measured first by one of the usual methods (immersion or 4-electrode technic) and then with a strip of metal applied over a given skin area, the second reading will be increased over the first by an amount dependent on (1) the capacity of the skin lying beneath the metal strip and (2) the local current density in the same area. The skin, under these conditions, acts as a dielectric enclosed between the metal strip and the deep tissues as conducting plates. Since the capacity per unit area of the skin in the region of the arms and chest may be assumed to remain substantially constant, a series of measurements with the metal strip applied over the various areas permits a mapping of the local current densities below the skin surface. Measurements of current density were made by this electrostatic method over the areas indicated in Fig. 1 which had been previously explored electromagnetically.

*Experimental Procedure:* The subject was instructed to immerse the forearms in 2 arm baths each containing 12 liters of one percent saline, palms down on the arm bath bottoms and the forearms extending upward substantially vertically. A Q-factor measurement was then made in the usual way with the cathode-ray phasemeter. A strip of tin 4″x1″x0.01″ encased in a closely fitting flannel cover and soaked in one percent saline was then applied by hand (a rubber glove served to insulate the hand from the strip) to various portions of the arm and chest with sufficient pressure to insure good contact, the length of the strip being maintained parallel to the direction of flow of current from arm to arm. The increase in Q-factor could then be measured with the phasemeter. In making measurements in the axilla and at the elbow, the strip was bent to conform to the skin surfaces in these regions.

The results obtained by this method are in good qualitative agreement with measurements of flux density. The Q-factor values remained unmodified with the strip applied over the anterior and posterior chest surfaces as well as over the thyroid gland. Along the arms and in the axilla, the changes indicated in parenthesis in Fig. 1 were obtained. The values given represent the Q-factor change multiplied by 1000. Thus (5.0) is equivalent to a change of 0.0050.

At the elbow level the capacity increment values found are somewhat higher than would be expected from the flux density results. This would appear to be due to the fact that measurements of flux density represent the additive effect of the flux in a group of parallel current paths taken through a considerable portion of the arm thickness, whereas those obtained by the capacity increment method correspond to conditions immediately beneath the skin surface. It is to be noted, however, that the relative values obtained by both methods in passing around the arm at any given level show the same general type of current distribution.

The concordant results obtained by the flux density and constant capacity increment methods which are based upon independent electromagnetic and electrostatic modes of exploration leave little doubt that the arm-to-arm segment is best represented as a heterogeneous impedance, and it remains now to be shown that the segment in question is also heterogeneous as to Q-factor. To do this, it is only necessary to compare the Q-factors of the constituent portions of this segment which is composed of (1) a chest portion or section containing a large mass of pulmonary tissue, (2) a shoulder portion traversed by tendinous and muscular masses and (3) an arm portion proper consisting predominantly of muscular tissue. Each of these portions or sections differs markedly in size, shape and internal structure from the others. It will be recalled that, in the 4-electrode method of Horton and Van Ravenswaay, current is passed from arm to arm by means of a first pair of electrodes and the (inner) impedance properties of any portion of the body lying between these current carrying electrodes is measured by tapping off voltages from a second pair of spaced bands. If this pair of voltage tapping bands be placed over each of the shoulders and under the corresponding axilla, the Q-factor of the chest section so delimited may be measured separately. A similar pair of spaced bands mounted on the upper arm permits a measurement of the upper arm alone, while with one band on the upper arm and the other passing under one axilla and over the corresponding shoulder, values for a shoulder section may be obtained.

*Experimental Procedure:* The original method of Horton and Van Ravenswaay was employed with the following minor modifications: Current was fed to the arms *via* a pair of arm-baths containing 1% saline. The voltage tapping bands used by these authors (phosphor-bronze) were found to be too stiff to lie in contact with the axillae and were replaced by ordinary solder wire 1/16" in diameter, the skin being moistened with normal saline before applying the wire thereto. Measurements of Q and Z were made by tapping off voltages from the bands to the grids of 2 tubes and determining (1) the amount of resistance necessary to produce an equivalent voltage drop and (2) the difference in phase between the current and voltage, these values being obtained by means of a special circuit (to be described elsewhere), coupled to the cathode-ray phasemeter already mentioned and functioning as an a.c. comparator.

The Q-factors of these 3 separate body sections in 6 unselected normal subjects of varying physical conformation are given in Table I. Differences in physical conformation are indicated by the arm circumferences and the elbow-to-elbow length. It will be seen

TABLE I.
The Q-factor of Component Sections of the Arm-to-arm Segment.

| Subject | Sex | Age | Arm circumference in cm. | Elbow-to-elbow length in cm. | Q-factor | | |
|---|---|---|---|---|---|---|---|
| | | | | | Arm Section | Shoulder Section | Chest Section |
| 1. | Female | 37 | 26 | 90 | .047 | .066 | .056 |
| 2. | ,, | 26 | 28 | 89 | .060 | .079 | .071 |
| 3. | Male | 20 | 22 | 87 | .063 | .108 | .082 |
| 4. | ,, | 19 | 30 | 96 | .099 | .106 | .081 |
| 5. | ,, | 23 | 28 | 102 | .065 | .116 | .092 |
| 6. | ,, | 48 | 24 | 90 | .068 | .086 | .056 |

that the Q-factor of these various sections may vary among themselves by ratios as great as 1.8:1, the value obtained for any particular section depending, apparently, on its size, shape and internal structure.

*Summary and Conclusions.* The arm-to-arm segment is shown to be heterogeneous both as to impedance and Q-factor. It follows, therefore, that the Q-factor of this segment cannot properly be assumed to be independent of differences in physical conformation. Q-factor measurements which fail to take into account the possible effect of size and shape are open to serious question.[5]

## 9302 P

## High Intestinal Obstruction In the Dog Treated with Extract of Adrenal Cortex.

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Acute intestinal obstruction as a representative of a group of conditions that are characterized by hyperazotemia and hypochloremia bears resemblance to adrenal insufficiency.[1, 2, 3] Indeed, we described the histologic[1] changes of the adrenal glands in the dog with high intestinal obstruction as that of lipoid exhaustion of extreme degeneration of the adrenal cortex.*

In view of Kendal's[5] separation of 2 fractions of the cortical extract one of which produces results only when salt is administered with it, it seemed desirable to study the combined effect of cortical

[5] Horton, J. W., and Hertz, S., *Endocrinology*, 1936, **20**, 831.

[1] Wohl, M. G., Burns, J. C., and Clark, J. H., PROC. SOC. EXP. BIOL. AND MED., 1936, **33**, 543, 546.

[2] Wohl, M. G., and Brust, R., *J. of Lab. and Clin. Med.*, 1935, **20**, 1170.

[3] McCance, R. A., *Lancet*, April 11, 1936, page 829.

* Dr. J. E. Sweet called the attention of one of our coworkers, Dr. J. H. Clark, to the fact that in several of his writings he spoke of the peculiar similarity between dogs that have died after bilateral suprarenalectomy and those from toxic injection.[4] We are glad to make this correction. However, Dr. Sweet stresses the changes that occur in the medulla of the adrenals and not in the cortex which we are inclined to look upon as one of the chief factors concerned in the disturbed pattern of the water and electrolyte metabolism in high intestinal obstruction.

[4] Sweet, J. E., *Penna. Med. J.*, April, 1913.

[5] Kendal, E. C., *J. A. M. A.*, 1935, **105**, 1486.